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INTERMODAL LINKAGES

Scientific Expert Group on the Safety of Vulnerable Road Users (RS7)

SAFETY OF VULNERABLE ROAD USERS

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## FOREWORD

The Programme centres on road and road transport research, while taking into account the impacts of intermodal aspects on the road transport system as a whole. It is geared towards a technico-economic approach to solving key road transport issues identified by Member countries. The Programme has two main fields of activity:

- international research and policy assessments of road and road transport issues to provide scientific support for decisions by Member governments and international governmental organisations;
- technology transfer and information exchange through two databases -- the International Road Research Documentation (IRRD) scheme and the International Road Traffic and Accident Database (IRTAD).

Its mission is to:

- enhance innovative research through international co-operation and networking;
- undertake joint policy analyses and prepare technology reviews of critical road transport issues;
- promote the exchange of scientific and technical information in the transport sector and contribute to road technology transfer in OECD Member and non-member countries.

The scientific and technical activities concern:

- infrastructure research;
- road traffic and intermodal transport;
- environment/transport interactions;
- traffic safety research;
- strategic research planning.

## ABSTRACT

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This report presents a review of the current safety situation of vulnerable road users in OECD Member countries. Industrialised societies are aware of the environmental problems generated by motorised traffic in cities and encourage the development of non-motorised traffic in order to improve living conditions for both road users and urban residents. This aim cannot be reached unless safety conditions cease to be a deterrent to walking and cycling. The study was started in 1995 by a Scientific Expert Group of the OECD Road Transport Research Programme. Based on a problem-oriented approach, the report sets the main safety problems faced by vulnerable road users taking full account of their social, regulatory and physical environments. It provides an overview of their mobility patterns and accident characteristics based on available travel surveys and national statistics. The challenges to improve the safety situation of vulnerable road users lie with a better understanding of their accident patterns. To this end more detailed research analyses are used to identify well adapted accident countermeasures. The review of current experience in policies aiming at the protection of vulnerable road users takes into account recent evaluation results of some safety measures which although not entirely new, tend to get more and more widely used. Problems that still call for adequate remedial solutions are the basis for exploring prospective measures. The report consists of the following chapters: Chapter I -- Introduction; Chapter II -- Characteristics and environment of vulnerable road users; Chapter III -- Mobility of vulnerable road users; Chapter IV -- Safety of vulnerable road users: an overview; Chapter V -- Identification of accident factors; Chapter VI -- Non-infrastructural safety measures; Chapter VII -- Infrastructural safety measures; Chapter VIII -- Implementation requirements; Chapter IX -- Conclusions, policy recommendations and research needs. A Glossary is provided in Annex A and a summary of the travel surveys used to identify mobility patterns is presented in Annex B. The report provides directions for concrete actions to ensure full interaction between the various road users' groups through a better integration of the vulnerable groups in the existing traffic and transport system.

**Field classification:** Accidents and the human factor  
Accidents and the road

**Field codes:** 83, 82

**Key words:** safety, pedestrian, cyclist, mobility, accident prevention, accident rate, education, publicity, junction, cycle track, old people, disabled person, behaviour, statistics, policy, OECD, danger, segregation (traffic, pedestrian)

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## CHAPTER I -- INTRODUCTION

### I.1. Who are “vulnerable road users”?

“*Vulnerable road users*” is a term applied to those most at risk in traffic. 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 motorised two-wheelers, with heavier machines and higher speeds, may present a danger to others. The mandate of the scientific expert group therefore focuses on pedestrians and pedal cyclists.

In practice, it has to be noted that, in some countries, mopeds (or light motorcycles) are assimilated to bicycles, in the law, in statistics, and in the way the road infrastructure is designed, while in others, mopeds are treated as motorcyclists. These two approaches make it somewhat difficult to compare accident and risk figures in different countries, and they produce different evaluation results as to the effects of various infrastructure measures aimed at improving bicycle or two-wheeler safety. Both the review of current experience in protective measures for vulnerable road users and the recommendations for prospective safety policies will therefore have to be interpreted in relation to the current status of two-wheelers in each country.

Among vulnerable road users, some are more vulnerable than others, in particular the elderly, the disabled, and children.

- *Elderly people* show a gradual decrease of their abilities to cope with difficult traffic situations and therefore sustain a greater risk of being involved in an accident. They are also becoming physically more fragile, which means that the lesions sustained in a collision may have more severe consequences for them than for members of the younger age groups. As a consequence, most elderly people who are aware of their own difficulties tend to disengage from traffic, thus reducing their mobility and the scope of their social life. This form of compensation between mobility and safety usually shows in accident figures, which are lower than could be expected because of lower exposure to traffic, and may thus encourage the decision-makers to ignore the specific problem of the elderly as pedestrians and cyclists. However, improving traffic situations and infrastructural amenities to facilitate the movements of those with weakening abilities is not only a safety measure, but also a course of action that should enable the elderly persons to keep their place in society longer.
- *Disabled persons* include any individuals with a physical, sensory or mental impairment affecting their movements. They are usually pedestrians, either walking, with or without artificial aids, or using a wheelchair; some may be cyclists. As the elderly, the disabled are more at risk of a collision in difficult traffic situations or on parts of the infrastructure that are not adapted to their abilities, and they may also in some cases present a lower faculty of

recovery from injuries. If disabled people suffer from a handicap in traffic, this handicap results from the conjunction of their disability and of the kind of environment they have to move in. Creating a physical environment that reduces handicaps and thus enables the disabled to move about with a level of ease and protection similar to that of other road users is not only a safety measure, it is a basic action to treat the disabled with equity and fully integrate them in society.

- *Children* are also particularly vulnerable road users as their abilities to cope with traffic evolve with age and remain severely limited in the first nine or ten years of their life. They are therefore highly at risk in any situation where motorised traffic is heavy or fast, visibility is limited, or the drivers focus their attention on other vehicles and tend to forget about pedestrians or cyclists. Although children may recuperate more easily from injuries than most adults, the shock resulting from a traffic accident is never to be underestimated. Protection of children cannot rely on better behaviour on their part: it is the responsibility of decision-makers to allow them freedom of movement in appropriate surroundings and to promote more careful behaviour of the drivers.

It can be seen that vulnerable roads users are not one entity, but a gathering of different groups of people with different characteristics, travel habits and behavioural patterns, having in common their difficulties to cope with motorised traffic in an environment which has seldom been primarily designed for them. The scope of this research and report is therefore very wide and the work undertaken by the OECD expert group was very ambitious from the start.

## **I.2. Aims of the Group**

The safety of vulnerable road users is a major concern in many OECD Member countries and is even a more serious problem in a large number of non member countries. Traffic accidents result not only in bodily damage, loss of life, severe pain to individuals and economic loss to the society, but also in reduction of movements or opportunities to travel for the less socially favoured and for the most vulnerable sections of the population. In both OECD and developing countries, there is a need to establish a good basis in terms of research findings, for implementing the most efficient safety measures and policies taking due account of the prevailing local conditions.

In OECD Member countries, large-scale progress is still possible to reduce the number and severity of accidents to vulnerable road users, while facilitating their travelling. Moreover, industrialised societies are more and more aware of the environmental problems generated by motorised traffic in cities, and of the consequences on public health, not only of accidents, but of pollution and noise. The future trend will therefore be to encourage development of non-motorised traffic in order to improve living conditions both for road users and for urban residents. This aim cannot be reached unless safety conditions cease to be a deterrent to walking and cycling. It is therefore essential to make the best of the accumulated experience of OECD Member countries in protecting vulnerable road users. Once subjected to appropriate analysis, such experience should also be of great benefit to a larger number of countries where road safety activities are at a less advanced stage, and where the vulnerable road users are particularly prominent in traffic.

The aims of the group were therefore:

- to collect data and results of accident, risk and behavioural studies on pedestrians and cyclists (and, in some countries, on mopeds), in order to compare the scale and main

characteristics of the road hazard as it affects vulnerable road users, and to define the most prominent safety problems, in terms of accident characteristics, processes generating the accidents, and contributory factors;

- to review measures and policies for the protection of vulnerable road users in OECD Member countries, focusing on recent approaches in the areas of infrastructure, urban planning, regulations, education, or combinations of these, as well as on some of their effects and implementation requirements.

Children, the elderly and disabled persons are not the main focus of the Group, but they are the most vulnerable sections of the population. As such, their specific issues are therefore considered in all areas of the research carried out. Possible negative effects for these road users of traffic and safety measures not intended particularly for them need to be examined. It has also to be noted that any policies aiming at the protection of the less able road users bring benefits to the whole population, at least in terms of ease of movements and of quality of the environment.

Although a number of OECD Member countries are now in the process of designing or adopting transport policies that are sustainable from an economic, energetic and environmental viewpoint, it has not been the concern of the group either to discourage or to recommend the use of any particular transport mode, but rather to provide directions so that walking and cycling, if found useful for specific purposes or preferable to other modes, can be performed in the best safety conditions.

### **I.3. Background**

#### ***I.3.1. Historical background***

In industrialised countries, road infrastructure and its environment have gradually developed to meet the needs of growing traffic and mobility. Their present state reflects the conflicts and compromises between the different transport modes -- particularly between the vulnerable road users and motorised traffic -- the traffic regulations, and the beliefs and doctrines of the engineers responsible for road design and traffic management, particularly with regard to road users' duties and behaviour. Conflicts, beliefs and regulations have evolved over time, and one key to the present mobility and safety problems experienced by vulnerable road users can be found in the historical perspective.

The 1960s and 1970s were marked by the rapid expansion of car ownership. Roads were built or widened to accommodate growing car traffic, with often disastrous effects to vulnerable road users and residents of built-up areas: as speed increased, pavements were narrowed to put in additional car lanes; parked vehicles invaded a large amount of space previously devoted to pedestrians or cyclists; large new urban thoroughfares secluded parts of urban areas or cut through historical neighbourhoods. On top of this, the limited space allocated to pedestrians was not always properly maintained and tended to be obstructed by all sorts of obstacles, including traffic signs. Traffic growth was a particular problem in small settlements on the main rural roads. In some countries, this problem was exacerbated by widening the carriageway at the expense of road sides and pedestrian footpaths, with the additional side effect of encouraging vehicle speed in the very location where the speed limits were the lowest!

Urban areas also expanded, increasing the travel distances from home to work, thus disqualifying walking and cycling as means of performing a large part of everyday trips. Some politicians, as President Pompidou in France, were heard to say that "*cities should adapt to the private*

*car*". Meanwhile, some new residential areas were built by architects and planners on the principle of complete segregation of pedestrians and motorised vehicles, first in Sweden (Scaft guidelines), then in some British New Towns. The concept of complete segregation started to spread, without putting into question the general priority given to the private car.

The trend started to reverse at the end of the 1970s when it was found that the street networks of old towns and city centres could not take an indefinite increase of traffic. Traffic plans were instituted, for example in France or in the Netherlands, to optimise the use of the existing street space. It was soon found that this involved reducing private car traffic in city centres, and as a consequence, increasing the offer of public transport and/or providing better facilities for cyclists. Pedestrianised streets started to appear, mostly in commercial or tourist areas. However, no particular attention was paid to pedestrians' needs in terms of network to facilitate walking across a city. Car parks were built at the exit of pedestrian precincts, or park-and-ride schemes organised, clearly showing that pedestrians were nothing more than car drivers or passengers having managed to abandon their vehicle for a short while. Cyclists were hardly better treated, with the exception of some cities such as Groningen in the Netherlands.

Meanwhile, the virtues of segregated residential areas started to be questioned. They were expensive; they did not allow easy planning of public transport. It was not clear which of the networks the bicycles or other two-wheelers belonged to. They made orientation difficult for visitors. They precluded any sort of mixed activities, and the principle applied only to newly built areas. A new concept of integration of mixed traffic, termed "woonerf" in Dutch, appeared, based on the idea that drivers should slow down and give precedence to vulnerable road users on the street, particularly to children. For the first time, it was acknowledged by decision makers that urban streets could have another function than just motorised traffic. Existing residential areas, those built on a square grid or otherwise admitting through traffic, started to be redesigned to eliminate through traffic from neighbourhoods, decrease speeds of motorised traffic and protect children. Some facilities were introduced for cyclists.

Retrospectively, it is clear that the schemes implemented in residential areas marked the beginning of a new era for vehicle speeds in towns and cities. Professionals became aware that publicity and police enforcement were not the key to inducing more adequate speed behaviour, and that physical design of the road environment could play a much more efficient role. It also became acceptable to promote speeds lower than the usual urban speed limits, at least in particular types of neighbourhoods. The concept of traffic calming was slowly taking root.

It is only in the 1980s that the idea of comprehensive networks for pedestrians and cyclists started to make way in some countries, thus acknowledging walking and cycling as full-fledged means of transport. Cycle tracks or cycle lanes were introduced, with various degrees of success or failure from a safety viewpoint. In a number of cities, pedestrian footpaths were organised to provide continuing routes and were often widened and resurfaced. Pedestrianised streets in city centres became better integrated into overall schemes aimed at providing better mobility for all with less private car traffic. The concepts of mixed traffic and traffic calming -- obtained through physical self-enforcing speed reduction measures -- spread and extended from the previous schemes in residential areas to the treatment of urban thoroughfares with heavy traffic. The idea that fast motorised traffic may have to yield priority to local traffic and vulnerable road users through some parts of urban areas generating a lot of activity onto the street finally became acceptable. Such traffic calming schemes were also implemented on trunk roads in some villages (for example, in France), in order to revive local life as well as increase safety of the residents, thus reversing the trends observed in rural road design in the last decades.

While vulnerable road users were often ignored in infrastructure design and traffic planning, action plans were nevertheless initiated to teach pedestrians -- and to some extent cyclists -- to cope

with traffic conditions as they were. Traffic clubs addressing young children were, for instance, initiated in the Nordic countries over 25 years ago. However, education has evolved over time as much as road engineering practice or town planning, towards better integration of road safety in the school curriculum. The concept of life-long education is gradually developing. It aims at improving the quality of road users' participation in traffic, from their early days in life, through adolescence and access to bicycles, then to mopeds, then to cars, up to the driving licence. Education programmes for the elderly are now just being initiated in a few countries such as in Japan. The goals of education are thus moving from an immediate - getting the children to try and safely cross the road or go to school -- to a long term objective in which individuals are considered as potential users of all modes of travel.

In spite of the changes of attitudes in society, car ownership and traffic have kept increasing in most OECD Member countries. As a result, environmental problems are now becoming a concern for a large part of society. Pollution and noise from motorised traffic in towns and their effects on health are more and more often associated with road safety issues. It is now widely acknowledged that transport and mobility have unacceptable side effects in killing or injuring people, and that transport planning should endeavour to minimise these side effects and, at the very least, prevent any further aggravation. Road accidents have long been considered chance occurrences and the necessary price of progress. Adding the effects of pollution and noise, which cannot be described as "accidental", the price to pay is becoming too much for society. Long-term planning for sustainable transport policies, aimed at fulfilling mobility needs while reducing health costs, are already being promoted, for example in the Netherlands (OECD Expert Group ERS1 on *Integrated safety/environment strategies*, on-going). Such form of transport planning usually implies operating modal transfers from motorised road transport to rail and non-motorised means. Vulnerable road users should thus get better attention in the future.

### **1.3.2. OECD research reviews**

Changes in attitudes and historical evolution cannot be dissociated from research efforts which have been carried out in order to improve the situation of vulnerable road users. Most OECD Member countries have been involved in pedestrian and cyclist safety research in the 1970s when the accident problems were the most acute. Most engineering solutions or education plans were monitored and experimental schemes were undertaken. Traffic calming has now become a particularly important topic for experimentation in different types of environmental and traffic surroundings. Research efforts have thus been displayed in most countries, involving a large number of teams, and the need was quickly felt to compare findings and widen the scope of knowledge.

A large amount of knowledge generated in OECD Member countries has thus been gathered by previous OECD groups, in particular:

- An OECD symposium on *Better towns with less traffic* (1975), that examined examples of several European or Asian cities that had limited car traffic in urban centres through various means (traffic plans limiting entry, parking restrictions, tolls, etc.) while enhancing walking and cycling networks and public transports.
- An OECD Research Group on *Prevention of accidents to users of two-wheeled vehicles* (1975-76) that reviewed existing regulations and accident statistics. Accident contributory factors as well as research on crash factors and two-wheeler protection were analysed and a comprehensive evaluation of accident countermeasures was provided.

- A joint OECD-ECMT group on *Pedestrian safety* (1976-78), that compared the scope of accident problems in OECD Member countries and examined the (then) new approaches in the fields of road environment (pedestrianisation schemes, footpath networks, speed reduction, etc.), of education, and of mass media communication, with particular attention to methods of evaluation of pedestrian safety measures.
- An OECD group on *Safety of residential areas* (1978-79), that examined area-wide environmental schemes to reduce through traffic and vehicle speeds in predominantly residential urban neighbourhoods. Both planning and improvement schemes were considered.
- An OECD group on *Traffic safety of children* (1982-83), that reviewed statistical trends of road accidents involving children and provided an assessment of measures and demonstration projects implemented in OECD Member countries.
- A joint OECD-WHO group on *Safety of elderly road users* (1983-84), that attempted to describe the characteristics of this road user group in relation to traffic, to identify accident trends and to suggest environmental and educational approaches to improve safety of the elderly on the roads while maintaining the necessary level of mobility.
- An OECD group on *Effectiveness of road safety education programmes* (1985-86), that assessed the efficacy of a wide range of education programmes and provided strategies for their development, implementation and evaluation.
- An OECD group on *Integrated safety management in urban areas* (1988-89), that examined examples of urban safety policies associating different types of measures, including protective measures for pedestrians and cyclists, and the institutional conditions for their implementation.
- An OECD group on *Marketing of traffic safety* (1992-93), that highlighted the scope for innovative approaches through sociological analyses of road user groups, systematic communication processes, and back-up marketing strategies.

Considering this background, the present Group of experts has decided to focus on the most recent developments in policies to protect vulnerable road users in OECD Member countries, rather than on updating previous work, whose findings are now sufficiently well-known. The report that follows is therefore based on new experience and has required a substantial amount of research and analysis.

#### **I.4. Method of analysis**

The Group has adopted a problem-oriented method to gather data and analyse it. Problems related to vulnerable road users in OECD Member countries are first identified and described, in order to be able to select relevant experience in terms of measures and policies, assess it, and find out in which areas progress can still be made and which prospective courses of action could be promising.

As it is clear that accident problems cannot be entirely separated from mobility needs and conditions and cannot be properly understood without adequate awareness of the characteristics of vulnerable road users and of their environment, background data have been gathered on these issues. Safety problems are defined in terms of types of accidents and accident conditions, but also in terms of

accident factors -- as emerging from international and national statistics, and from in-depth analyses based on accident investigations, comprehensive accident reports, and/or observation data. It is felt that more thorough understanding of accident generating processes and the factors intervening in them is generally conducive to the design of more efficient and innovative safety measures or policies, and that further progress can be achieved only through the development of such knowledge.

The review of current experience in policies aiming at the protection of vulnerable road users has been oriented by the safety problems identified, but has also taken into account recent evaluation results of interest concerning some measures which are not entirely new, but tend to get more and more widely used at present. The problems that do not seem to have been met yet with adequate solutions are the basis for exploring prospective measures.

The goal of the Group was ambitious as the scope of the analysis was extremely wide. Within the time imparted for literature reviews and the gathering of research results, it was not possible to take into account all results and knowledge produced since the late 1980s. The information base was mostly limited to what could be gathered by Group Members in their own countries. Little could be added from countries that chose not to be represented in the Group. Given these limitations, but considering the heavy amount of research and synthesis performed by the Group, it is hoped that this newly gathered and formalised knowledge will cast new light on aspects of the safety of vulnerable road users that are common to OECD Member countries. The underlying thesis of the report is that pedestrians or cyclists are road users travelling for various purposes, and with as much right to attention and appropriate treatment as car, bus or lorry drivers and passengers.

## **I.5. Content of the report**

In order to understand fully the road safety problems experienced by vulnerable road users, it is essential to view accidents as the effects of interactions between road users and their environment. To analyse these interactions, both the specificities of vulnerable road users and the characteristics of the traffic environment have to be known. Chapter II thus describes: the particular needs of the various groups of vulnerable road users to take into account in the provision of adequate travelling conditions; the regulatory environment -- including the rights and duties allocated to pedestrians and cyclists and the general image of them provided by the rules and regulations; the physical environment -- including the present general state of infrastructure and the design features that are required to fulfil the needs of vulnerable road users; and finally the social environment -- based on the analysis of current education and information programmes and the type of attitudes they may induce towards vulnerable road users, particularly from car drivers.

Mobility is the primary aim of any traffic and transport system. Facilitating mobility of vulnerable road users cannot be separated from improving their safety. Chapter III gathers quantitative information on mobility of pedestrians and cyclists, as available from surveys carried out in Member countries, and provides a discussion on qualitative aspects of mobility. Special characteristics of different road user groups, such as the children and the elderly, are indicated. Finally, the main principles of policy measures related to mobility, particularly to promoting walking and cycling, are given on the basis of some examples.

Chapter IV is devoted to analysing statistical data on accidents and injuries, in order to identify the main components of the vulnerable road users' safety problem. International data bases as well as national statistics from Member countries have been gathered and examined in detail. The chapter provides indications of the main accident situations in different countries and of the factors that can be

identified through statistical analyses. It concludes with the high rate of under-reporting of accidents or injuries involving vulnerable road users, as seen from the comparative studies of hospital and police data carried out in a number of countries.

It is useful to know the scope and main components of the accident problem in order to target remedial road safety action. However, this is not sufficient for devising and designing innovative safety measures. Better understanding of the factors leading to the main groups of accidents is needed. Chapter V thus examines various methods that can be used as a complement to statistical analyses in order to increase our knowledge of accident conditions and causation: organisation and treatment of intermediate accident databases; in-depth on-site accident investigations; observation and behavioural studies. Examples of applications of such methods are provided and some particular accident circumstances and factors are identified and discussed.

We can best learn to plan safety programmes for the future from experience gathered from past road safety action. The problems of vulnerable road users unsolved by existing well-proven measures lead to the search of prospective courses of action. Chapter VI reviews the measures not related to the road infrastructure, both those which have been evaluated and those which seem promising and should be experimented or further developed. Similarly, Chapter VII summarises successful engineering safety measures and potentially interesting ones.

Road safety policies and implementation of strategies to improve safety of vulnerable road users more and more often require the participation of partners of diverse disciplinary backgrounds and assuming different professional duties. Complex forms of organisation may be necessary. Chapter VIII provides an outline of the institutional requirements for road safety work at the local, national, and international levels.

Finally, Chapter IX summarises the conclusions drawn from the various analyses included in the report and provides a list of recommendations for future policy-making and research, especially in the areas of general policy principles, infrastructure and the road environment, road user behaviour and attitudes, regulatory environment, vehicle design, and priorities for research.

In order to help the reader, a Glossary of Terms used throughout the report is provided in Annex A and a summary of the National Travel Surveys is available in Annex B to the report.

## **I.6. Literature**

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## CHAPTER II -- CHARACTERISTICS AND ENVIRONMENT OF VULNERABLE ROAD USERS

### II.1. Diversity of vulnerable road users

Vulnerable road users can be divided into two main groups: pedestrians and cyclists. Taking into account their mobility and their capability to cope with traffic situations there are some especially vulnerable groups: children, the elderly and disabled people.

#### II.1.1. *Pedestrians*

In most of the OECD Member countries, the definition of a pedestrian is: a person who travels by foot or pushes a pram, a wheelchair, a bicycle or a moped. Some countries also consider a person who travels by skis, skates or similar means to be a pedestrian.

Therefore, on this definition, pedestrians can be a rather heterogeneous group of road users. People moving by roller skis or skates are considered to be pedestrians, even though their speed is considerably higher than a normal walking pace. The often rather narrow routes planned earlier solely for the purposes of walking are nowadays used by window shoppers, dog-walkers, sport fans, skating, children on skateboards playing or frolicking etc. People walk also for pleasure or exercise rather than to a specific destination which makes the definition “travel” seem a little unsuitable. Pollution from traffic is a particular hazard as pedestrians often walk alongside roads. Pedestrians may feel threatened by fear of violence or robbery particularly during the hours of darkness. Women and elderly people in particular have problems in darkness and when pedestrian paths are isolated.

#### II.1.2. *Cyclists*

According to the Vienna Conventions a cycle is any vehicle which has at least two wheels and is propelled solely by the muscular energy of the person on that vehicle, in particular by means of pedals or hand-crank. This definition makes cyclists a more homogeneous category than pedestrians. However, high speed sport cyclists increase risks for the other vulnerable road users. Especially in those countries which typically have combined routes for both pedestrians and cyclists, the speed differences between the groups cause problems.

Exhaust gases and other pollution from motor traffic cause hazards for cyclists since cycle routes are often located close to motor traffic routes, causing cyclists to breathe polluted air.

### ***II.1.3. Specially Vulnerable Groups***

#### *Children*

Children can be subdivided by age which tends to correlate with distance travelled and their range of activity. Younger children walk outside of their neighbourhood only when accompanied by adults. Mostly they begin to walk alone when starting school. Sometimes their parents still cross the main streets with them. Older children, who go to school, travel by foot or by bicycle. The environment they move around is much bigger and more diverse than that used by the younger group.

The children's perception about traffic as a total entity and their knowledge about traffic rules is not fully developed until about their tenth year of age. They do not have the ability to cope with complex traffic situations and they easily mix the real world with their imagination. However, even by ten years of age, children's skills and abilities may be insufficient in the context of the potential speed to be attained when cycling.

#### *Elderly people*

There are a variety of definitions. For the purpose of this report, the elderly persons are defined as the population of persons aged 65 or more. This is the age when most people in almost all OECD Member countries have withdrawn from the labour market (OECD, 1985). The elderly are not a homogenous group. Some elderly people are in very good health and can cope with traffic very well. Of course, there comes a time when they do have some kind of restrictions in walking and cycling. Some elderly people may have very strong restrictions on their mobility and may not walk alone at all.

The proportion of the population which is elderly and has high pedestrian activity has increased and will increase further. For example, the Japanese experts forecast that the proportion of the population which is elderly will increase from 12 per cent in 1990 up to 25 per cent in the early 2000s (Seo, 1995).

The reactions and decision speeds of the elderly deteriorate and their eyesight and hearing become less acute than before. Elderly people cannot always walk very long distances and their walking or moving speed is slower than younger people. Furthermore, as the memory and eyesight of the elderly people deteriorates, their ability to recognise places in twilight and dark becomes weaker.

The elderly are a particularly vulnerable group of cyclists. Motorised traffic has increased enormously since they were young and began to cycle. Their capability to cope with the traffic situation when concentrating on cycling is not very good and injuries in an accident are usually very severe.

In the United Kingdom, 55 per cent of people in retirement have a problem with cracked and damaged pavements, 40 per cent say there is too much traffic, 31 per cent fear uncleared snow and wet leaves, 29 per cent have a problem with cyclists on the pavement, 27 per cent with vehicles parked on the pavement, 20 per cent are in difficulty because there is no pedestrian crossing and 15 per cent need more time to cross (Pedestrian Association, 1995).

*Disabled people*

Disabled people are those with a physical, sensory or mental impairment which affects their mobility. Ambulant disabled people are able to walk, but may depend on artificial limbs, callipers, sticks, crutches, or walking aids. Wheelchair users depend on a wheelchair for mobility, whether independent or assisted (IHT, 1991).

The ambulant disabled have a slow walking speed and they cannot walk long distances without rest. Visually impaired people have to find the way by hearing and touching.

According to Japanese reviews, the major difficulties of wheelchair users for going out are the differences of level between carriageway and pavement, weather conditions including rain, and inability to use public transport (Yoshitaka, 1992).

According to a study made in the late 1980s, in the United Kingdom, 142 in every 1 000 people aged 16 and over -- a total of some 6.2 million adults in Great Britain -- had physical, sensory or mental handicaps. About one in 12 of the adult population have some form of locomotive handicap [IHT, 1991]. In Sweden, 1 081 000 people, i.e. 16 per cent of the population, have some kind of reduction of ability (ScB, 1992).

**II.1.4. Other special groups**

Other special groups to be defined as pedestrians are persons moving by skateboards, roller skis or -skates as well as by kick sleds or kick sleds equipped with wheels.

Roller-skates and skateboards are a fad among young people. Moving on either of these requires much training before it may be regarded even as marginally safe. This kind of traffic is closely related to the need to "show off", which always has a negative effect on safety. The speed which may be acquired with these devices is far too high to be used among pedestrians and causes sudden movements and hazardous situations.

Roller skiers are mainly sportsmen and exercisers. Roller skis may reach a speed of 50 km/h and it is impossible to stop them rapidly from this speed. The roller skiers in Finland do not usually ski along pedestrian paths, for the sake of their own safety, but they prefer the combined paths for both cyclists and pedestrians.

The Scandinavians use kick sleds mostly in the Winter. Nowadays there are also kick sleds equipped with wheels for the summertime used mostly by elderly people. Speed is in no way comparable with the roller skates or skis, but may rise relatively high when going downhill.

**II.2. Regulatory environment**

Countries have different sorts of legal systems. Accordingly, this chapter gathers legal rules as well as rules with the status of strong recommendations. Furthermore, the degree to which details are stated concerning certain legislative aspects varies a lot among countries. Habits or customs of citizens in each country directly influence the legislative concepts, and regulations are often only introduced after having analysed these habits. This is the fact, for example, in countries with a long cyclist tradition like

Denmark or the Netherlands, where a wide legislation includes special provisions for cyclists, while in others, like Spain, cycling has only recently begun to gather momentum. The same is valid for pedestrians and for children, especially in the United Kingdom, where they are involved in a great number of accidents, and a traditional concern for reducing the accident rate for these road users can easily be observed, with the help of all types of measures, including most notably legal provisions, like introduction of “traffic calming regulations”.

When mentioning each type of different vulnerable road users, references will be made to the Vienna Conventions on Road Traffic and on Traffic Signs of 8 November 1968, of the United Nations, as most of the national legislation in Member countries of the United Nations include provisions or rules of these Conventions, either because they adhere to or endorse these international instruments or because they constitute a reference or an essential guide to driving and to road signs.

In this section, rules relating to “right” and “left” refers to situation in countries where the traffic must drive on the right hand side.

### ***II.2.1. Pedestrians***

#### *Restrictions of movements for pedestrians*

Rules applying to pedestrians are rather similar in all surveyed legislation; almost all of them follow the provisions of the Vienna Convention on Road Traffic, as shown below.

The place reserved for walking on public roads is pavements, footpaths and verges. If it is not possible to use pavements, footpaths or verges, pedestrians may walk on the cycle tracks, if existing, or the roadside. When using the roadside they shall walk in the opposite direction of the traffic, except if doing so implies danger or if special circumstances force them to walk in the same direction as the traffic. In any case, pedestrians shall keep as close as possible to the edge of the roadside.

The Vienna Convention states that, unless pedestrians take part in a procession using a carriageway, they should, if possible, move in a single file, especially, for traffic safety reasons, in poor visibility conditions or very dense vehicular traffic. This paragraph has been implemented in the Spanish law.

Persons wheeling a cycle, a moped or a motor cycle shall in all cases keep to the right. Some of the legislation analysed (Finnish, Danish, Spanish) establishes that pedestrians may not wheel cycles or carry bulky objects on pavements, footpaths, cycle tracks or verges if seriously impeding other pedestrians by doing so. Moreover, in Denmark, pedestrians using a cycle track may not impede other traffic meant for this space.

#### *Obligations to drivers*

Almost all the countries state right of way for pedestrians on marked pedestrian crossings, and thus demand drivers to give way to pedestrians crossing the road or even likely to step in. In the case of pedestrian crossings with traffic lights or police traffic patrols, the law usually specifically states that pedestrians must observe the traffic lights or indications from a traffic controller. In some countries, the obligations to drivers are much stronger. For instance, the Danish Road Traffic Act states that drivers

approaching an uncontrolled pedestrian crossing shall adjust the speed so that pedestrians in the crossing or about to enter it will not be endangered or impeded. If necessary, a driver shall stop to allow such pedestrians to pass.

Some countries, like France, have established that a gap of at least one metre is compulsory when overtaking or passing a pedestrian.

Finally, it should be mentioned that a car stopping or parking on pedestrian crossings and near by -- for example in Finland and Denmark within five meters -- is not allowed in most countries. This is sufficiently justified by the evidence that these areas are set aside for pedestrians to cross the carriageway and vehicles parked on them will form an obstacle and mask them.

### *Behavioural rules for pedestrians*

Pedestrians should cross carriageways on pedestrian crossings, if there is one available near by; if there is no crossing, pedestrians should cross the carriageway or the cycle track at a right angle, and preferably at an intersection. However, this rule is not equally applied in all countries. It was abandoned recently in the Netherlands where pedestrians are also allowed to cross the carriageway outside even if in the vicinity of a pedestrian crossing.

Pedestrians should always take due care to other traffic and take into account the distance and the speed of approaching vehicles. Thus, they should cross the carriageway without unnecessary delay. But in some countries, for example Great Britain, there are no legal obligations regarding pedestrians, but only recommendations.

Groups of pedestrians led by a person or forming a procession shall keep to the verge in the near side and move in the same direction as the traffic. In Denmark and Finland, a group of children with a maximum of two children beside each other shall, if possible, use a pavement, footpath, verge or cycle track.

At night, pedestrians are commonly recommended to use reflective devices; in case of pedestrian groups or organised processions, white or yellow lights must be used in the front and red lights in the rear. Always, of course, to the off side of the road. In Spain, these reflecting devices must be visible for drivers at a minimum distance of 150 metres.

### ***II.2.2. Provisions for particular pedestrian groups***

Most legislation points out the importance of paying special care and attention to particular pedestrian groups, in terms like “the driver must exercise extreme care when approaching a stationary school bus, bus or tram, as well as children, elderly people, disabled persons and other people who have obvious difficulties travelling safely in traffic”.

Some countries state more specific regulations, perhaps to face some problems which have recently arisen in these countries. For instance, in Spain persons using roller-skates, skate-boards or similar devices are not allowed to ride on carriageways, except when the way or area is specially reserved for them. They are only allowed to move around on pavement or in residential streets conveniently marked with the appropriate sign for residential street; and they are in no case allowed to be trailed or drawn by other vehicles.

### *Special arrangements for disabled people*

The degree of disablement varies according to the extent of decrement in physical, sensorial and mental faculties. Legal provisions concerning persons with reduced mobility exist in some countries; for example, disabled persons who are driving wheel chairs at normal walking speed will be put on the same footing as pedestrians. In Finland, however, they must comply with the same rules as cyclists if their speed exceeds 15 km/h; in Japan, this reference speed is 6 km/h. Furthermore, before installing traffic lights in pedestrian crossings in Finland, representatives for the organisation of visually disabled people are invited to comment on the projects.

In some, and probably most countries, there is a special policy towards the problems encountered by disabled people in their everyday life, particularly their access to public buildings and public transport. For example, according to the Swedish plan and constructing law, new buildings, extensions of old building for housing, working sites and public service must be designed to give access to people with reduced mobility. Concerning public transport, the Swedish legislation makes a distinction between existing public transport, for which rules set a lowest level of adaptation to disabled people, and new public transport with regulations regarding footsteps, door width, preparation for hoists, provisions of space for wheelchairs and ventilation.

In France, a special policy was specified by decrees and technical requirements adopted in 1978 and 1982 concerning transport vehicles and systems. In order to facilitate the trips of disabled persons, some statutory measures are taken towards both adaptation of public transport services, progressive modification of vehicle design standards and facilitation of special services for disabled persons. Another major step was taken in 1989, with the announcement of about 60 measures aimed at improving accessibility for everybody to all means of transport within a five-year period.

### *Parking for the disabled*

Most countries have special parking permissions for the disabled. Rules and requirements differ from country to country. Moreover, in Finland, a taxi and an invalid taxi may stop free of charge to pick up or set down a disabled passenger in a parking lot where a fee is set. The granted advantages are similar in various countries: the possibility to park without time restrictions or longer than usual; parking without paying the fees; exceptions to the rules of stopping and parking prohibition, provided that it does not imply a risk for the traffic. Thus, in the Finnish legislation, on request of the police, a parked vehicle which is obviously a hazard shall be moved to a spot designated by the police.

Finally, reference should be made to the European Council Project of recommending parking cards for disabled. The aim of this recommendation is to standardise national parking cards for disabled persons (restricted mobility) to be used in all EU member States. This measure is aimed at enhancing road safety and promoting free travel of disabled people in their private cars. This card should grant the right to use the parking premises valid for residents of an EU member State.

Nowadays, some countries recognise the international sign for a disabled person and give holders of this sign the same treatment as compared to their own residents. For instance in Finland, a car with an international sign for a disabled person is granted the same advantages as a disabled resident's car: it may be parked free of charge in a parking lot where a fee is set; in an area where parking is prohibited by a traffic sign; without time restrictions in a parking lot where parking time is limited by traffic signs.

### *II.2.3. Cyclists*

#### *Restrictions on cyclists*

As a rule, cyclists must keep to the cycle tracks, where they exist. Where no tracks exist, cyclists must in general use the verges or keep to the near side of the carriageway. In Japan, they are exceptionally allowed to use the pavements. Even if cycle tracks exist, cyclists are allowed to ride on the roads in Sweden, if it is more suitable considering the destination and if done with extra care. Cyclists are generally not permitted to ride on motorways.

The Vienna Convention directly prohibits cyclists to carry passengers on their vehicle, but allows Contracting Parties to authorise passenger transport on an additional saddle or a child's seat which may be mounted to the bicycle. Most legislation allows transport of people up to the number of persons for which the bicycle has been designed. Some countries provide rules for trailers behind bicycles as well.

Nevertheless, there are some differences in legislation concerning the age. In Finland and Sweden, the cyclist should be at least 15 years old to carry passengers below the age of ten, or 18 years old to carry two children below the age of six. In Denmark, a 15 year old cyclist may carry two children below the age of six. In the Netherlands, the only requirement stated by the law is carriage of children below the age of eight years; they must be seated on a safe place with sufficient support for their backs, hands and feet.

The different regulations do not require special permissions to ride a bicycle, no licence is required and there is no age restriction, except in Denmark where children under the age of six must be accompanied by a person aged 15 at least.

Most countries have common regulations for cyclists, but differences concerning specific infrastructure for cyclists appear between countries with a long bicycle tradition and countries where cycling is a new reality. Infrastructure issues are rarely referred to in regulations, being simply the object of recommendations or administrative decisions. It is evident that infrastructure issues sometimes turn out to become so important or general, that they will provide the background for regulations.

#### *Obligations to drivers*

Concerning right of way, legislation states that drivers of motor vehicles, intending to turn right must give way to cyclists going straight ahead. The same rule exists for drivers turning left, who must give way to oncoming traffic.

When overtaking a two-wheeler, or when a two-wheeler is overtaking another vehicle, the Spanish law requires a minimum safety distance between the two road users of at least 1.5 metres; however as an exception to the general rule, overtaking of a two-wheeler is not forbidden at intersections or near intersections.

#### *Behavioural rules for cyclists*

Referring to the Vienna Convention, some legislation states that cyclists are not allowed to ride a bicycle without holding the handlebars with at least one hand.

Concerning cyclists riding abreast, there are no common rules. But the Vienna Convention raises the possibility of allowing cyclists to travel two or more abreast. In Spain, however, riding abreast is not allowed except when overtaking another vehicle, and even in this case certain requirements should be observed. In other countries, legislation is more permissive. In France, Denmark, Sweden and the Netherlands, for example, cyclists are allowed to ride abreast if not causing danger or impediment -- i.e. when a vehicle is approaching from behind, they must return to a single file. In some countries, such as Denmark and the Netherlands, cyclists are allowed to overtake a vehicle other than a bicycle or moped from the near side.

As to road traffic rules, almost all countries have special rules for cyclists turning left, as this is one of the most dangerous traffic manoeuvre for cyclists. As a general rule, cyclists must keep as close as possible to the edge of the carriageway in order to turn left after stopping to see that they do not hinder other road users. In Spain, this provision should always be enforced except when there is a lane specially designed for the left turn.

In Sweden, there are also special rules for cyclists crossing the road -- i.e. at non controlled crossings between streets and cycle tracks -- the cyclist must take the speed and distance of the oncoming vehicles into consideration before crossing. In the Netherlands, cyclists must always give way to motorists at intersections without right of way regulations, except in special residential areas -- the so-called "woonerven" -- where all road users have equal status.

While riding on public roads, cyclists must observe the same traffic rules as other road users. In some countries, drunk or drugged cycling is an offence which may be punished similar to drunk driving. It can in principle even be an offence to allow a drunk person to cycle. Thus, the owners or waiters of restaurants should prevent drunk cyclists from cycling and report if necessary to the police. As a consequence, cyclists suspected for drunk cycling must pass a blood alcohol test. In Sweden, although the law does not forbid cycling after drinking, cyclists may be prosecuted for careless behaviour in traffic.

#### *Special requirements for equipment*

The Vienna Convention states that bicycles should be equipped with: brakes, a bell, a red reflecting device at the rear, devices ensuring that the bicycle can show white or selective yellow lights ahead and red lights to the rear.

Not all legislation deals with the compulsory equipment on bicycles; but the Swedish law, for example, agrees with the Vienna Convention. In the Netherlands, side reflectors on the tyres are compulsory for all bicycles. In Spain, the Road Traffic Code states that the red lights at the rear should be visible at night, at a minimum distance of 300 metres.

It is mandatory to wear cycle helmets when riding a bicycle only in some Australian and US States, contrary to motorcycle helmet wearing which is compulsory world-wide. However, the safety aspects of implementing such a measure have been considered in most countries. But, as recently shown in studies carried out in the United Kingdom, in order to be a success, a higher level of acceptability and voluntary wearing must exist before introducing compulsory measures to protect people from injury, such as seat belts and helmets.

#### **II.2.4. Law implementation in practice**

##### *Trends in changing regulations*

Law must be observed: by establishing rules, efforts are made to regulate certain aspects of life which, otherwise, would fall under complete anarchy, bringing about the clash of vested interests. Concerning traffic, efforts are taken towards serving the interests of all parties using public ways, in order to increase road safety. But the fact is that regulations are infringed by drivers as well as by cyclists and pedestrians.

Generally, most pedestrians have had the experience of crossing the street away from a pedestrian crossing although one exists only a few minutes walk away. In the same way, most pedestrians have crossed against red because no car was in sight, or so far away that they perceived having time enough to cross. Therefore the main problem is not the lack of a suitable regulation, but the lack of compliance with existing rules, and thus, action must focus on the enforcement of laws.

In the Netherlands, the question of whether such a regulation is adequate or not has been raised. The recently revised Dutch "Highway Code" (RVV, 1990), that became effective in November 1991, points out that "in a great number of situations road users are very well capable to determine which behaviour is desired and safe". As a consequence, a number of rules has been abandoned and there are few specific rules for all road users, compared to the former Highway Code.

The question is now, whether it should be advisable to give a wide margin of freedom for individuals to determine by themselves which rules should be observed in public ways. Up to a certain point, and referring to adults, the answer might be yes. But the question could be raised whether road users have received enough education to be able to know their rights and duties in traffic. And, further, it is a question whether they are aware that other users should be respected. It is crucial that road users are able to distinguish between safe and correct behaviour, compared to actions managed by their own impulses.

##### *Are rules observed?*

It is also particularly interesting to know to which degree existing rules are observed by vulnerable users. It has been verified that, in most cases, the introduction of a given rule also creates a high degree of observation. As an example, it can be cited that since January 1, 1987, side reflection in the form of wheel circles fitted to both wheels has been made compulsory for all bicycles in the Netherlands. Before the introduction of the legislation, about 25 per cent of the bicycles had side reflectors. Observations made in February 1994 showed that about 72 per cent of cycles stored in the sheds of secondary schools and about 77 per cent of cycles stored in company bicycle sheds were fitted with side reflectors to both wheels. But it also appears that 90 per cent of all-terrain bikes did not have side reflectors (Varkevisser et al., 1994).

Rothengatter concludes that "normative behaviour becomes attractive, if road users perceive that most road users comply to it, and that those who do not comply get confronted with the negative consequences. In addition to enforcement, feedback should be considered as a major factor influencing road user behaviour because it is the only way to tell the road user that it is normal, hence acceptable, to be normative." (Rothengatter, 1991).

Further, Huguenin and Aebischer explain that “the main psychological variables determining the observance of rules seem to be: reaction against or approval of a rule; personal competence; value of safety; conformity; which should be regrouped at the operational level while taking better account of the influence of the variable ‘anticipated penalty’.” (i.e. anticipation of a penalty if an offence is detected). As they point out in their conclusions, knowledge of rules hardly plays any role in the observance of rules; but, on the contrary, reaction against or approval of rules plays an unquestionable key role. If this preliminary assumption is correct, it would be necessary to introduce as much as possible new rules minimising the aspect of restricted freedom and maximising the aspect of enhanced safety (Huguenin et al., 1991).

### *Judicial practice*

Judicial sentences have an undeniable practical importance as they interpret the law and create a doctrine transformed into legal practice (according to the legal systems prevailing in each country).

The trend in court is illustrated by an example from the Netherlands; in 1992, the High Court ruled that even if vulnerable road users do not adhere to the rules and consequently become involved in an accident with a motorised vehicle, half of the damage costs should be paid by the car driver (Netherlands Dagblad, 1992). We have to distinguish between the concept of guilt that has to be determined by a Criminal Court and the civil liability that establishes, if necessary, the accident compensation.

Spanish courts normally follow the doctrine of assessing the behaviour contributing to the final consequences, from the offender’s as well as from the victim’s point of view, in the way that the behaviour of each party should be considered separately and compensation for guilt should be excluded in the criminal sphere (Gil Sáez, 1986). In the same sentence, the court refers to the principle of confidence according to which drivers should not be able to foresee the pedestrians’ offences. This principle of confidence is excluded by the principle of safe driving in case of accidents with children, disabled and elderly people, due to their unpredictable impulses and ignorance of regulations, which demands increased care and diligence by the drivers.

## **II.3. Behavioural patterns on the road**

### ***II.3.1. Pedestrians***

Movement of pedestrians is often not straightforward travel from one place to another. They do window shopping, carry bags, push prams or walk a dog, which might make unpredictable movements and cause hazard to the other road users. Reasons for walking can be divided into three categories: journeys to work or school etc., exercise or leisure.

When people are walking to work, they usually choose the shortest route and do not want to spend any extra time on the trip. They obey the rules when they think it is sensible and necessary. Taking the shortest route can mean that they do not use underpasses or pedestrian crossings. They may not obey traffic lights, if waiting for the green light seems to take too long. Pedestrians on familiar routes tend to pay less attention to traffic than when walking in unknown surroundings.

People who are walking to get some exercise have normally enough time to choose the safest route and to obey traffic rules, too. They prefer pedestrian footpaths which are separated from car traffic, even if it makes the trip a little longer.

During leisure time adults may be chatting and walking around, particularly in pedestrian areas, in shopping centres, or in parks. Often, when walking at leisure one does not concentrate on traffic or on traffic rules. In pedestrian areas, one feels safe and assumes that conflicts or collisions between motorised traffic and vulnerable road users are impossible. Young people with roller-skates and skateboards disturb other pedestrians in crowds with their speed. Children may play in the carriageway but they usually do so only in residential areas. When playing children can also suddenly rush into the street.

Elderly pedestrians who suffer from losses of sensory abilities often have trouble coping with difficult traffic situations, for example crossing a busy street, or at junctions where there may be turning traffic (SWOV, 1987, Zeeger et al., 1993). Hence they exercise more caution in their crossing behaviour, wait longer at the kerb, but take less notice of other traffic when actually crossing the road (Carthy et al., 1995). The elderly who are aware that heavy or fast traffic, or adverse weather conditions, make their trips difficult or stressful tend to walk less, thus restricting their own mobility.

As a rule, pedestrians do not follow traffic rules as well as motorists. Walking is every man's right, whereas driving a car requires a good perception of traffic rules. For example, pedestrians often walk against the traffic lights, even in countries where it is illegal. The main reason for the behaviour of pedestrians may be that the traffic environment has been planned from the point of view of car drivers, on the assumption that pedestrians are willing to wait longer for a green light or walk a little longer to cross the street safely. However, in Japan, only 15 per cent of pedestrians are responsible for the accidents, most of which are caused by darting-out, crossing at the front or rear-end of vehicles and neglecting signals. In accidents with cyclists, cyclists are responsible for only 20 per cent of the accidents and this amounts to 40 per cent in the case of fatal accidents. Most of these cases are caused by failure to stop and ignoring signals.

### ***II.3.2. Cyclists***

Cyclists have a difficult position in traffic. As seen earlier, they are sometimes supposed to follow rules for motorists, sometimes rules like those intended for pedestrians. Their needs are similar to those of pedestrians (shortest routes, smooth surfacing, etc.), but they are taken into account in traffic as a last resort. The situation does not encourage homogeneous patterns of behaviour.

There is indeed a great deal of variation in cyclists' behaviour in traffic. The younger cyclists are not yet able to cope with all the traffic signs and rules that apply to them. Young cyclists often like to play and show off, which leads to risk taking. There is also some amount of recklessness among adult cyclists, especially at signalised intersections, where they are often more inclined to act upon their own perception of traffic rather than wait for the red light ("which has obviously been meant for car drivers") and when performing turning movements.

Elderly cyclists' capability to cope with the traffic situation while concentrating on cycling decreases with age; they tend to react more slowly (Van Schagen & Maring, 1991). Moreover, they display loss of control with regard to steering the bicycle more frequently than other age groups. However, their patterns of behaviour do not significantly differ from those of younger cyclists, except for their mean speed which is lower (Maring, 1988).

Differences in cyclists' behaviour are also related to the purpose of their trip. When they use a bicycle to go to work or to school, they are on familiar routes and tend to pay less attention to other traffic. Just like pedestrians, they choose the shortest possible route to reach their destination, which sometimes leads them to use one-way streets in the wrong direction, or to cycle on the pavement, thus creating conflicts with pedestrians. When cycling for exercise, different bicycles are often used, and the speeds reached may be high.

Cyclists do not always follow traffic rules correctly. The main reason for this may be that traffic planning has worked for a long time with the emphasis almost solely on motorists, which made it sometimes difficult, even almost impossible for cyclists to perform their task as prescribed by the rules. Traffic arrangements and environmental conditions as well as traffic rules therefore cause problems for cyclists. In addition, their knowledge of traffic rules has proved to be insufficient (Liikenneturva, 1987 and 1991). It has to be noted that elderly cyclists, perhaps in part because they are aware of their own limitations in adapting to traffic situations, are more than others inclined to follow clearly defined rules: they indicate more often when they intend to change directions, they keep to the side of the road better, they check more often on traffic that is supposed to give them priority (van Schagen & Maring, 1991).

## **II.4. Physical environment**

### ***II.4.1. General conditions of the physical environment of vulnerable road users***

As mentioned in Chapter I, the road environment of vulnerable road users has evolved over the years and bears the mark of successive attitudes and priorities of society, embodied in the designs of planners and engineers. Evolution trends seem to follow the same patterns in all industrialised countries. However, changes occur at a different pace in different countries, and often in different areas of the same country, according to local institutional conditions, availability of information, or degree of awareness of the population and/or the decision-makers. As a result, the physical environment of vulnerable road users is heterogeneous and varies according to the geographical location as well as to the amount of concern generated in the local communities. When attempting to describe the physical environment in its present state, this can only be done following fairly general lines.

On most inter-urban roads, priority has remained with the car. Walking or cycling is assumed by engineers to be a marginal activity. Roadsides are most often not equipped to suit the needs of pedestrians or cyclists. Better facilities may be provided for walking through villages or small built-up areas, but crossing facilities still demand greater attention from pedestrians than from drivers and are implemented in such a way as not to further impair motorised traffic, already considered as penalised by a severely restrictive speed limit (50 km/h in a majority of countries). The most critical location seems to be the transition between built-up and non built-up areas, where drivers are not yet quite aware that they enter a village or a town, but where pedestrians are already numerous; infrastructure details are usually not clear as to which sort of situation to emphasise. For example, pavements for pedestrians are seldom provided outside the densest part of the built-up area, except in some very new schemes aimed at warning drivers that they need to be more aware of local traffic and of the need to reduce speed immediately.

Cities show a more varied aspect. In most old and dense city centres in Western Europe, traffic has been reduced, and public transport has partly taken over, so that pedestrians and, in some countries (such as the Netherlands or Denmark), cyclists, are getting a more and more comfortable environment to move in (if one ignores pollution, particularly from diesel engines). In some countries, such measures have brought back residents to city centres that had previously been fled by the population and reduced to

daytime activities. Apart from city centres, a substantial proportion of residential areas have been either built to avoid through traffic, or redesigned as traffic calming areas (or 30 km/h zones), and accidents have decreased. However, comprehensive networks across cities for pedestrians and cyclists, although gradually being implemented in some countries (as in Finland, for example), are far from being generalised yet. Getting out of a residential area still calls for the use of private cars or, at best and in zones that are not too peripheral, of public transport.

Also, a serious problem generally remains on parts of urban areas with mixed activities, which are usually suburbs and/or neighbourhoods of large radial trunk roads. Local centres are usually found there, including shops, workshops or small industries, and even schools. Little effort seems to have gone into improving such areas, either because of local social problems involving the municipal authorities, or because the question of accommodating heavy through traffic with local life and vulnerable road users has been solved by favouring traffic. Accidents may be both frequent and severe, due to the lack of will to slow down vehicles. There are exceptions, such as for example the schemes of traffic calming implemented within the French programme “Ville plus Sûre, Quartiers sans Accident” (safer town, neighbourhoods without accidents) in suburban areas, or the demonstration programmes in some cities in the Netherlands and in Denmark. Such examples are still far from being generalised.

Few countries can boast of a physical environment taking good care of the most vulnerable road users. Although a number of design features have been meant primarily for the safety of children -- such as newly built or improved residential areas or traffic calming schemes -- they are still very much at risk in the suburban types of areas described above and in the parts of towns or cities that still reflect the old design forms giving priority to motorised traffic. Elderly people are no better off and often have to cope with traffic lights or crossing conditions meant for more alert pedestrians or cyclists, and with pavements or footpaths left with obstacles or littered, etc. The attempts made in the past at building overpasses or tunnels for pedestrians -- a course of action which has now been mostly abandoned for reasons of cost and lack of efficiency although already widely used -- have been particularly penalising for elderly people or anybody with reduced mobility.

Finally, few cities have been designing specific facilities to promote mobility of the disabled. Pavements are often too narrow to accommodate wheelchairs. The level differences, especially between pavements or footpaths and crossings, also cause problems. Furthermore there is still too often no alternative to using stairs on pedestrian routes. For blind people, the great difficulty lies in finding the right and obstacle-free route to the destination; however, the situation is gradually improving. Some experiments with tactile or auditory guidance for blind pedestrians along routes or at crossings have been made in several countries. Some cities have endeavoured to organise pedestrian networks for use by all, including wheel-chair users -- no steps, raised pedestrian crossing, removal of major obstacles -- but such examples are still rare.

General design features do not fully describe the environment of vulnerable road users: infrastructure condition is also relevant for mobility and safety. It can be observed that, even when carriageways are usually kept in an adequate state of repair to fulfil the needs of motorised traffic, maintenance and repair of footpaths, pavements, and cycle tracks are not always performed. Uneven surfacing causes problems for all the vulnerable road users, especially for the elderly and disabled persons. During the wintertime, there is a problem of slipperiness, at least in the countries suffering long periods of rain, frost or snow; fallen leaves create additional hazards for pedestrians and cyclists, with increased risk of skidding.

Although inadequate design and maintenance of facilities for the most vulnerable road users may not necessarily translate into more accidents overall as travel is discouraged, mobility is reduced, and

therefore there is lower exposure to risk. However, the risk for those who do continue to get out of their homes is increased. Reduced mobility also disfavours these vulnerable road users and is an additional disadvantage.

#### ***II.4.2. Design requirements for vulnerable road users***

The road infrastructure is supposed to be designed as a support for transport activities, and thus to be adapted to the needs of the various kinds of road transport. In fact, care has always been taken to adapt road networks to the needs of car, lorry, or bus traffic, calculating road-width in relation to traffic flows, road design and surfacing in relation to expected speeds, curve radii in relation to vehicle steering characteristics, etc. While this kind of “good practice” constituted the basis of engineering work, the needs of vulnerable road users were considered as marginal and introduced only after most infrastructure details had already been fixed. Cyclists were mixed with motorised traffic, and special facilities were provided mostly on streets wide enough for allocating some space without taking it off car lanes. Also, the needs of pedestrians taken into account were those considered “average”, not the needs of the most vulnerable.

This situation can be illustrated by an example. In a road and traffic system based primarily on cars and other forms of motorised modes, pedestrian crossings were introduced, openly to protect pedestrians getting to the other side of the road, implicitly to concentrate the movements of pedestrians into a limited number of locations, thus reducing the frequency of perturbations to the drivers. In countries like Great Britain, where laws on pedestrian priority at zebra crossings are particularly strict, it was soon found that the zebras were still too much of a constraint on car drivers: pelican crossings (or push-button signalised crossings) were introduced, on which pedestrian priority was limited to the short periods of time provided by the traffic light system. In countries like France, where regulations are not so favourable to pedestrians, zebras on urban arteries with high traffic flows proved inefficient in protecting pedestrians, who consequently did not feel compelled to cross there. The introduction of traffic lights was often thought a solution, but the period of time allowed for pedestrians to cross was calculated on an average pedestrian speed which could never have been met by elderly or disabled people, nor by pedestrians carrying heavy loads, pushing a pram, or accompanied by young children; hence some stress for the most vulnerable users, as well as accidents. The introduction of overpasses on the main through-traffic arteries called for pedestrians to perform additional physical efforts, which again proved impossible for the less able, thus limiting their movements or forcing them to cross in traffic at a far greater risk than before the overpass was put in place.

In a balanced traffic and transport system, the needs of vulnerable road users should be taken into account in the design of the road infrastructure: a “guide of good practice” including design criteria similar to those applied to motorised traffic is in order. Engineers and decision-makers should thus bear in mind that mobility of pedestrians, with an acceptable level of built-in safety, requires that a consistent network of footpaths, pavements, pedestrianised streets, specifically designed mixed traffic streets, etc. should be organised, taking due account of the diversity of vulnerable road users (children, elderly, disabled persons, etc.); of the need to provide adequate pavement width to ensure smooth moving and thus avoiding pedestrians walking on the carriageway; and of the need to keep any parts of the pedestrian network clear of any obstruction; well maintained and in good state of repair, and finally to provide sufficient street lighting to ensure that pedestrians are conspicuous, and avoid insecurity feelings at night-time.

As mobility and safety are major issues for the social integration and life of people with a disability, characteristics of the walking networks should take into account their own needs, so as to

enable them to perform trips with a degree of ease comparable to that of everyone else. For example, ramps at an acceptable angle should be provided instead of (or in addition to) steps; guidance systems should be installed for road users with a vision impairment; minimum width of pavements or footpaths should be sufficient to accommodate wheelchairs; etc. Attention should also be paid to the fact that moving is particularly strenuous for the elderly and the disabled persons, and areas for stopping and resting should be provided at suitable distances.

At crossing points between the pedestrian networks and the motorised traffic ones, care should be taken to make the motorists aware of the presence and rights of pedestrians. Enough protection should be afforded to pedestrians, in relation to the type of networks and to the composition of traffic at the location. As already stressed, the performance of the less able pedestrians should be taken as a basis for designing protective devices, as they would otherwise be at higher risk of a collision or an injury than other road users. Visibility conditions between the different road user flows should be satisfactory at all times, and any obstruction to free access to the facilities or to visibility should be removed.

Similarly, a “good practice guide” should mention that mobility of cyclists requires a consistent network on which they can move with adequate comfort and protection. Width of lanes and tracks should be sufficient to accommodate actual bicycle flows; adequate visibility distance should be ensured as well as maintenance; also, adequate separation between cycle and pedestrian routes should be provided to avoid conflicts that could prove dangerous, mostly to pedestrians; proper street lighting is as much of a need for cyclists as for pedestrians; at the crossing points between cycle and motorised traffic networks, and at road junctions adequate facilities should be provided to ensure safe manoeuvring for cyclists and without getting into conflicts with motorised road users.

More detail on appropriate safety measures for both pedestrians and cyclists is provided in Chapter VII.

In addition to satisfying the needs for mobility, urban public space is now often considered to have to support not only travelling, but also social and commercial activities. Road users can take part in these, either in relation to their daily trips, or separately. Obviously, any increase in the use of walking or cycling as transport modes will facilitate social and commercial activities. Again, the needs and behaviour of pedestrians, while playing, meeting socially, or shopping are not the same as those related to commuting. Increased protection is needed since, at such times, the attention of the vulnerable road users is not on traffic, and their movements may be erratic and thus unexpected by drivers. In the parts of public space where such mixed activities are taking place, it is essential to achieve a low speed of all vehicles and increased attention of the drivers, through adequate organisation of the environment, in addition to stressing the priorities to vulnerable road users through features of the environment as well as through legal means.

## **II.5. Social environment**

### ***II.5.1. Introduction***

The social environment in which vulnerable road users operate is governed by the rules controlling road use by various groups; social attitudes; and educational aims and objectives. There are two aspects of the issue. First, how do motorised road users see the needs of vulnerable groups, what are their attitudes to them, what are their responsibilities to them, and how is this taken into account in their education, training and publicity campaigns? Secondly, what responsibility do vulnerable road users have

for their own safety, and how is their safety improved through education, training and publicity programmes.

Increasingly, as society has become more motorised, there has been a tendency for the needs of vulnerable road users to be subjugated to the requirements for traffic to move freely. At its most extreme, in towns this can lead to segregation of pedestrians behind barriers, with road crossings only permitted through underpasses or over bridges. The safety of the vulnerable is therefore in their own hands and they must protect themselves by conforming to the physical restraints imposed on them. At the other end of the spectrum, vulnerable road users in certain areas may be accorded priority through facilities for cycling, pedestrianised town centres, traffic calmed areas. There are signs that the needs of the vulnerable and the necessity to create urban environments sensitive to their needs are increasingly being recognised. Concerns about congestion, air pollution and road accidents have focused attention on the need to reduce dependence on the car.

The physical environment and the degree of priority accorded to pedestrians is a strong indicator of the attitude of society to the needs of vulnerable road users. In turn, this influences the way that drivers behave, and their sensitivity to the vulnerability of pedestrians and cyclists. Despite the fact that all drivers are also pedestrians at either end of their journey, research carried out in Great Britain has shown that there is little sensitivity to the position of pedestrians, who do not figure in drivers' assessments of risk. In the competition for road space, pedestrians are seen to impose little threat.

Traditional driver training concentrates largely on the skills required to pass the driving test. But an integral part of the process of learning to drive should be how to react safely to other road users, including the most vulnerable. Driver training programmes, and the rules of the road as set out in national legislation and advice can influence driver behaviour towards other road users. Behaviour can also be influenced through publicity programmes which stress the vulnerability of pedestrians and cyclists and the need to moderate speed. Drivers need to be aware that young children are unpredictable and cannot be relied upon to ensure their own safety. The driver has the responsibility, particularly in residential areas or close to schools and shops where pedestrian activity is high, to moderate speed and anticipate pedestrian movement.

Whilst driver behaviour has a major part to play in protecting the vulnerable, it is also necessary to recognise that pedestrians and cyclists must be aware of traffic danger, and that children in particular need to be taught the skills to move safely in the presence of traffic. Road safety education and training has a crucial part to play to complement safety programmes aimed at drivers.

This section therefore considers how the social environment affects the safety of vulnerable road users through the influence of driver training, road safety education and training, and publicity programmes.

### ***II.5.2. Driver training***

With the exception of Great Britain and Ireland, some form of formal driver training is mandatory in European countries. Many countries also allow informal practice and training with friends and relatives, but this is not permitted in Germany, Denmark, Netherlands, Portugal, Luxembourg, Greece and Spain, and is restricted in some others e.g. in France only under the "*Apprentissage*" system. In practice, even where formal training is not compulsory it is the norm e.g. in GB 98 per cent of learners take some formal lessons. The obligations of drivers towards pedestrians and cyclists are set out in most countries in driver training curricula and in publications setting out rules for road users. The aim is to

instil a need for consideration for vulnerable road users, their rights when crossing the road, and the special problems of children and the elderly. Often stressed is the need to moderate speed in the presence of pedestrians and cyclists and to allow them room (TRL, 1995).

Theory tests, which are compulsory for drivers in EU countries, under the 2nd Driver Licensing Directive from 1 July 1996, give an opportunity to inculcate social responsibility and awareness of risk in drivers, and to highlight the need to behave in a considerate fashion towards vulnerable road users. Learner drivers are expected to develop the ability to make judgements based on anticipation, and must be familiar with the differences and special features of the different types of road user.

Some examples follow which indicate particular aspects of driver training which are relevant to the needs of vulnerable road users.

- In Great Britain, in preparation for the driving test, detailed instruction and advice are available in the Driving Manual and the rules which apply to road users are set out in the Highway Code. The Driving Manual does not have a specific section on vulnerable road users, but the section on Defensive Driving sets out the behaviour of the driver towards pedestrians and cyclists. It emphasises the need to watch out for them, to give them plenty of room, and to give way when pedestrians are crossing the road. The special needs of children and elderly and disabled people are set out. It is pointed out that cyclists may swerve into the path of a car, and have problems in bad weather or on poor road surfaces. Children may be unpredictable and drivers should slow down in narrow roads and in residential areas to 20 mph (Driving Standards Agency, 1992). Similar requirements are included in the section on pedestrian safety in the Highway Code (Department of Transport, 1996). Drivers are taught to slow down near schools and to stop for a school crossing patrol. At road junctions, drivers must give way to pedestrians who are already crossing the road into which they are turning. On narrow country roads, drivers must look out for pedestrians and give them plenty of room.
- In Finland, the Driving School Curriculum does not have a specific section on behaviour towards vulnerable road users, but the sections on Interaction among road users and Driving in Crossings are both relevant. The legal speed limit is often too high in densely populated areas where there are many pedestrians. The driver must regulate speed so that it is consistent and predictable for the benefit of other road users. On low speed residential roads speeds must not exceed 20 km/h, and drivers must give way to pedestrians. Drivers should pay attention to traffic on cycle lanes and on pedestrian crossings. Specific instruction is given on driving across a pedestrian crossing or a cycle lane. The importance of observation and perception is stressed, particularly when turning, when attention may be on other traffic rather than the crossing, and a cycle lane may be missed. Drivers are obliged to give way to people crossing on pedestrian crossings, and when crossing a cycle lane whilst turning. In addition, drivers are instructed to always look out for cyclists even when they have the right of way (Ministry of Transport and Communications, Finland, 1994).
- In Sweden and Denmark the theory part of the training programme discusses speed and the increased risk of an accident particularly to vulnerable road users, as speed increases. Vehicle drivers have special obligations to vulnerable road users, must give them enough space, and give them priority when crossing a cycle path or other restricted areas. Drivers must slow down and give way to pedestrians on crossings, and watch out for elderly people and children who may misjudge traffic. It is prohibited to overtake before or at a pedestrian

or bicycle crossing. There is a whole chapter in the Swedish training manual on “The city, children and car traffic”.

- In the Netherlands the new Highway Code which came into effect in November 1991 emphasises the responsibility of the driver in deciding how to behave properly. In driver training instruction it is explained why certain rules exist and which safety consequences may result from certain behaviour in traffic. Central issues are “social and responsible driver behaviour” and “risk awareness”. Driving instructors are examined on the needs of other road users, which is an indication of the importance of this in driver training. They must indicate where pedestrians and cyclists are likely to be, and how driving should be adjusted to ensure their safety.

These examples show that in some countries at least there is good theoretical and practical driver training on the needs of vulnerable road users. However, once a driving licence is obtained, the accident statistics indicate that in practice these lessons are not always followed. There may be reasonable attention paid to pedestrians on crossings, but less consideration at other places. A study in the United Kingdom has shown that at least 90 per cent of drivers in London stop immediately at a zebra crossing when pedestrians are waiting to cross, but casual observation suggests that drivers are much less likely to observe the rules on giving way to pedestrians when turning into side roads.

There is a growing recognition, however, of the need to shift the onus of responsibility towards drivers, at least where children are concerned. In Germany, a driver going too fast for the conditions cannot argue in mitigation that a child ran out of nowhere when an accident occurs. In Great Britain, when child pedestrian accidents are being investigated by the police, a key factor is the speed of the motorist involved.

It is notable that the first part of a major study of social attitudes to accident risk in Europe -- European drivers and traffic safety: social attitudes to road traffic risk in Europe (SARTRE) -- virtually ignored vulnerable road users. The only reference in the questionnaire is opinion on whether “more consideration should be given to pedestrians and cyclists when planning towns and roads”, which takes responsibility away from drivers (Barjonet et al., 1994). A study of road users’ perceptions and attitudes to risk and road safety was carried out in Great Britain for the AA Foundation for Road Safety Research. This showed that drivers had a lack of perception of pedestrian activities and risk. Drivers did not take pedestrian activity into account in assessing risk of accidents. Pedestrians were found to be low in the hierarchy of road users, and since they were perceived by drivers as presenting little competitive threat for road space, their needs and safety were ignored. Drivers underestimated the risk to pedestrians when they were driving, but were better able than non-drivers to assess risk to themselves when walking. There was substantial overestimation of a pedestrian’s probability of survival if hit by a car at a range of speeds. Whilst in actuality 50 per cent are likely to be killed if hit by a car at 30 mph, the survey result was only 14 per cent were thought likely to be killed. This misperception is carried through into driver behaviour, with 80 per cent of drivers admitting to breaking speed limits. This is a similar finding to that of the SARTRE study where over 80 per cent of respondents thought that other drivers break the speed limit (Carthy et al., 1993).

### ***II.5.3. Road safety education and training***

Most Western European countries have a compulsory requirement for road safety education to be taught in schools. The focus is primarily on walking and cycling, but for older children pre-driver issues are included. The aim is to give children the skills they need to use the road safely. Road safety

education has a primary role in developing skills, knowledge and understanding of young people, as well as influencing their attitudes. Increasingly, as well as school based education programmes, the need to involve parents in teaching their children the necessary skills is being recognised.

The following examples indicate how road safety education is approached in a sample of countries.

- Child safety is a high priority policy area in Great Britain which has relatively high child pedestrian casualty rates. Road safety education is one of the main policy tools for reducing casualties. It is the responsibility of local authorities and not part of the National Curriculum. However, materials and resources have been developed for schools which can be integrated into subject lessons as part of the National Curriculum. Guidance on road safety education in the form of good practice guidelines have been produced and provided to local education authorities. They present local authorities with a model for the provision of road safety education in primary and secondary schools. A Secondary Steps package for 10-12 years old has been distributed to all secondary schools (Department of Transport, 1995). Local authorities have a statutory duty under the 1988 Road Traffic Act, to promote road safety, including road safety education. Provision at a local authority level (Police have responsibility in Scotland) is usually co-ordinated and initiated by Road Safety Officers who are responsible for education, training and publicity in their local area. For pre-school children, Traffic Clubs, which comprise a series of books sent to children from the ages of three to five, encourage and enable parents to train their children in an active and developmental way to be safe road users. In primary schools, in addition to traditional road safety education materials, increasing use is made of practical pedestrian training methods using parent volunteers. This involves learning in small groups in the local road environment, in situations where children are encouraged to develop safe skills rather than be given a set of rules. These methods have been found to greatly enhance children's ability to choose safer routes and find safer crossing places (Thomson & Wheelan, 1996). In Great Britain, road safety education is primarily targeted at pedestrians and cyclists, although for the 16+ age group, pre-driver education is being encouraged. This aims to introduce safety issues and responsibility to other road users rather than provide actual driver training.
- In the Nordic countries, the approach is to regard road safety education as a lifelong process. Skills and knowledge develop and adapt to the different stages of life. The aim is to raise public awareness of road safety issues. Road safety education is based on guidelines issued by the authorities, but in practice its extent is at the discretion of local authorities. Road safety experts and organisations offer their services to schools. Community based initiatives are encouraged with emphasis on neighbourhood safety schemes. Voluntary road safety clubs arranged in co-operation with parents provide pre-school children with a basic grounding in road safety. For school age children road safety comes under the official school curriculum, although each school decides on its extent. The role of road safety authorities is to motivate teachers by offering teaching models and materials. An effort is being made to include road safety education in basic teacher training. In Denmark, in addition, children are taught safe behaviour as both cyclists and pedestrians and take three voluntary cycle tests (Jarvinen, 1995).
- In France, the responsibility for road safety education in schools rests jointly with the Ministry of Education and the Ministry of Transport. Teaching of the Highway Code is officially part of the school curriculum in primary schools. All students at secondary school are required to study for a road safety certificate (ASSR). At the end of the second year of

secondary education (about age 12), this covers pedestrians and two wheeled vehicle riders; another ASSR was added in 1993 at about age 16 which covers wider road safety and travel concepts and the student's future status as a motorist. Education for the second ASSR is mandatory, not as a separate topic but integrated in nearly all subjects. It is mandatory for access to moped training and riding. The general aim of ASSR is to create links and continuity with the apprentice driving scheme for 16 year-olds, and more generally with car driving.

- In addition to formal road safety education, Germany in 1980 introduced its "Children and Traffic" initiative specifically aimed at reducing child casualties. Coupled with this was a change in the German Traffic Code specifying that drivers must behave towards children, the disabled and the elderly in such a way that their safety is not endangered. The law does not presume guilt, but does provide a specific offence and gives a clear public signal that there is a strong commitment towards reducing accidents involving vulnerable road users. The initiative recognises that the road safety of children can only be improved by changing the pattern of behaviour of all road users. Therefore it co-ordinates educational programmes for children and drivers. Parents are recognised as having a particularly important part to play in teaching children how to behave in traffic. Parents are taught about road safety in small groups by trained individuals known as "moderators" of which there are currently around 2 000. On the well established understanding that children learn by copying adult behaviour, the encouragement of all adults to act responsibly in traffic is considered to be an important element of child safety. Through advertising and publicity adults are urged to behave in a safe way whether or not they have children with them. This approach reflects the German attitude of collective responsibility for children's safety. For drivers to be able to adapt their driving style to ensure that they minimise the risk to children's safety they need to have an understanding of how children behave. In particular, it is important for drivers to understand that children do not perceive and process events like adults do. Press advertising, radio and television are used to inform drivers.
- In the Netherlands road safety education is compulsory for primary school pupils (aged 4-12 years). Teachers are responsible for teaching road safety theory in schools whilst parents and teachers together share responsibility for practical training. To assist teachers in their understanding of road safety issues, extensive handbooks and materials have been produced and in-service courses developed. Road safety is also part of teacher training courses. The statutory duty to teach road safety in primary schools is set out in the Primary Education Act which refers to "promoting social skills, including behaviour in traffic". Road safety education is not compulsory in Dutch secondary schools and there does not appear to be much enthusiasm for making it so. Nevertheless road safety education materials are provided to schools and some road safety issues are included as a cross curriculum activity (Oscar Faber, TPA, 1996).
- In Spain, traffic education has been compulsory since 1991 in primary and secondary schools. Each school sets its own traffic education targets by considering social conditions, children's and parents' opinions and the level of risk. Objectives are defined in co-operation with parents' associations, and city councils. Traffic education is incorporated into the school curriculum by subject teachers rather than being separately taught. Educational materials are produced by central government, schools, local authorities and private companies.

A few countries have also developed educational programmes for elderly and disabled people. For example, in Spain there is a programme of education for disabled people which aims at developing their capacity for independence so that they can fend for themselves in traffic.

#### ***II.5.4. Road safety publicity campaigns***

Driver training and road safety education have the primary objective of imparting the necessary skills to become safe road users, and their effectiveness in terms of influencing attitudes and behaviour is limited. Road safety publicity campaigns are designed in recognition of the need to convey to road users the need to adapt their behaviour. Vulnerable road users are also targeted through publicity, both directly in terms of protecting themselves, and via messages to drivers, to create a safer environment.

Publicity campaigns which have the objective of improving the safety of vulnerable road users can be categorised in two ways. Firstly, there are campaigns directly addressed at the vulnerable group. These campaigns imply that responsibility for safety is in the hands of the vulnerable themselves. Examples are campaigns to increase wearing of cycle helmets and child pedestrian campaigns which give instructions to children on how to stay safe.

- In Australia, in 1983 male pedal cyclists aged 8-16 were identified as a high accident risk group and a campaign to increase cycle helmet wearing was launched. Helmets were made available through schools, and TV and radio commercials and leaflets targeted parents. The messages stressed in the TV advertising were the vulnerability of child cyclists to head injuries, and the regret that a parent would feel if they failed to protect their child. This campaign therefore was aimed directly at reducing the severity of injury rather than at increasing cyclist safety (OECD 1993).
- A cycle helmet campaign in Denmark in 1990 targeted child cyclists aged up to ten years through folders and posters. There were also press and TV adverts aimed at the general public to show the benefits of cycle helmets. This campaign was followed up in subsequent years with others, and in 1994 children up to 12 years and their parents were targeted through posters, press and TV adverts. Again, the purpose of this campaign was injury reduction rather than primary safety, with the focus on cyclists protecting themselves.
- In 1993, the Scottish Road Safety Campaign launched a nation-wide television campaign “Cars Kill” aimed at children aged 8-15 years. It was also shown in cinemas in 1994 to coincide with a Walt Disney film. The aim was to alert children to the potential dangers on residential roads. The message from the commercial was that cars can “come out of nowhere”. Children were found to have a good awareness of the campaign, and a positive response to it.
- The Willy Whistle campaign in the USA was developed in the 1970s in order to reduce mid-block dart and dash accidents in 3-8 year old children. Films, posters and television advertisements were produced, which used a cartoon character Willy Whistle to demonstrate correct road crossing behaviour. Behavioural observations showed that children crossed more carefully and mid-block dart accidents were reduced. The Willy Whistle campaign was found to have little impact on the 8-10 year old age group for whom a pedestrian safety film “And keep Looking” was developed later. This had a more sophisticated message and

was found to improve children's knowledge and behaviour (Preusser & Blomberg, 1984 & 1988).

- A Spanish campaign, aimed at elderly pedestrians and cyclists, uses a theatrical play "Tango's Essence" to get the road safety messages across in an amusing and entertaining way using song and dance.

Whilst it is recognised that child pedestrian training and road safety education are essential tools in increasing children's traffic safety, the need to target the driver is now given much more emphasis. The goal in most countries is behavioural change of the driver.

Therefore, the second type of campaign is one which seeks to make drivers of motor vehicles aware of their responsibility towards vulnerable road users. These campaigns shift the onus for safe behaviour from the cyclist or pedestrian to the driver. For instance anti-speeding campaigns which focus in particular on child pedestrians, are designed to show drivers the consequences of driving too fast in residential areas. The ultimate aim of such publicity is to change society's attitude to speeding drivers. In the same way as drinking and driving has become seen as anti-social behaviour, the hope is that speeding also will change from a behaviour widely practised and condoned, to one seen to be clearly dangerous and anti-social.

- In Great Britain, a major publicity programme "Kill Your Speed" uses high profile television advertising, together with radio commercials and press advertising. The campaign stresses the effects of speed and the need to moderate speed when pedestrians and cyclists are around. The slogan "Kill your speed, not a child" emphasises the responsibility of motorists towards children. A recent campaign has used film and photographs of actual children who have been killed in road accidents, but without using any violent imagery of road accidents. This campaign, by directly addressing drivers, aims to change the social climate by making driving too fast a socially irresponsible act. The focus on children is the first stage in a wider campaign aimed at speed reduction. It uses imagery and film which bring the message home with great emotional force. Tracking research has shown the television and radio advertising to be highly effective in reaching the target audience, with good recognition and recall, but it is too early to detect any effects in terms of behavioural change.
- Previous anti-speed campaigns which focused on the message "40-30-20" and the effectiveness of reducing speed in saving lives, were found to communicate the message effectively. But it was not effective in making speed a recognised offence nor in making speeding socially unacceptable. The new campaign has shown the consequences of driving too fast in terms of the loss of innocent children due to others' selfishness. Early indications are that this has had more direct appeal to drivers and the recognition in the advertisements that "we all drive too fast" has triggered guilt.

Both types of publicity campaign are widely used, and it is generally recognised that neither approach alone is adequate. However, there has been a shift in emphasis in recent years. Earlier campaigns were directed more at the vulnerable road user than the driver. This shift in emphasis is particularly apparent in the case of child pedestrians. Examples of publicity material from ten years ago show a preponderance of instructions to children and warnings to watch out for traffic. A good example of this is the Great Britain campaign "One false move" which used posters depicting a child about to step off the kerb into the road, with the slogan "One false move and you are dead".

In addition to overt road safety publicity which has the objective of conveying information to road users about behavioural improvements, social attitudes may be influenced by advertisements by motor manufacturers.

- For example, a study in Spain considered the influence of car advertising on children and young people. It was found that the publicity for cars tended to persuade youngsters that technology guarantees safety and favours speed without risk. Publicity is generating a misrepresentation of safety which leads to a feeling of invulnerability. The result of this could be increased deaths and injuries amongst the unprotected vulnerable road users. Some car advertisements were found to invite breaking the law on speed limits. They suggest that cars are made for speeding, which appeals to the ego, although it is irrational and dangerous. Teenage boys in particular are attracted by images of speed and power, and the car as a means of self-expression in competition with other drivers.
- In some other countries there have been approaches to motor manufacturers and advertisers to seek a reduction in the emphasis on speed in advertisements. Although safety is given more attention in car advertisements in recent years, this is only in the context of occupant safety, not the risk to other more vulnerable road users.

An OECD report on “Marketing of traffic safety”, published in 1993, reviewed the use of social marketing of road safety as a means of promoting and promulgating safety messages, and motivating target groups to change their attitudes and behaviour. The report concluded that applying social marketing techniques can increase the effectiveness of existing measures; create a ground-swell in favour of a given measure; reinforce and bring about safety oriented behaviours (OECD 1993).

Despite the difficulty of evaluating the success of publicity campaigns, their use is widespread. Particularly for drivers, such campaigns are often the only means of influencing behaviour, apart from physical constraints through engineering measures.

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## CHAPTER III -- MOBILITY OF VULNERABLE ROAD USERS

### III.1. Introduction

Mobility data attempts to describe the quantitative and qualitative exposure of road users. Quantitative exposure variables help describe the type of transport used, number of trips, journey time and distance travelled. Qualitative exposure variables look at qualitative differences in exposure like the type of traffic environment in which the exposure takes place and factors like whether children are escorted by adults.

Most exposure measures are designed to be readily quantifiable and rarely attempt to characterise the complexities of the individual behaviour of road users whilst mobile in the traffic environment. Mobility data are important because they provide a snapshot of transport use and, over time, can show trends in transport use which can inform policy makers of the need for measures to improve transport patterns in terms of safety and environmental sustainability.

Exposure data can also be used in conjunction with casualty data (exposure data as the denominator and casualty data as the numerator) to provide estimates of the relative risk of different types of road users and sub groups of road users which may not be evident from examining casualty numbers of rates per head population alone.

This section will look at the following issues:

- Availability of mobility data in OECD Member countries;
- Quantitative exposure variables;
- Travel patterns of vulnerable road users;
- Other issues related to travel patterns of vulnerable road users;
- Trends in mobility;
- Trade-offs between transport modes;
- Policy measures related to mobility;

### III.2. Availability of mobility data in Member countries

Despite the importance of exposure data, few OECD Member States routinely collect this information. A review of travel survey data supplied from Member countries show only a limited number of comparable databases, where information is collected with different frequency (monthly to six yearly) using different types of measures or different variable ranges e.g. distance ranges. Little information is

available on how the data are collected. The methodologies utilised indicate the use of travel diaries or self-completion questionnaires issued to a nationally representative sample though little information is given on the response rates of these methods. The travel surveys include, for example, information on how far the respondent travels, how many daily journeys and their purpose. The background of the various travel surveys is described in Annex B to the report.

Throughout the literature on mobility it is generally agreed that mobility is economically driven; however only a few surveys look at the relationship between quantitative exposure and levels of car ownership and none look at socio-economic factors. The exposure of motorised two-wheeler transport is rarely identifiable, being part of the 'other' transport mode category. The mobility of sub groups like children and the elderly or those with physical disability has been examined in separate surveys but only in few countries. Most of the databases can be analysed by sex and certain age ranges, but only a few look at the seasonal travel patterns.

However, there is no standard data collection nor agreement of the range of values for each variables which makes comparability difficult. Further, there may be differences in the definition of which trips should be registered, for example short trips below 1 km. Therefore, the figures in this chapter should not be taken for granted, but merely looked upon as an attempt to compare mobility data.

### **III.3. Quantitative exposure variables**

Based on data supplied by OECD Member States, the following quantitative measures of exposure are illustrated: trips and person kilometres by transport mode, modal split on short trips and modal split for home-work trips. It should be noted that data from all travel surveys are nation-wide, except for France and Japan. Figures from France show mobility in Grenoble and figures from Japan are related to the Tokyo municipality area.

#### ***III.3.1. Modal split in trips***

Modal split in trips according to main transport mode, is shown in Figure III.1. 20-40 per cent of all journeys are travelled by cycle and on foot, with the highest percentage in the Netherlands and the lowest in Finland and Australia. Trips on foot take place most frequently in Great Britain and in Grenoble/France and Tokyo/Japan (which only covers urban areas) whereas bicycle trips are most frequent in the Netherlands, Denmark and Sweden.

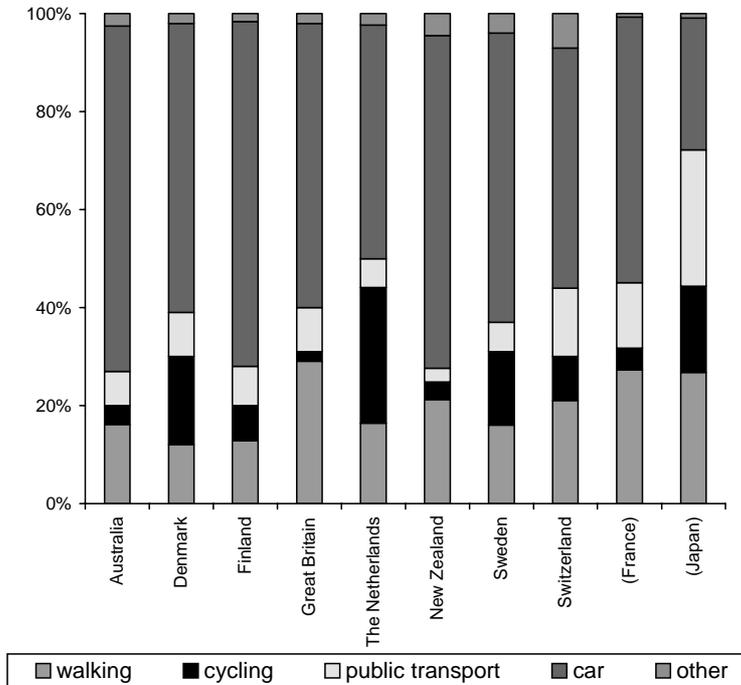
Public transport is used most often in Tokyo/Japan, followed by Switzerland and Grenoble/France. Car use dominates in all countries (50-70 per cent of all trips), except for Tokyo/Japan where the use of the car is significantly lower (less than 30 per cent of the trips).

#### ***III.3.2. Modal split in person kilometres***

Modal split in person kilometres is shown in Figure III.2. Car driving dominates in all countries, except for Japan where public transport accounts for most kilometres travelled. But, as mentioned earlier, data from Japan only covers the Tokyo municipality area.

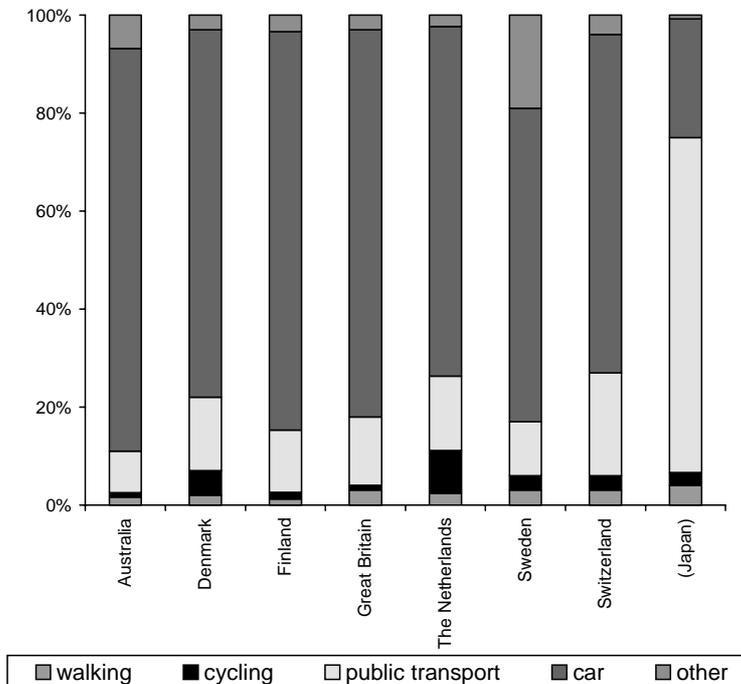
As for cycling, the Netherlands especially show a fairly high percentage of kilometres (about 9 per cent of the travel). Denmark follows with 5 per cent. It should be noted that cycling includes other two-wheeler modes in the data from Tokyo/Japan and they are thus not comparable.

**Figure III.1 Modal split in trips (main transport mode)**



Source: OECD

**Figure III.2 Modal split in person kilometres**



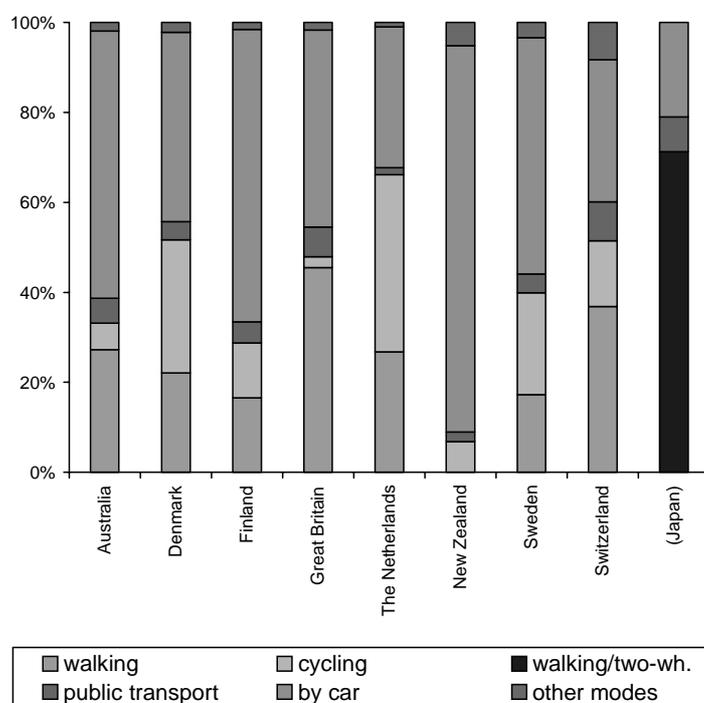
Source: OECD

### III.3.3. Modal split on short trips

For short trips under 5 km (Figure III.3) the car is still used frequently (20-65 per cent of the trips) for the main transport mode, showing highest percentages in Finland and Australia. In the Netherlands, the Nordic countries and Switzerland, cycling accounts for between 12 per cent and 39 per cent of the short trips, with the highest percentage in the Netherlands and the lowest in Finland. Walking is common on short trips, showing percentages from 15 to 45, with a maximum in Great Britain. Public transport as main transport mode is not used very often for short trips in any of the countries, showing percentages less than 10 per cent in all countries.

It should be noted that data from New Zealand do not include walking and that data from Tokyo/Japan show both walking, cycling and other two-wheeler modes in the category “walking/two-wheeler”.

**Figure III.3 Modal split on short trips (main transport mode)**

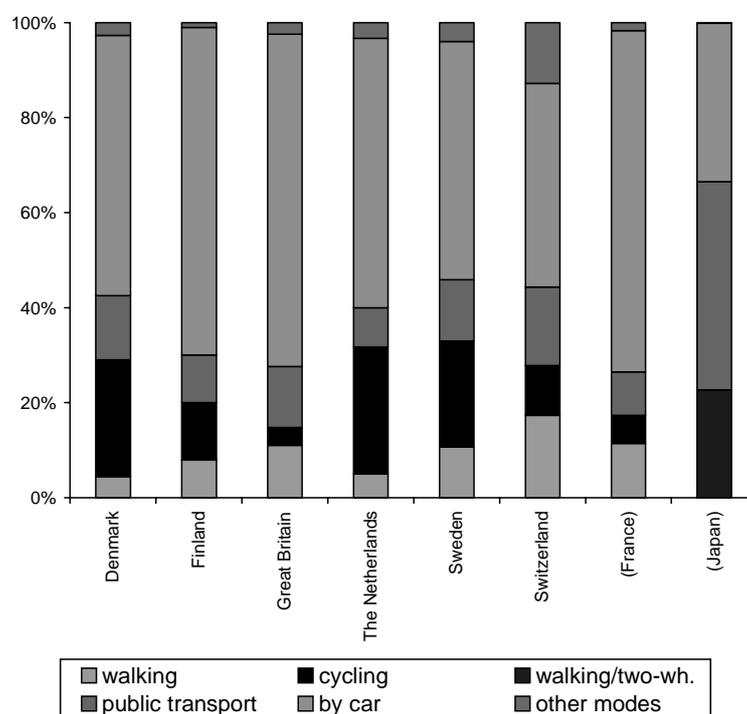


Source: OECD

### III.3.4. Modal split for home-work trips

Figure III.4 illustrates the home-work trips by main transport mode. Public transport is most frequently used in Japan/Tokyo for the home-work trips, in the other countries car use dominates.

Cycling to work accounts for 20-30 per cent of these trips in Sweden, Denmark and the Netherlands. Further, walking is often used on short trips to work in Sweden, Great Britain, France/Grenoble and Switzerland (about 10 per cent of these trips in the three first mentioned countries and about 17 per cent in Switzerland).

**Figure III.4 Modal split for home-work trips (main transport mode)**

Source: OECD

### III.3.5. Future changes in people's mobility

Across the developed world, the proportion of elderly and very elderly people in the population is increasing. In Great Britain an increase of almost 40 per cent in the number of people aged 65 or more is expected over the next 40 years, compared with an overall population increase over the same period of less than 7 per cent. Statistics from Japan too bear out this changing profile: in 1990, 12 per cent of the population were elderly, but by the 21st century it is forecast that 25 per cent of the population will be in this category. Given a correlation, it could be assumed that the number of disabled people in the population will also increase. Indeed in Japan, in the 40 years between 1951 and 1991, the number of disabled people increased more than five-fold; from about half a million to nearly three million people.

Changes in mobility of society generally also need to be considered in establishing the likelihood of these groups being exposed to risk. The opportunities for independent mobility among societies generally have increased dramatically over recent years, particularly with the increased ownership and use of private cars. It could be assumed that in comparison with other road users, elderly and disabled people will have an increased expectation of mobility.

The use of the private car has influenced mobility among elderly and disabled people particularly as car passengers. For the time being at least, driving is less significant, although the increasing proportion of licence holders suggests that this will change over time. In Japan, for example, there was a three-fold increase in the number of elderly people holding a driving licence between 1983 and 1993; and among disabled people the numbers increased from about 150 000 to about 200 000 people in the same period (National Police Agency, 1994).

The car ownership is very important for the choice of transport mode, as compiled from the Danish national travel survey (Ministry of Transport, 1994). The level of kilometres travelled per person per day by cycle and on foot is very high among people who do not own a car, whereas car owners travel more kilometres per day than people without cars. Public transport is also used mostly by people who do not own a car. In the same way, the number of trips by cycle and on foot is higher for respondents who do not own a car, and this number decreases according to the increase in number of owned cars. In other words, if the respondent owns a car, he will use it regularly.

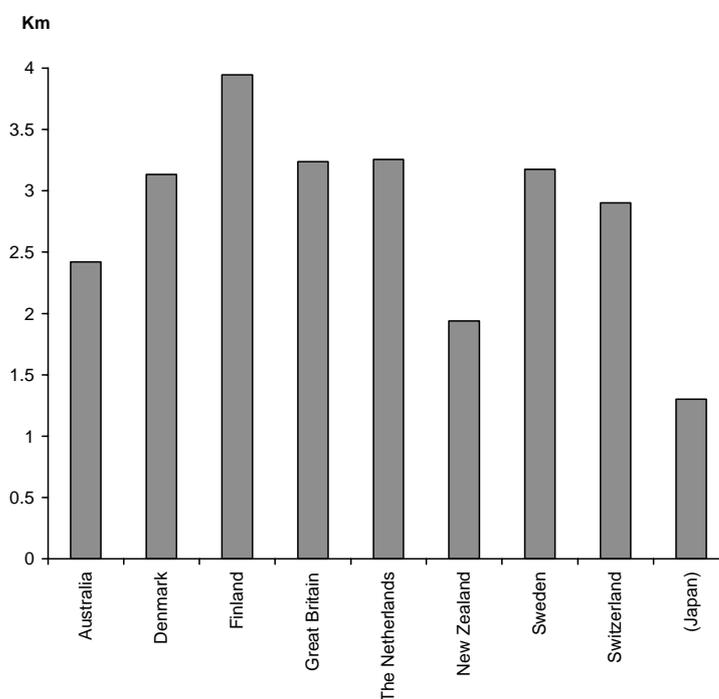
#### III.4. Travel patterns of vulnerable road users

With the help of national travel surveys, more knowledge can be obtained on cycling and walking. The following quantitative measures have been compiled in selected OECD Member States: average trip lengths for cycling and walking, distribution of person kilometres by trip purpose for cycling and walking and the amount of cycling and walking by age and sex.

##### III.4.1. Trip length for cycling and walking

Based on available data, the average trip length for cycling should be around 3 km in most countries, i.e. Finland, Sweden, Denmark, Great Britain, the Netherlands and Switzerland. In Australia, an average trip by bicycle is about 2.4 km, in New Zealand about 2 and in Japan 1.3 km for all two-wheelers, including bicycles (Figure III.5).

Figure III.5 Average trip length for cycling (kilometres)

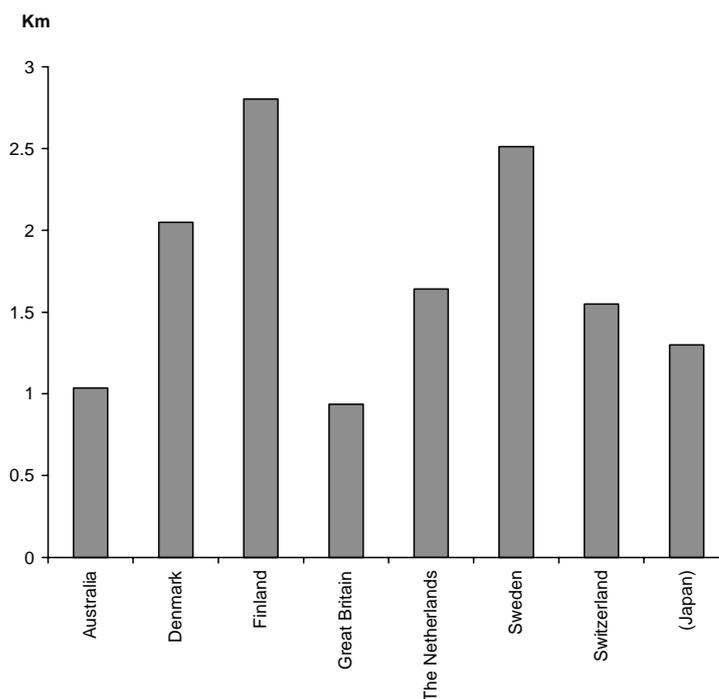


Source: OECD

It should be noted that the extent of covering of short trips may vary from country to country in the national travel surveys. This will affect the comparability of average trip length. As for Denmark, short trips under 300 metres are excluded from the survey, whereas all trips between 300 and 1 500 metres are recorded to be 1 km. On the contrary, all trip lengths are included in Great Britain.

The average trip length on walking trips varies from about 2.8 km (Finland) to less than 1 km (Great Britain), as shown in Figure III.6.

**Figure III.6 Average trip length for walking trips (kilometres)**



Source: OECD

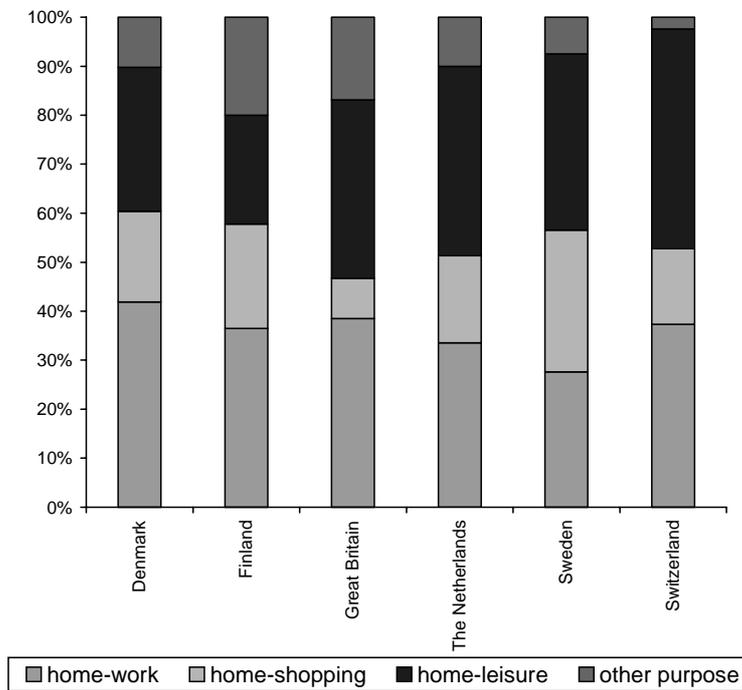
#### **III.4.2. Purpose for cycling and walking trips**

Only six countries' travel surveys compile trip purpose for cycling and walking in a comparable way. Figure III.7 illustrates the percentages of bicycle person kilometres in various countries (on an average day) according to purpose.

About 40 per cent of the person kilometres by bicycle is travelled on home-work trips in Finland, Denmark, Great Britain and Switzerland, whereas this percentage is lower in Sweden and the Netherlands. The home-leisure trips cover from about 20 per cent to 45 per cent of the person kilometres, with Switzerland at the top and Finland at the bottom.

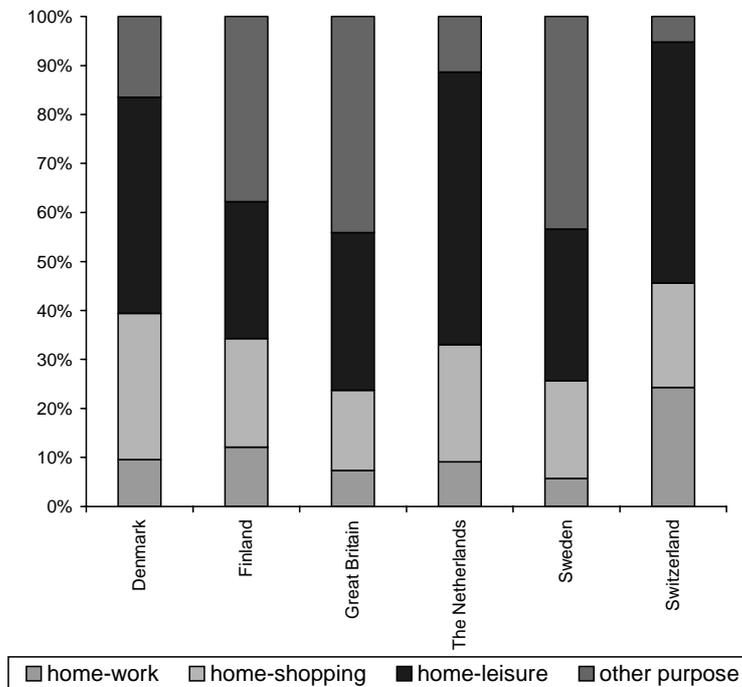
Figure III.8 illustrates the percentages of person kilometres walked (on an average day) according to purpose for the various countries. Between about 30 per cent and 40 per cent of the person kilometres on foot is travelled on home-work trips in all countries. Home-leisure trips cover about another third of the walked distances, that is between 30 per cent and 55 per cent of the person kilometres, with Switzerland at the top and Finland at the bottom.

**Figure III.7 Distribution of bicycle kilometres by trip purpose**



Source: OECD

**Figure III.8 Distribution of walking kilometres by trip purpose**

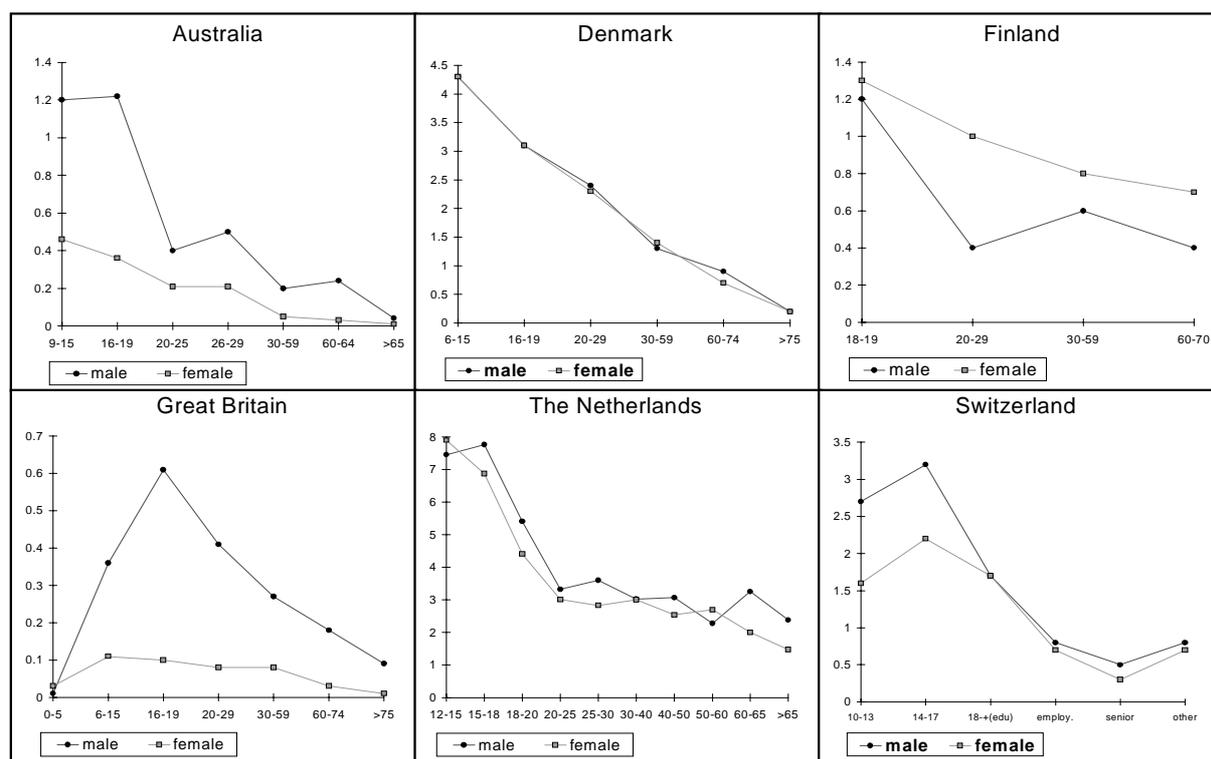


Source: OECD

### III.4.3. Distances cycled and walked by age and sex

Based on travel data from the Member countries, Figure III.9 illustrates the distances cycled per person per day by sex and age group, showing most cycling among children and young people. Most kilometres are cycled in the Netherlands (2-8 km/day/person, depending on age), followed by Denmark and Switzerland (up to 5 km/day/person). In Great Britain, Finland and Australia, less than 1 km is cycled per day per person. Men cycle more per day than women in the Netherlands, Australia, Great Britain and Switzerland, but not in Finland, where women cycle most, as illustrated in Figure III.9.

Figure III.9 Distances cycled per day per person by age and sex



Source: OECD

In Denmark and the Netherlands, elderly people walk most, whereas the opposite is the case in Finland and Australia. The distances walked per day vary between about 0.5 and 2 km for all age groups and both sexes. Only in Finland women in all age groups walk more than men. For further differences in walking distances by age and sex, see Figure III.10.

### III.4.4. Number of cycle and walking trips by age and sex

Figure III.11 illustrates number of trips cycled per person per day by age and sex. Children and young people make cycle trips more often than elderly people. The daily trip rate for young people varies from about half a trip per day (Finland and Australia) to about one trip per day in Switzerland, and about two trips per day in Denmark and the Netherlands. Great Britain shows a totally different picture for children: only about one trip per week for boys and one trip in three weeks for girls. Elderly people cycle approximately one trip per week, except for the Dutch who travel about one trip in two days. Women

cycle more often in Finland, whereas the opposite is seen in Great Britain, Switzerland and Australia, as shown in Figure III.11.

Generally, the number of trips on foot is higher for women than for men, as shown in Figure III.12. But the daily number of walking trips does not seem to vary much by age, except for Denmark and Switzerland where elderly people take up walking again. For all countries, the daily number of trips on foot for children amounts to between half and one-and-a-half trips per day, with maximum in Switzerland and minimum in the Netherlands. For elderly people, the daily number is between half a trip and one trip.

### **III.5. Other studies related to travel patterns**

The above data based on national travel surveys give an overview of people's travel patterns. But in addition to this overview, more qualitative exposure variables concerning travel patterns and reasons for these travel patterns are available in various countries.

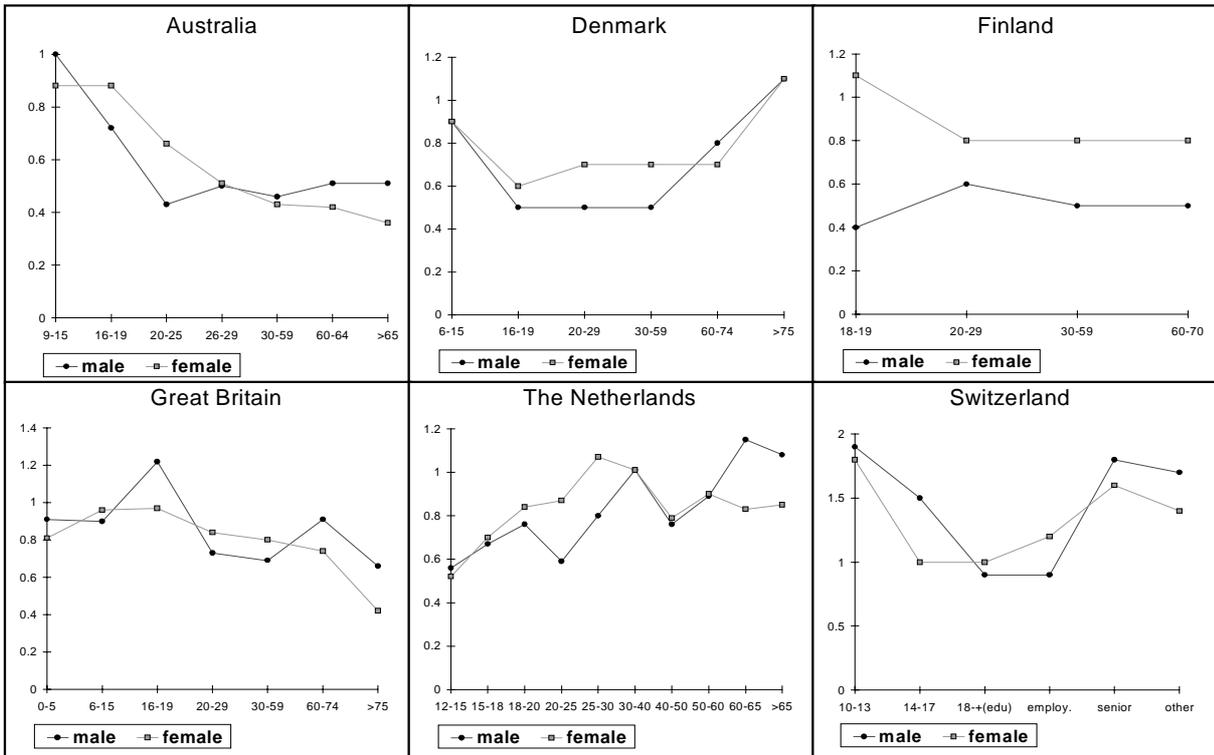
There has only been little research into the mobility needs of vulnerable sub groups like the elderly and the very young. For these groups, mobility may be restricted because of the perceived accident risk in traffic. The elderly are becoming an increasingly larger proportion all over the Member countries and therefore their mobility is particularly important. In many countries elderly cyclists and pedestrians are over represented in casualty data as well.

There are very little data related to the qualitative aspects of road users' exposure. Qualitative measures of exposure like child accompaniment have only been taken nationally in the United Kingdom and Spain. Qualitative data are usually collected by separate studies carried out on an ad hoc basis and cover: accompaniment of children, mobility of those with a physical disability and the environment in which mobility takes place.

The only detailed study of pedestrians' travel patterns which was available was carried out in Northampton, Great Britain, with a population of 180 000 people. The study focused on a sample of 400 households, reporting walking patterns of the individual household members. Northampton was considered to be representative of the population and road environment found in many English free-standing towns. A major objective was to quantify exposure for different groups of pedestrians in different situations. Respondents were asked to record all journeys on foot on a specified day, in sufficient detail for the journeys to be reworked. A total of about 1 000 people took part, and data were obtained on walks in Northampton for 737 of them. The full range of ages from five upwards was covered. Overall three quarters of the sample walked on the survey day, but the proportion ranged from 86 per cent for children aged 10-15, to 59 per cent for people aged over 65. 8 per cent of people who walked on the survey day reported some difficulty with mobility, but for those who did not walk, the proportion was 24 per cent (Ward, 1994).

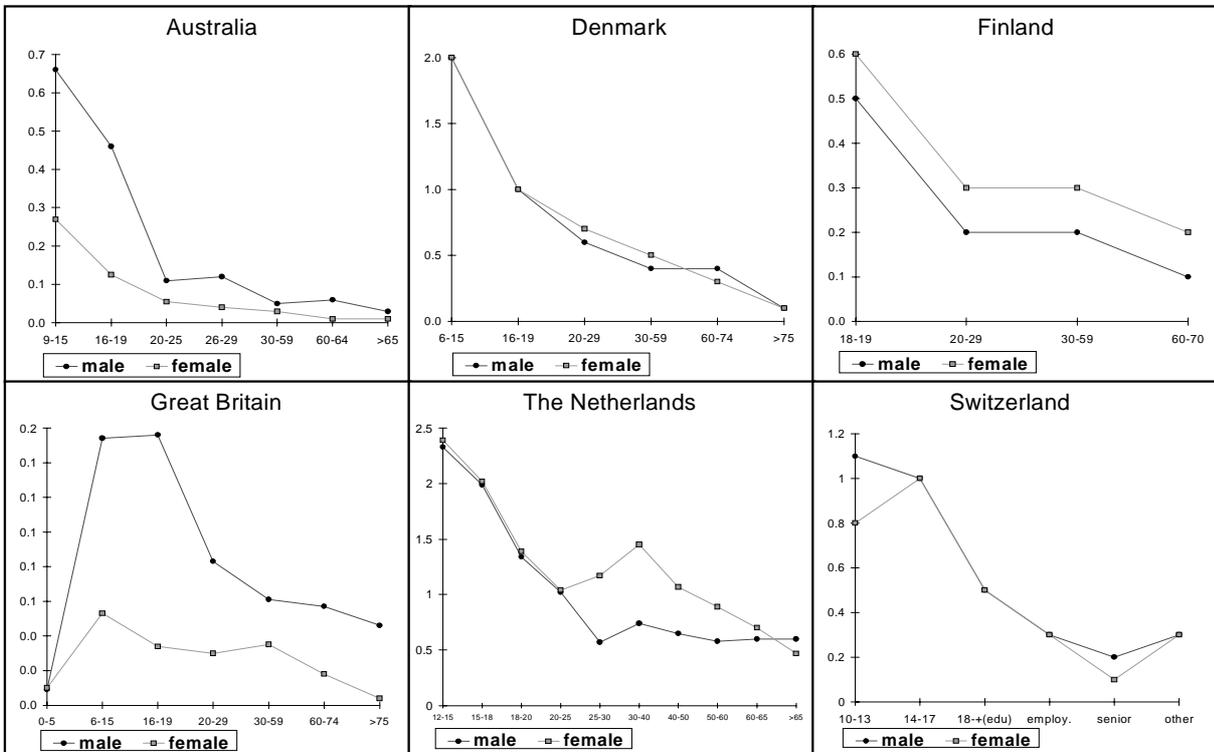
Vulnerable road users' exposure to risk needs to be studied. In the Northampton study it was found that 40 per cent of the walking take place in residential areas, and nearly 25 per cent away from roads on footpaths. Thus two thirds of walking take place in these quieter places.

Figure III.10 Distances walked per day per person by age and sex



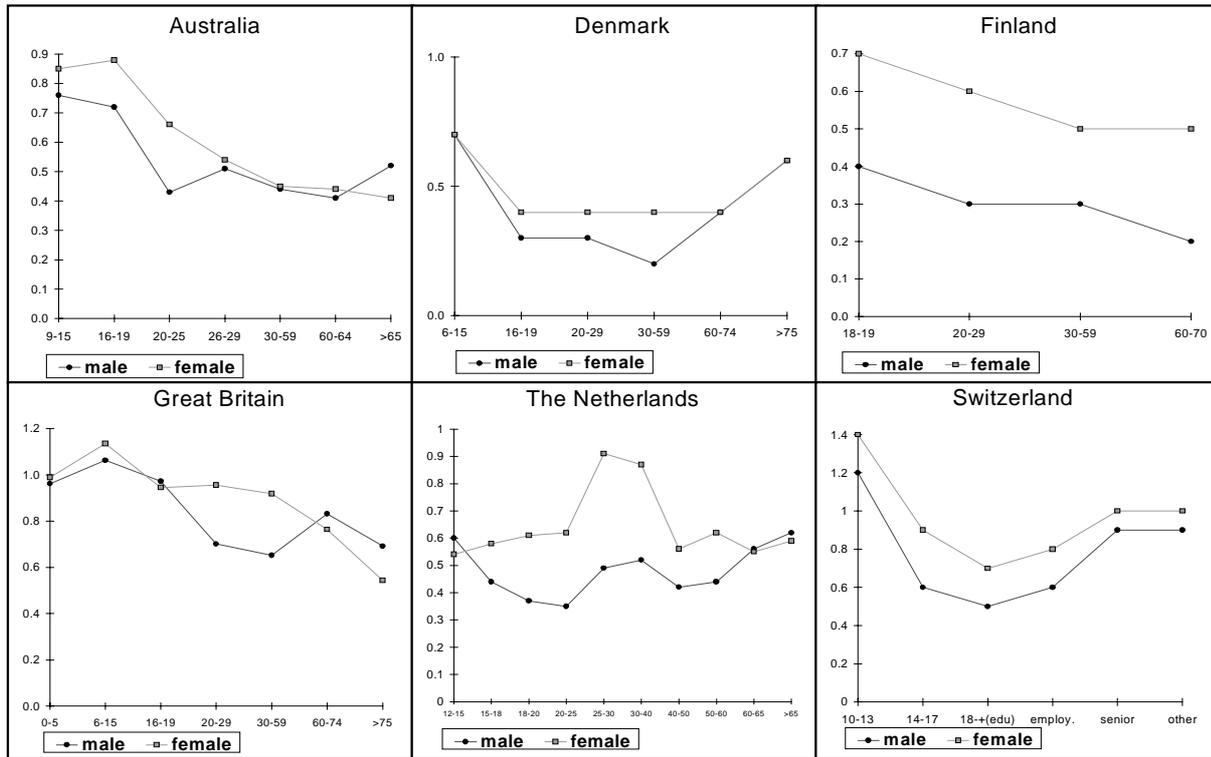
Source: OECD

Figure III.11 Number of trips per person per day by cycle by age and sex



Source: OECD

Figure III.12 Number of trips per person per day on foot by age and sex



Source: OECD

### III.5.1. Mobility of children

Children’s walking patterns have been studied in England with the following questions: how much, on which roads, at which time of the day and for which purposes the journeys take place. Walking (or being pushed in a push car) is an important mode of transport for children of all ages, accounting for at least 40 per cent of all journeys. Children aged 11-15 years walked more than any other age group, making 432 journeys per year on average compared with 297 for adults aged 21-29 and 356 for the 16-20 year old group. The journey to and from school accounts for 35 per cent of all journeys made by school children aged 5-15. 55 per cent of these journeys were on foot, and 52 per cent were less than 1.5 km in length. However, walking to or from school declined between 1975/76 and 1989/94. This decline mainly affected journeys of 1.5 to 3 km, where there was a significant shift from walking to car. The percentage of journeys made on foot declined from 56 to 42, with most of the difference being accounted for by extra journeys by car (Department of Transport, 1995).

The Northampton study shows that for children aged 5-9 years the proportion of walking in quiet places is three quarters. Nearly 10 per cent of walking for this age group is on main roads, and most often the journey is to school, with 70 per cent being accompanied by an adult and 23 per cent by an older child. Older children, aged 10-15, do more walking on local distributors and only 40 per cent are accompanied when crossing main roads. The older teenagers not only walk twice as far as other people, they walk four times as much on main roads and cross nine roads per day compared with four for people of all ages.

A research study in 1990 in England and Germany explored the travel patterns and levels of personal autonomy of children aged 7-11 and 11-15. It partially replicated a study in England in 1971, thus providing trends over time as well as cultural comparison between the two countries. Surveys were

carried out in schools in England and Germany in areas matched as closely as possible. The aim of the study was to devise a set of behavioural indicators of danger to children through consideration of “licences”, i.e. the extent to which parents allow their children independence. Over the period 1971-90, English children had become significantly less independent. In 1971 nearly half of the seven year olds crossed roads unaccompanied, but this proportion had fallen to a fifth in 1990. Compared to this, more than half of the German children of seven had this freedom in 1990. By the age of 11 this difference between English and German children had disappeared.

Some of the largest variations between England and Germany are in junior children going home from school alone. In Germany 85 per cent of seven year olds do this whilst only 11 per cent in England are allowed to. Even by 11, only two thirds of English children were allowed home from school alone compared to over 90 per cent of German children. Bus use in England fell substantially between 1971 and 1990, whereas travel by car to school was higher in England than Germany for all junior children, in line with the increase in car use indicated by a doubling of car ownership. By the age of 15, half of the English and two thirds of the German children were allowed out after dark compared with 2 per cent and 10 per cent at the age of ten. The main reason cited by parents for restricting children from going out after dark at all ages was fear of molestation, although the child’s unreliability was also important for the youngest children. Traffic danger was only cited by 10 per cent of parents of even 7 year olds, with similar patterns in England and Germany (Hillmann, 1990).

### ***III.5.2. Mobility of elderly people***

In Great Britain, elderly people aged 70 and over travelled about 4 500 km per year in 1992/94, including all transport modes, which is only one third of that of younger adults aged 30-59. Elderly females travelled less than elderly males. Whereas elderly males walked as much as younger men, 280 km per annum, elderly females walked much less, 210 km compared with 325 km for younger females. Walking declined with age: for the 70-79 age group, males walked 315 km and females 220, but the over 80 years old group walked much less, 200 km for males and 120 for females. Walking accounted for 5 per cent of the distance travelled by elderly people compared with 2 per cent for the younger adults. This proportion varied little between males and females. Although elderly men walked more than elderly women, their average annual trip length fell by 24 per cent between 1989/91 and 1992/94, whilst female walking fell little, by only 6 per cent. Walking by younger adults of both sexes fell by 17 per cent. Elderly women made fewer journeys on foot than elderly men, 222 compared with 271, and more of these trips were under 1 km in length and fewer were over 1.5 km. A similar pattern was found for the younger adults.

Although walking is a very minor mode in terms of distance travelled because most walking journeys are very short, journeys on foot accounted for 36 per cent of all journeys by elderly men, and 40 per cent of elderly females’ journeys. By comparison only 19 per cent of younger men’s journeys and 27 per cent of younger females’ journeys were on foot (Department of Transport, 1995).

Four areas of the city of Newcastle-upon-Tyne, Great Britain, were selected for a study of the mobility and safety of older pedestrians in 1993. Interviews were carried out with 215 respondents aged 65 years or older, 76 men and 139 women. In all areas, walking was the most frequent activity, with bus being the main motorised mode. As would be expected, the shorter journeys, up to 500 metres are predominantly on foot. Very few journeys of 1 km or longer are walked. The majority of people reported going out on foot most days, and 84 per cent walked at least 3-4 times a week. Over 40 per cent of all journeys were on foot. Shopping trips accounted for two out of three journeys. Respondents were also

asked about reasons for not going out. Women were concerned about being out late and personal safety. Concerns about traffic did not feature strongly (Carthy, 1995).

Similar figures for elderly people's journeys were found in the 1991 New Zealand Household Travel Survey. This survey shows that 33 per cent of journeys made by people aged 70 or over were made on foot, compared with 16 per cent for adults aged 25-59. The average length of trip was slightly longer for the elderly pedestrians, 0.3 km compared with 0.24 (New Zealand Land Transport Safety, 1994).

In Finland 100 people aged 65+ were interviewed about their mobility patterns. Walking was their main means of transport. But they tended to make short trips and less trips in winter because of slippery roads and darkness. 50 per cent wanted more practical comforts on public transport and many felt their mobility was restricted by fear of aggression in the dark (Liikenneturvan Tutkimuksia, 1986).

Whether accident involvement influence people's mobility has been studied in Spain. A sample of 80 pedestrians in Salamanca aged between 50 and 92 years who had been involved in a road accident was examined. On average, they went out three times a day, mainly for leisure, shopping and attending religious services. 35 per cent of trips were between 100 m and 500 m in length, 24 per cent 1-5 km, and 21 per cent were less than 100m. During the day, the peak periods for travel were 11 am-1 pm, and 5 pm-9 pm. Over 70 per cent of travel was on roads with up to three lanes of traffic. 35 per cent of all travel took place on Mondays (Ministerio de Interior, 1995).

Timing of journeys needs to be considered in assessing the risks to these vulnerable user groups. The Spanish study indicates that elderly and disabled people are less likely to travel in rush hour traffic and are significantly less likely to travel at night. This is supported by evidence from Japan which indicates that although 43 per cent of 60-69 years old go out at 5 pm, only 14.6 per cent of that group went out at 7 pm (Broadcast and Culture Research Institute of NHK, 1991).

Journey purpose of the elderly and disabled also needs to be considered. As mentioned, the Spanish study showed that the majority of the elderly's trips were for shopping, leisure and religious services. A similar finding from Japan indicates that medical visits, shopping and work were the significant trip generators for disabled people (Department of Welfare, 1990). Although in Sweden, work/school journeys were under represented for disabled people, according to NTS 1978 (SCB Statistics Sweden). This could, of course, be explained by the fact that a high proportion of disabled people are over retirement age.

One Japanese study on elderly people's walking speed, showed difficulties for elderly people in managing to cross streets with light signals. The study compared gap acceptance, walking speed and delay time for young and elderly people. There was a significant correlation between walking speed and age, especially for those over 75 years of age, whose walking speed on average was only 72 per cent of the speed of younger adults aged 19-35. When walking speed of those over 75 years of age was compared with the green-light time of pedestrian signals for different road types and widths, crossing times were inadequate for nearly half the elderly pedestrians crossing a 40 m-eight-lane road. When gap acceptance was compared for elderly and younger pedestrians, there was little difference (Mizohata, 1990).

Studies in Sweden indicate that more than one third of the elderly find it difficult to be pedestrians. The problems are caused by the following: the elderly are afraid to be involved in accidents caused by their personal limitations, they are afraid to fall due to poor maintenance of the roads and their gathering of information in traffic is difficult due to rapid, complicated and changing traffic situations. Even cyclists present a considerable problem to many older pedestrians. In fact, elderly people's lower

physical ability and related fear and anxiety often result in their trusting traffic regulations which actually might result in a sense of false feeling of security and increase the risks for accidents (Ståhl, 1991).

### ***III.5.3. Mobility of disabled people***

There is also some evidence that those with ambulatory or sensory disabilities have restricted mobility in traffic which has implications for transport policies.

Data from the Swedish NTS in 1988 review personal mobility and travel patterns of disabled persons. The survey is based on interviews with 8 400 persons from 15-84 years old. Access to transport and travel performance of three groups of persons with certain degrees of personal mobility/limitation are analysed (severe limitations, some limitations, no limitations). 92 per cent of all journeys are made by persons with no limitations. It is interesting to note the modal split of persons with severe limitations compared with people with normal mobility: They have a relatively low level of car use (34 per cent compared to 57 per cent), public transport use (9 per cent compared to 12 per cent) and use of two-wheeled vehicles (1 per cent compared to 9 per cent) but a high level of walking (43 per cent compared to 20 per cent) and taxi use (14 per cent compared to 1 per cent).

People with certain limitations in personal travel capacity make few trips. On average the most disabled people only make one move outside their home every second day (Vilhelmson, 1981).

Car ownership would be a way of increasing disabled people's travel. But data from Sweden show great differences in the possessing of a driver's licence for people with severe travel limitations (49 per cent) and people without limitations (84 per cent) (SCB Statistics Sweden, 1993).

In the future, countries all over the world will experience an increase in the proportion of the elderly population. Japan has already seen a rapid increase, as mentioned earlier in this chapter. The proportion of the handicapped has also been increasing, as has the tendency to encourage both the elderly and the handicapped to take part in work and volunteer activities. The participation rate of the elderly in volunteer activity, in which they "always" or "often" take part, was 27.3 per cent in 1990, i.e. about twice the comparable proportion (14.4 per cent) in 1981. The fact that elderly people spend more time outside their homes, is expected to result in further increases in travel by the elderly (Broadcast and Culture Research Institute, 1991).

On average, wheelchair users have activities outside their home 4.7 times a week. The number of trips by the handicapped is about 60 per cent of those with no handicaps. The major travel mode by wheelchair users is car (Motoda, 1992).

### **III.6. Trends in mobility**

There is some information on mobility trends from the North European countries, where it is agreed that mobility trends are strongly related to car use. The general pattern across Europe is a growth in mobility in terms of number of car kilometres travelled. Currently around 75 per cent of all person kilometres are travelled in cars. In Sweden, daily trips and travel have increased since the 1950s from 10 km to 40 km per day. Most countries expect that car share will increase if no policy interventions are made.

The mobility of vulnerable road users may have changed because of the increasing threat of the car. Research in the United Kingdom has shown that adult accompaniment of children in traffic has increased in Great Britain during the period 1970-1990 and this is due in part to the perceived danger of traffic. And, as mentioned earlier in this chapter, elderly pedestrians' travel in Finland and Spain is restricted to day time.

In spite of the boom in car ownership, the ownership and use of bicycles has grown in recent years in the Netherlands. Many municipalities and provinces implemented plans for bicycle paths. Within seven years the length of the Dutch cycle paths increased by 55 per cent and that of lanes by more than 70 per cent. The aim of all plans is to stimulate the use of the bicycle by offering attractive facilities for the cyclists, consisting of paths of high quality separated from the motorised traffic, of direct connections, and of special green phases in traffic lights for cyclists.

Besides this aim directed at use and comfort, there is always the aim of safety for cyclists: to reduce the number of casualties and the accident rate. Sometimes it is also stipulated that this cyclist-friendly policy must lead to a reduction in car use (Wittink, 1994).

The amount of travel has increased by 40 per cent during the last ten years in Denmark. 71 per cent of the person kilometres is travelled by car, 21 per cent by public transport and 8 per cent by bicycle or on foot. If no political decisions/changes are made, the cars' share of travel will rise to 75 per cent, and the share of public transport will decrease to 17 per cent. Cycling and walking will remain constant. The new Danish national traffic plan "Traffic 2005" declares that 4 per cent of the total car traffic should be converted into cycling and walking before the year of 2005. In comparison, this means that one third of all car trips shorter than 3 km is to be converted into non-motorised transport. On short journeys, in particular, bicycles can be substituted for cars, but also on some longer journeys combinations of public transport and bicycle rides or walks can be alternatives to car driving (Danish Government, 1993).

As indicated above, since the 1950s daily trips and travel have increased in Sweden from 10 km/day to 40 km/day. But as a matter of fact half of the population travel less than 14 km per day whereas only 10 per cent travel more than 100 km per day. More than half of the mobility of the population is related to "free time" activities, i.e. visits, meetings, leisure time and recreation. Trips in connection with work only account for one third of the total travel. On average, people in Sweden spend 80 minutes per day on transport. The hypothesis is that people in the future will keep this transport time, but because of faster means of transport the daily mileage will increase (Vilhelmson, 1991).

### **III.7. Trade-offs between transport modes**

As a follow up to the objective of traffic plans in several countries of promoting cycling and walking, surveys have been conducted in some countries with the aim of knowing the potential for this objective.

In Denmark (Danish Road Directorate, 1995) 1 000 home-interviews have been conducted in two medium sized cities in order to find the potential for cycling. The questionnaire contains a travel survey and attitude questions. The result shows 13 per cent of all car trips being potential bicycle trips, corresponding to 3.6 per cent of all kilometres travelled by car. In other words this means a potential of one third new bicycle trips. The potential is based on both the existence of various cycle-friendly solutions and restrictions of car traffic. As a follow up to this project, a demonstration project is initiated

in order to set up a concept -- including implementation and evaluation -- of safety and promoting solutions for cyclists in four cities in Denmark.

In Sweden, a similar study has been conducted among 1 500 people who possessed a driving licence. This study indicates at least 9.5 per cent of all short car trips to be potential cycle trips, i.e. most of the trips with a recreational purpose (Nilsson, 1995).

Another survey among car drivers has been carried out in the Netherlands (Ministry of Transport, Public Works and Water Management, 1994). The car drivers themselves say that almost half of all car trips of a duration of four to ten minutes can easily be replaced by bicycle trips, while 15 to 20 per cent of the trips of 11 to 28 minutes could also be made by bicycle. Longer trips hardly qualify for replacement by cycling. It is remarkable that the bicycle is only mentioned as an alternative to 30 per cent of the very short car trips (up to three minutes). The reason could be that the car is deliberately chosen for these trips, i.e. to carry the goods from shopping. Such short car trips can also often be made by foot.

In the Danish study, the following reasons for taking the bicycle are stated: distance, exercise, convenience, habit, easy to get around on, lack of public transport. One of the reasons for choosing the car is bad weather.

The Finnish National Travel Survey includes statements on the seasonal variation in cycling in Finland. In summer (June-August), 12-14 per cent of the daily number of trips are by cycle, in winter (December-February) this percentage decreases to 4. In relation to mileage, cycling comprises 2-3 per cent in summer and 1 per cent in winter. The Survey includes a special questionnaire on seasonal cycle habits for work and school trips in the capital of Finland. In summertime, 7 per cent of the respondents in the centre of Helsinki state going by cycle to their workplace or to school two or more times per week. In wintertime, this percentage is zero. In the suburbs of Helsinki this percentage is 21 in summer and 2 in winter (Helsinki Metropolitan Area Council, 1983).

It is interesting to note that within the Fourth Framework Programme of the European Commission two projects have been initiated with the aim of replacing short car trips in cities with cycling and walking. One of the objectives will be to study the potential for both walking and cycling especially in large European cities (WALCYNG and ADONIS projects).

### **III.8. Policy measures related to mobility**

It should be kept in mind that policies aimed at enhancing mobility of particular groups of road users should also take into account their safety. Conversely, policies aimed at improving safety should not do so at the expense of mobility, on the contrary, safety policies should have a positive influence on mobility by the self-restraint of the road user groups concerned. For example, engineering and planning measures such as traffic calming areas, cycle track networks and pedestrian streets have had the effect of enhancing mobility of local residents and vulnerable road users.

Furthermore, in addition to speed reduction measures, the Netherlands have introduced "woonerfs"-areas where motorised traffic has to drive at a walking pace only. With this type of measure there has been a 50 per cent reduction in accidents, and the package of engineering measures based on the principles of reducing the volumes and speed of motorised traffic has resulted in a reduction in accidents with personal injuries of up to 80 per cent.

The problem of the most vulnerable road users has been outlined in a Swedish publication: "Streets for Everybody". This publication is meant as a guideline for local authorities in building, furnishing and maintaining street areas in order to meet the demands of all road users, especially the physically disabled, mentally retarded, visually or hearing impaired people (Swedish Association of Local Authorities, 1993).

Many countries are also promoting a bicycle-friendly infrastructure (e.g. The Dutch Bicycle Friendly Towns pilot scheme), for example by increasing the number of cycle paths, and in this way obtaining better direct connections with other transport modes, and by including special green phases for cyclists at traffic lights. In the Netherlands, 15 per cent of the road network has facilities for bicycles including cycle paths (separated from other traffic by a kerb), cycle lanes (separated by a line) and tracks with their own marked route. The government also aims at encouraging cycle use by advocating shorter distances from home to work. And the competitive position of the cycle in relation to the car is improved by providing better infrastructure facilities according to the "Bicycle Master Plan".

About 27 per cent of all trips and 12 per cent of all vehicle kilometres are travelled by bicycle in the Netherlands. The main objective of The Bicycle Master plan is: "To promote the use of the bicycle and at the same time increase the safety and appeal of bicycle use" (Wegman, 1992). In the Netherlands, the government aims at restricting car use and reducing it by 35 per cent from its level in 1986 by the year 2010, by achieving the following targets: a 30 per cent increase in the number of kilometres cycled by 2010 compared to 1986, a 20 per cent decrease in travelling time for cyclists to major facilities, a travel time on journeys up to 5 km not exceeding that by car, a 50 per cent increase in commuting by cycle and making sure that cycling becomes part of a company's transport plan.

In Denmark, the policy objectives outlined in the Traffic 2005 paper are to promote cycling and walking by converting 4 per cent of car traffic to cycling/walking and a third of all car trips of less than 3 km to non-motorised travel. At the same time, the goal of the Danish Action plan is to decrease the number of accidents with personal injuries by 45 per cent in a 12-year period starting in 1986. To reach this goal a collection of potential countermeasures were prepared. By carrying out the most effective of these measures the overall goal has been reached at least during the first half of the period -- except for cyclists and pedestrians. This has led to the preparation of supplements to the first set of measures. One study has set up a series of measures to reduce the number of cycle accidents and another study was directed towards accidents with elderly people (Danish Government, 1993).

A working group appointed by the Ministry of Transport and Communications of Finland designed a programme on cycling policy. The group has set up its main objective of doubling the cycling mileage in relation to the volume of all trips travelled in 1986 and reducing the bicycle accidents resulting in fatal casualties into one half of the 1989 level -- which is consistent with the safety objective set by the Council of State concerning all traffic casualties. According to the working group, it will only be possible to reach the main objective in the case where cycling is obtaining a major role in transport policy and planning. In 1993, the working group had presented a total of 82 recommendations for action concerning transport policy and land use, developing of cycling environment, improving the traffic safety of cycling, enhancing and effectuating the scope of bicycle usage, as well as improving the bicycle statistics (Ministry of Transport and Communications 1993).

Further, in 1995 the Ministry of Transport and Communications had appointed a working group with the task of following the realisation of the actions proposed in the cycling policy programme, making a proposal for further development of the programme and otherwise making proposals for developing cycling as a transport mode. The working group states that in 2005 the number of cycle journeys shall be

doubled from 1986 and the number of journeys by cycle shall represent 25 per cent of all journeys, and at the same time dramatic accident reductions are set up (Ojajärvi, 1995).

The Spanish Traffic and Road Safety Council observed, after careful analysis of two-wheeled vehicle accidents at national level, a remarkable decrease among mopeds and motorcycles, but not among bicycles. Three reasons for this are suggested: increased use of bicycles for sport and leisure purposes, cyclists' lack of attention to the rules and other road users' lack of attention to cyclists. Therefore the Parliament in 1995 approved a declaration founded on the study and follow up of road traffic accidents based on cycling practice. The 23 recommendations of the study sum up the suggestions, complaints and remarks of 100 persons surveyed. Some of these recommendations are: a more adequate road education, a more extensive legal coverage for cyclists, infrastructure actions, and compulsory cycle helmet use in some cases. All these measures are now being studied by the administration in order to select the ones which should be implemented. The challenge is that cyclists and cars may coexist safely, and thus sparing the 100 lives which cycling accidents cost every year in Spain (Ministerio de Justicia e Interior, 1995).

In the United Kingdom, the Department of Transport has established the Cycle Route Programme which aims to promote cycling by providing local authorities with new land use planning guidance to improve modal choice by implementing cycle routes, secure cycle parking, especially near shops, schools etc., and by improving links with local transport and bike-and-ride-schemes (Department of Transport, 1995).

Modal choice is related to the number and distribution of cars. On the other hand, this is related to economic conditions, and therefore some governments are considering economic measures to curb the growth in car travel. Taxes are regarded as a key means to regulating transport demand. But at the same time it is evident that efforts should be made in order to increase alternative travel possibilities, for example, by promoting high quality public transport, by regulating public transport fares and by ensuring good transfer facilities for public transport.

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## CHAPTER IV -- SAFETY OF VULNERABLE ROAD USERS: AN OVERVIEW

To grasp the importance of safety problems faced by, and policies for, vulnerable road users, it is necessary to understand the types of traffic accidents in which they are involved. This chapter thus provides an overview of accident types based on statistical information supplied to the Group.

Accident statistics can only provide limited information, in particular, accidents involving vulnerable road users -- such as pedestrians and cyclists -- are often under-reported. Moreover, it is unfortunate that there is little evidence concerning the types of traffic accidents involving people with disabilities. Because the information obtained from current accident data is limited, more detailed study is necessary to obtain the key factors to use when recording traffic accidents. This problem will be further discussed in Chapter V.

### IV.1. General background of fatal accidents

International data provided by the IRTAD database are analysed in this section, since definitions of accident data in the IRTAD database are harmonised. However, the database is limited in scope as it focuses on fatal accident statistics. Therefore the IRTAD database has been used to provide background information on the following data sets:

1. number of fatalities by road user type;
2. number of fatalities by age group;
3. fatality Rate per 100 000 population by age group; and
4. number of fatalities by road user type and age group.

The trend in numbers of fatalities between 1970 and 1993 is examined first. Then comparisons between countries are presented using the latest data. Data from the following countries have been analysed: Australia, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Spain, Sweden, Switzerland, United Kingdom and the USA.

Countries with different definitions of fatalities use correction coefficients to convert their data to the IRTAD standard definition of "30-day fatalities".

#### *IV.1.1. Fatal accidents by road user type*

##### *Trends in Fatalities (see figure IV.1)*

In almost all countries the number of fatalities of each road user type was smaller in 1993 than in 1970. In Spain, although the total number of fatalities increased until 1990, mainly due to the increase in fatalities of car occupants, the number of fatalities for each mode of travel decreased between 1990 and 1993. For most of the other countries there was a decrease in total fatalities between 1970 and 1980 followed by a lesser reduction in more recent years. The earlier decrease was particularly large in Denmark, Finland, Japan and Sweden, however in Finland and Japan this decrease was followed by an increase in the number of fatalities between 1980 and 1990. While in Finland this increase in total numbers resulted from the increase in fatalities of car occupants, the increase in Japan between 1980 and 1990 occurred in all road user types.

Examination of the percentage of total fatalities for each road user type for all countries showed that the percentage of pedestrian fatalities decreased between 1970 and 1993, while that of car occupants increased. Although there has been little change in the percentage of cyclist fatalities in most countries, in Italy since 1970 cyclist fatalities fell from 10.9 per cent to 6.2 per cent of total fatalities, and in Finland, the Netherlands, Japan and the USA the percentage of cyclist fatalities increased a little.

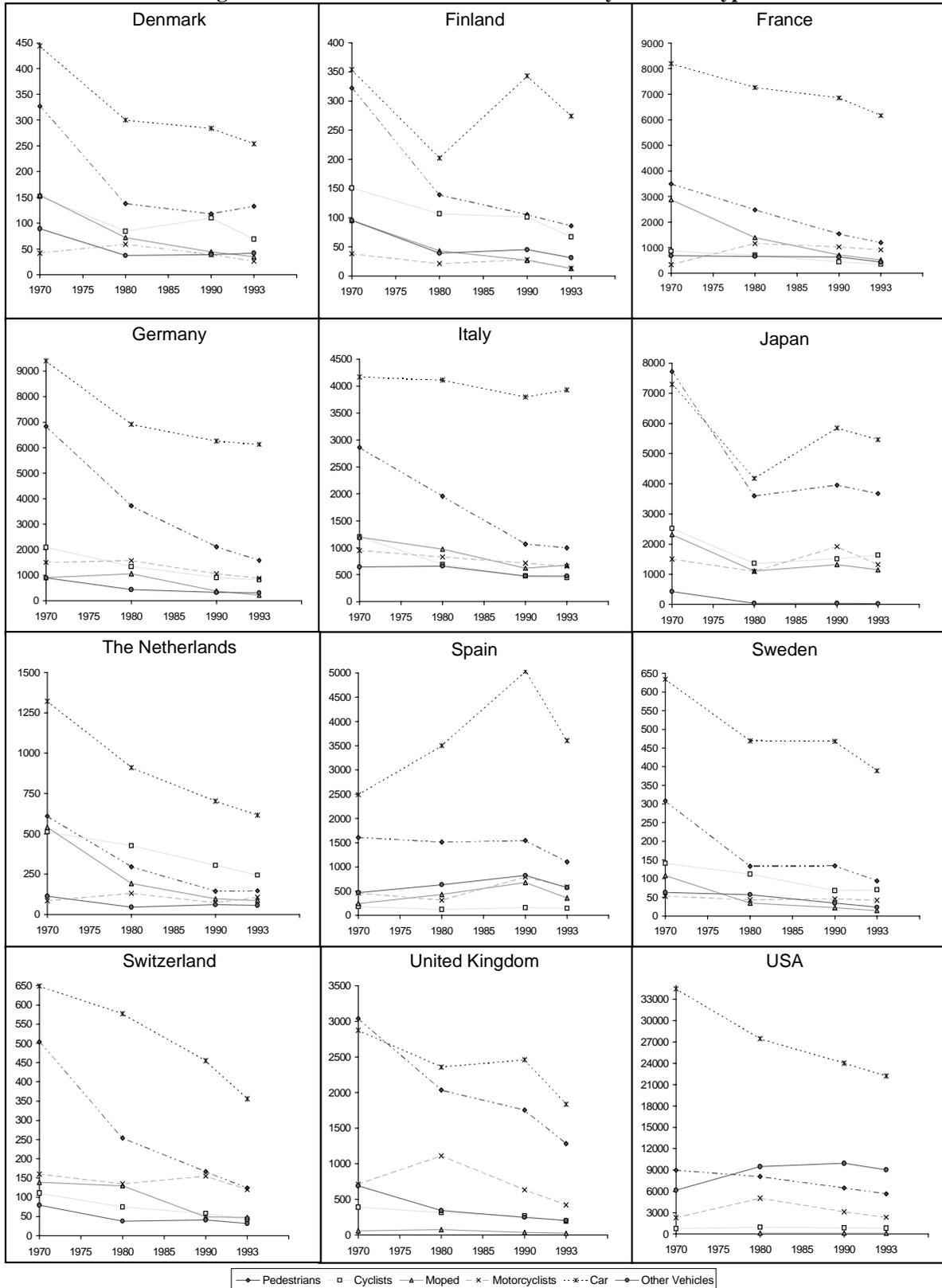
##### *Comparisons between countries in 1993*

For all countries, the group with the largest number of fatalities is that of car occupants. This is followed by pedestrian fatalities, except in the Netherlands, where cyclists make up the second largest group. For most countries the group with the smallest numbers of fatalities is either that of riders of mopeds, or of motorised two-wheelers. However in France, Italy, Spain and Switzerland cyclists contribute the smallest numbers of fatalities.

For each road user type, the percentage of all fatalities is dependant on the amount of use of that mode of travel. For example, where there is high ownership and use of bicycles, higher numbers of fatal accidents will occur, and these will represent a higher proportion of all fatalities.

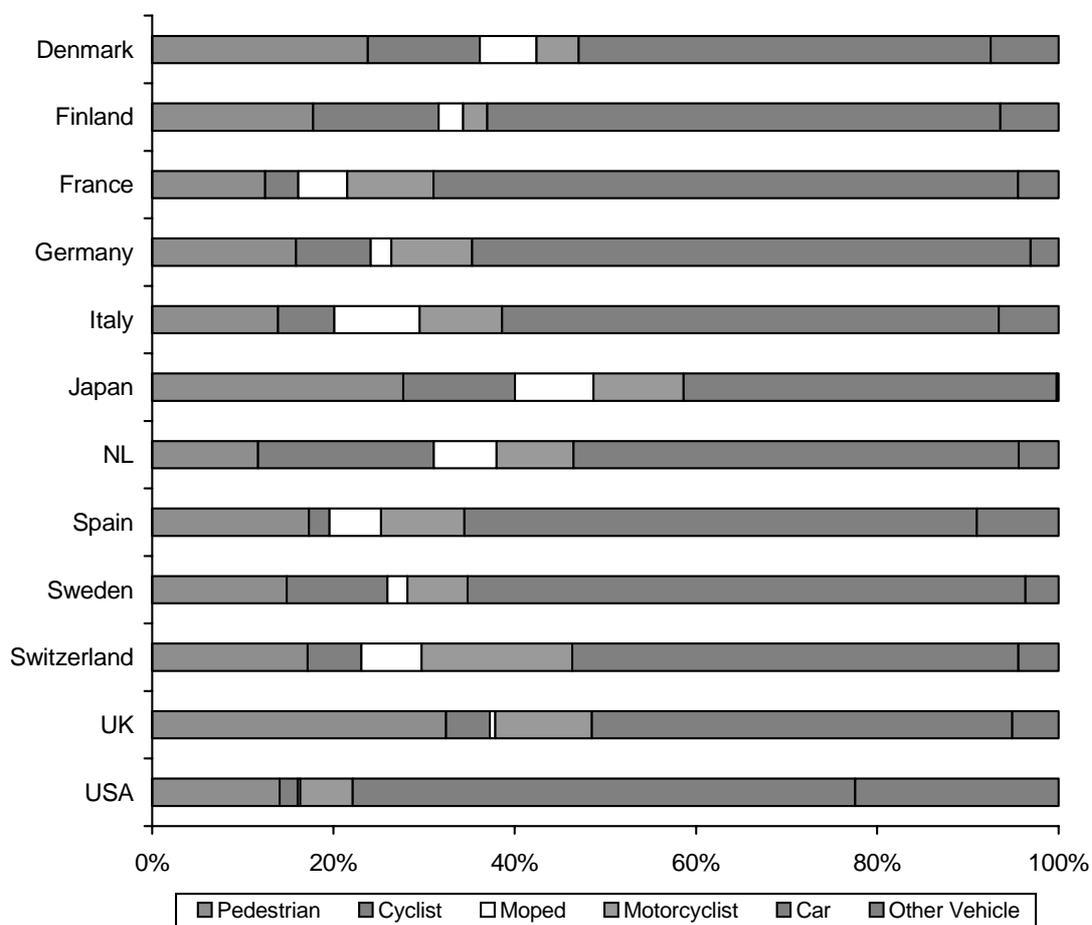
In France, Germany and Sweden car occupants contribute more than 60 per cent of all fatalities (see figure IV.2). In Denmark, Japan and the United Kingdom, the percentages of pedestrian fatalities are comparatively high (more than 20 per cent of all fatalities) while those of car occupants are lower than average (less than 47 per cent of the total). Denmark, Finland, Japan, The Netherlands and Sweden have a relatively high percentage of fatal accidents to cyclists (more than 10 per cent of all fatalities), while in Spain and the USA fatalities of cyclists amount to only about 2 per cent of the total. Italy, Japan and Switzerland have a comparatively high percentage of fatalities of riders of motorised two-wheelers (about 20 per cent of the total), while in Finland and the USA motorised two-wheelers contribute only about 6 per cent of all fatalities.

Figure IV.1 Trend in number of fatalities by road user type



Source: OECD

**Figure IV.2 Modal share of fatalities by country (1993)**



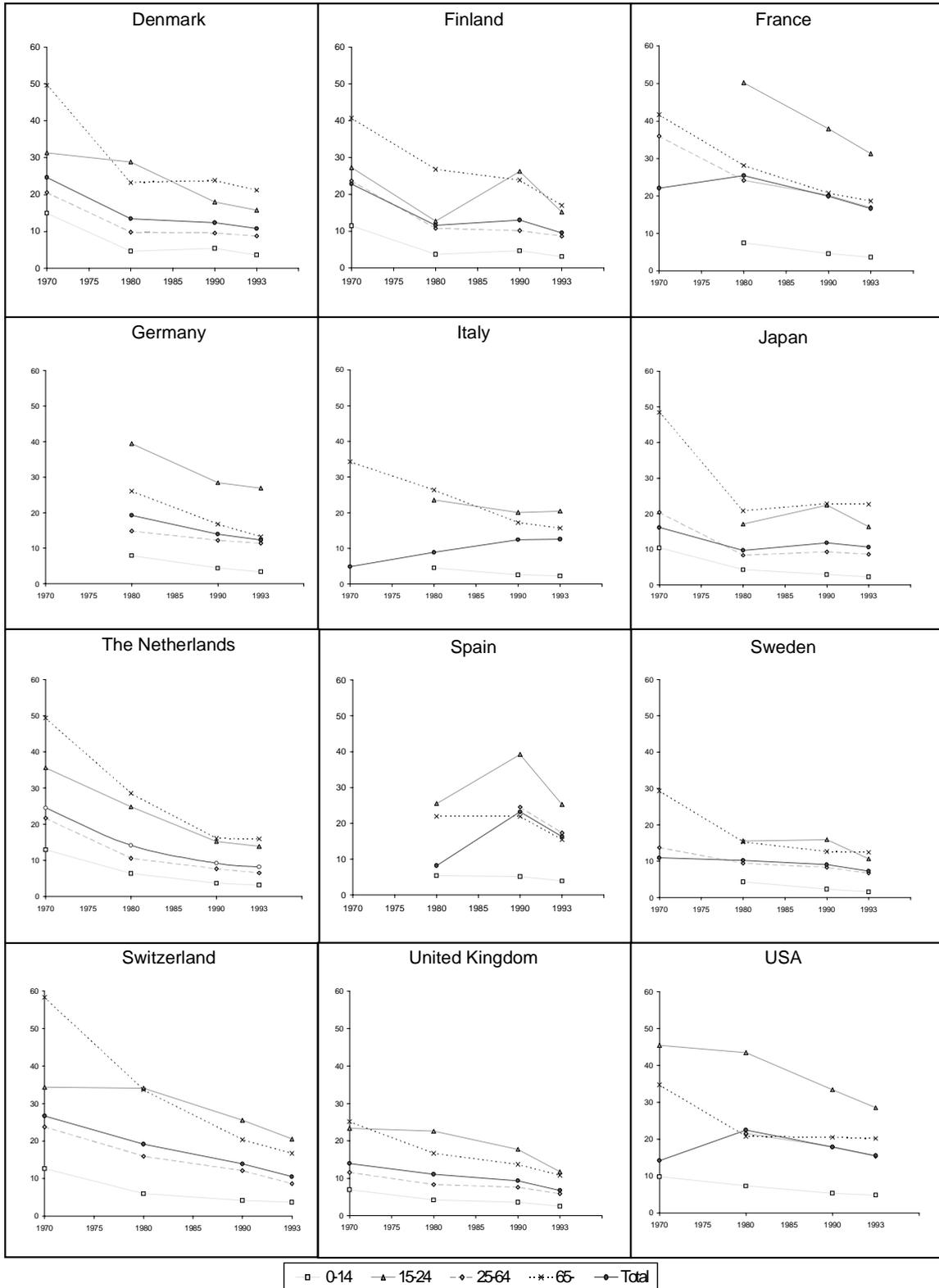
Source: OECD

**IV.1.2. Fatality rates by age group**

*Trends in Fatality Rates (see Figure IV.3)*

Between 1970 and 1980 the fatality rate by age group and by country decreased considerably for those countries where the information is available. Although the decrease continued between 1980 and 1990, the rate of the decrease became smaller in almost all countries. However in Japan and Spain the fatality rate increased for some age groups, in particular that of the 15-24 year olds.

Figure IV.3 Fatality rate per 0.1 million population by age group



Source: OECD

*Comparisons between countries in 1993*

Examination of the fatality rate per 0.1 million population for all age groups shows that France, Spain and the USA had relatively high rates of fatalities (more than 15 per 0.1 million population) in 1993, while Finland, the Netherlands, Sweden and the United Kingdom had low rates of fatalities (less than 10 per 0.1 million population). Looking at age groups separately, the 15-24 year olds had the highest rate of fatalities, except in Denmark, Finland, Japan, the Netherlands and Sweden, where the 65 year olds and over had the highest rate in 1993. However, in all countries, the rate for 15-24 year olds was close to 20 per 0.1 million or under in 1993, except in France, Germany and the USA where the rate for this group was nearer 30 per 0.1 million.

Countries that show comparatively high fatality rates for those aged 65 or over are Denmark (21.2 per 0.1 million population), Japan (22.6) and the USA (20.2). In the United Kingdom, on the other hand, the fatality rate of older people is the lowest (10.8) of all countries, followed by Sweden (12.4) and Germany (13.2).

The USA has the highest fatality rate of all OECD Member countries for children between 0 and 14 years old (about 5 per 0.1 million population). Children under 15 in France, Spain Switzerland and Denmark also have high fatality rates (more than 3.5 per 0.1 million population). On the other hand, children in Sweden have the lowest rate (1.6 per 0.1 million population), followed by Italy (2.3), Japan (2.3) and the United Kingdom (2.5).

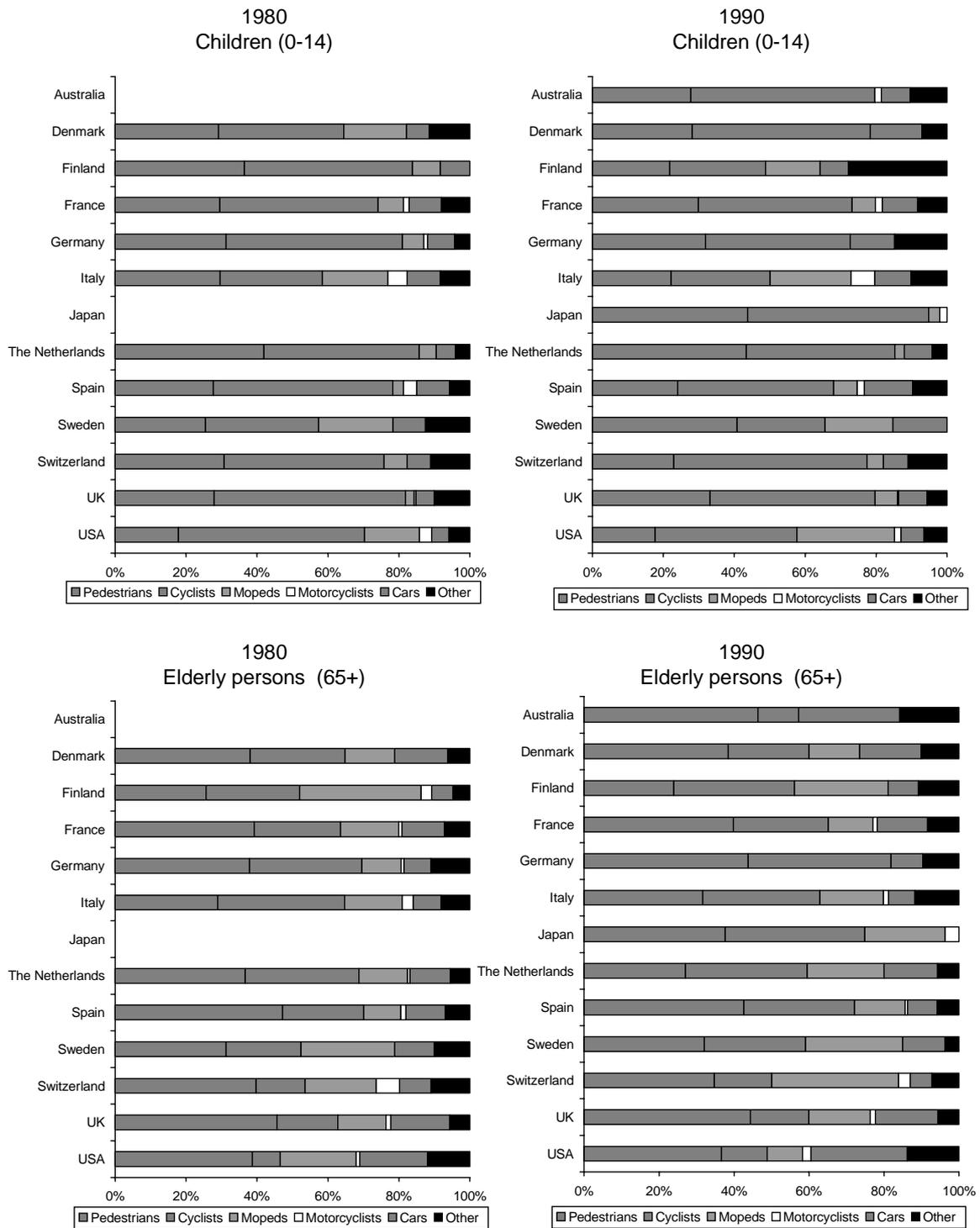
**IV.1.3. Fatalities by road user type and by age group***Trends in Fatalities (see Figure IV.4)*

For children (0-14 years), pedestrian and cyclist fatalities taken together as a percentage of all fatalities decreased between 1980 and 1990 for all countries except Denmark. Pedestrians and cyclists however still remained a large percentage of all child fatalities in 1990. For people 65 years of age and over, pedestrian and cyclist fatalities either increased their share of total fatalities or remained at about the same percentage of all fatalities.

Comparison of fatality rates per 0.1 million population in 1980 and 1990 (see Figure IV.6) show that for pedestrians aged 65 and over and for child pedestrians, although the fatality rate has remained high, there has been an overall decrease in the rate per 0.1 million population in all countries. Pedestrians aged 65 and over in the United Kingdom, Spain, Sweden and Denmark show a small decrease in their fatality rates per 0.1 million population, while other countries show larger decreases.

For cyclists, in 1980 the Netherlands had the highest fatality rate for both children under 15 and people 65 and over. In 1990 the highest rate for child cyclists was in Denmark where the rate had increased since 1980. For cyclists aged 65 and over the fatality rate increased in Spain, Denmark and the USA between 1980 and 1990, while it fell for all other countries. In 1990 the highest fatality rate per 0.1 million population for older cyclists occurred in Finland.

Figure IV.4 Fatality of children (0-14) and older people (65+) by mode and by country in 1980 and 1990



Source: OECD

*Comparison between countries*

(a) Distribution of pedestrian and cyclist fatalities by age group (Figure IV.5)

Examination of the percentages of all fatalities for each age group shows that there are greater differences between countries for pedestrians and cyclists than for car occupants.

In 1992, in almost all countries, the largest percentage of all pedestrian fatalities was that of people aged 65 and over. 64.2 per cent of all fatalities in Switzerland were of this age group, followed by Italy (52.2 per cent) and Japan (50.0 per cent). Half or more of all pedestrian fatalities are of older people in these three countries.

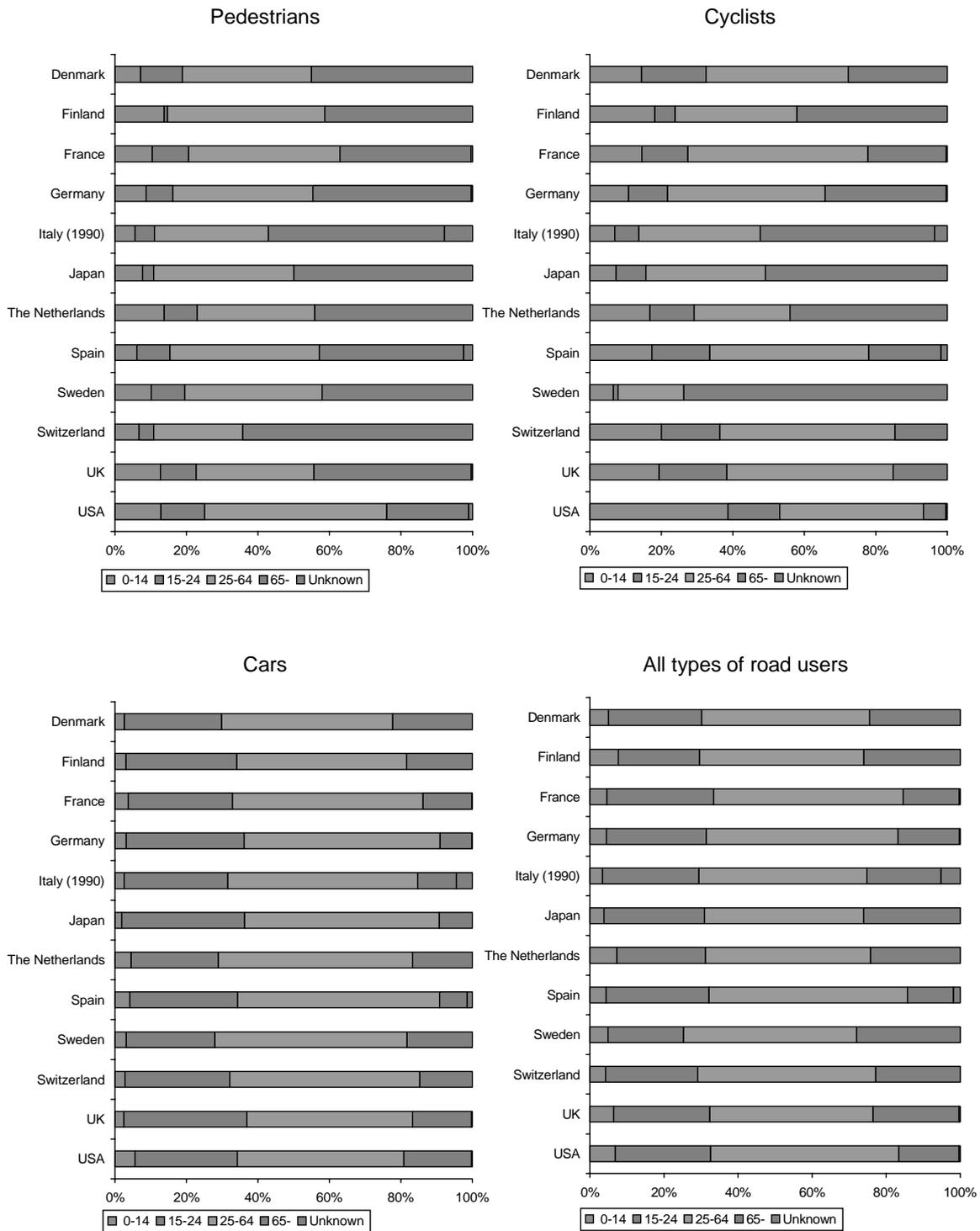
In 1992, the largest percentage (73.2 per cent) of all fatalities of cyclists was for those aged 65 and over in Sweden, followed by Japan (51.0 per cent of all fatalities of cyclists), the Netherlands (44.0 per cent) and Finland (42 per cent). Older cyclists in the USA had the lowest percentage: about 6 per cent of all fatalities among cyclists in the USA were 65 or over. It should be noted that child cyclists aged between 0 and 14 in the USA contributed the largest percentage of cycling fatalities for this age group (38.6 per cent of all fatalities of cyclists in the USA), followed by Switzerland (20.0 per cent) and the United Kingdom (19.4 per cent). In the USA, Switzerland and the United Kingdom a higher percentage of all fatalities among cyclists are under 15 years old than are 65 years old or older.

(b) Fatality rate per 0.1 million population for pedestrians and cyclists by age group (see Figure IV.6)

In 1990 for pedestrians of 65 or over, the countries with the highest rates of fatalities per 0.1 million population were Japan (12.32), Spain (11.57) and Switzerland (10.08), followed by the United Kingdom, Germany and Denmark, while the Netherlands had the lowest rate (2.41). Child pedestrians in the United Kingdom had the highest fatality rate (2.28), while those in the Netherlands, Italy and Sweden had the lowest rate (less than 1.0 per 0.1 million population).

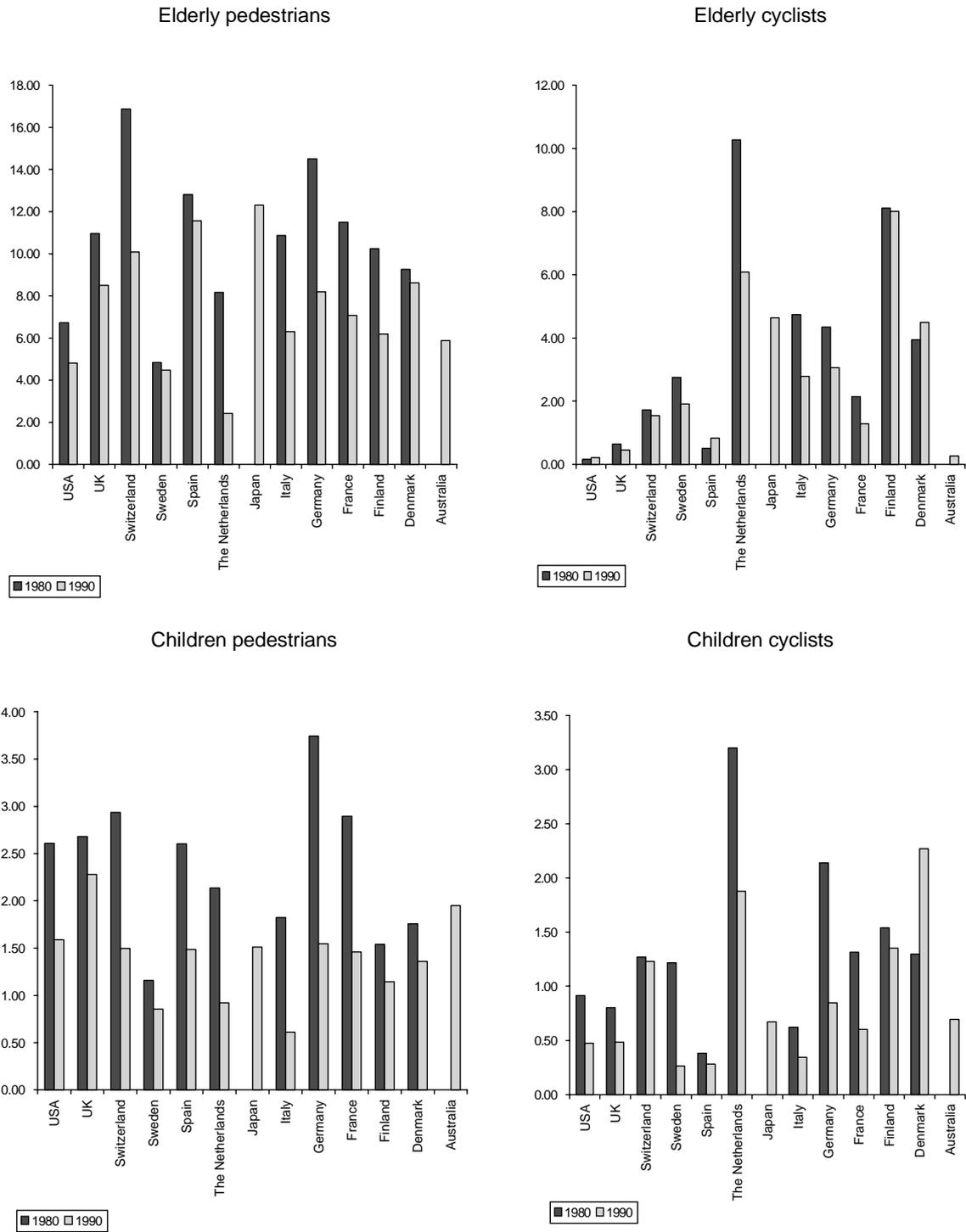
For cyclists 65 years old or over, in 1990 the highest fatality rates were in Finland and the Netherlands (8.01 and 6.09 respectively), followed by Japan (4.64) and Denmark (4.49). Older cyclists in the USA and the United Kingdom had the lowest fatality rate (0.21 and 0.45 per 0.1 million population respectively). Child cyclists in Denmark, the Netherlands and Finland had the highest rate (2.27, 1.88 and 1.35 respectively).

**Figure IV.5 Distribution of fatalities by age group in 1992**



Source: OECD

**Figure IV.6 Fatality rate per 0.1 million age population of children (0-14) and older people (65+) (Pedestrians and cyclists)**



1980 data are not available for Australia and Japan

Source: OECD

## **IV.2. Accident circumstances of vulnerable road users in Member countries**

### ***IV.2.1. Scope of this section***

In this section, for each country, accidents to vulnerable road users are identified through the national statistics of personal injury accidents, including fatalities, as provided by group members. Because accident data in each country vary in methods of collection and categories recorded, only limited international comparisons of the data provided by Member countries can be made (see Table IV.1 for fatal, serious and slight injury definitions). An overview of general aspects of accident circumstances in different countries is given through comparisons of the data compiled in accordance with the following key subjects:

- location;
- personal characteristics;
- type of vehicle;
- injured regions of the human body.

Although these data are more detailed than those of the IRTAD, the available data are very limited even in the countries which have prepared their national overviews. Other aspects of safety problems of vulnerable road users are also presented in related subjects based on information obtained from the group members. The data presented by each country were recorded in the following years:

- 1993: Denmark, Great Britain, Japan and Sweden;
- 1994: France and the Netherlands;
- the average of the years 1991 to 1993: Finland;
- 1994 (data by age, sex and location by mode and by severity) and 1993 (other data): Spain.

### ***IV.2.2. International comparison of accident characteristics***

#### *Location*

Accident characteristics are reviewed for each country according to the locations where accidents occur: urban or rural area, junctions or links, pedestrian crossings, pedestrian and cycle paths, etc. Although location definitions vary a little by country as shown in Table IV.2, comparison between the countries could be valid.

**Table IV.1 Definition of fatalities and severity of injuries in selected OECD Member countries**

<b>Country</b>	<b>Fatalities (Death in)</b>	<b>Personal injuries</b>	<b>Serious injuries</b>	<b>Slight injuries</b>
<b>Denmark</b>	30 days	Persons with injuries for which medical treatment or hospitalisation (even if only for observation) is normally required. Persons with lesser wounds, minor cuts and bruises are not recorded as injured.	Concussion, skull fracture, injury to face or eyes. Injury of trunk (chest and/or abdomen), spine and/or pelvis. Fracture/dislocation or severe sprain of shoulder, arm or hand, hip, leg or foot. Serious injuries in more than one main region. Burn.	Slight injury.
<b>Finland</b>	30 days	Any person requiring treatment in hospital or at home.	No special definition.	No special definition.
<b>France</b>	6 days	Hospitalised.	Hospitalised for more than 6 days.	Hospitalised for less than 6 days.
<b>Great Britain</b>	30 days	Serious and slight injuries.	Hospitalised, fractures, concussion, serious cuts and lacerations.	All others except serious injuries (e.g. minor cuts and bruises).
<b>Japan</b>	24 hours	Injured people requiring any treatments.	Injured people requiring treatment for more than 30 days.	Injured people requiring treatment for less than 30 days.
<b>The Netherlands</b>	30 days	Serious and slight injuries.	Person involved is admitted to hospital.	Injuries of a minor nature which do not require admission to hospital.
<b>New Zealand</b>	30 days	Severe and slight injuries.	Fractures, concussion, internal injuries, crushing, severe cuts and lacerations, severe general shock necessitating medical treatment and any other injury involving removal to and detention in hospital.	Injuries of a minor nature such as sprains and bruises.
<b>Spain</b>	30 days	Injured.	Hospitalised over 24 hours resulting from injuries caused by a traffic accident.	Those to which the definition of serious injuries cannot be applied.
<b>Sweden</b>	30 days	Serious and slight injuries.	Fracture, contusion, severe rupture, concussion of the brain or internal injury. Also other kind of injury that results in hospital care.	Other kind of injury not included in serious injury.

**Table IV.2 Definition of Urban/Rural Roads in Each Country**

<b>Country</b>	<b>Urban</b>	<b>Rural</b>
<b>Denmark</b>	Inside areas marked with the sign for built-up area.	Outside areas marked with the sign for built-up area.
<b>Finland</b>	Built-up areas.	Non-built-up areas.
<b>France</b>	Built-up areas marked by entry and exit signs.	Non built-up area.
<b>Great Britain</b>	Roads with speed limits up to 40 mph.	Outside urban area.
<b>Japan</b>	Areas with houses or human activities along a roadside for more than 500 meters, and with more than 80 per cent of the roadside occupied.	Areas other than urban areas.
<b>The Netherlands</b>	Within that area defined as such by law and indicated by blue Place-name boards.	Outside urban area.
<b>New Zealand</b>	All speed limit areas of 70 km/h and under and limited speed zones.	All speed limit areas of over 70 km/h.
<b>Spain</b>	Inside areas marked with the sign for built-up area.	Outside areas marked with the sign for built-up area.
<b>Sweden</b>	Roads with the highest speed limit of 50 km/h, or other roads with a urban character.	Roads outside the urban area, and roads separated from the surroundings with a fence or where only motor vehicles are allowed.

Most serious and slight injuries to pedestrians and cyclists occur in urban areas (see Figure IV.7). Examination of fatalities occurring in urban and rural areas reveals that there are more fatalities in urban areas than in rural areas. However, in rural areas, the percentage of fatalities is larger than the percentage of slight injuries. This means that accident severity is higher in rural areas, probably because of the higher vehicle speed in such areas.

Although this general tendency is observed, in France and Spain there are more fatalities of cyclists in rural areas than in urban areas. In addition, in Spain more pedestrian fatalities occur in rural areas than in urban areas.

Roads consist of junctions and links. A junction is in general the physical joining of roads. There are, however, differences of how this physical area on each arm of the junction is defined. In some countries this definition is unclear and may differ according to the type of road users involved in accidents. Figure IV.8 needs therefore to be interpreted with care.

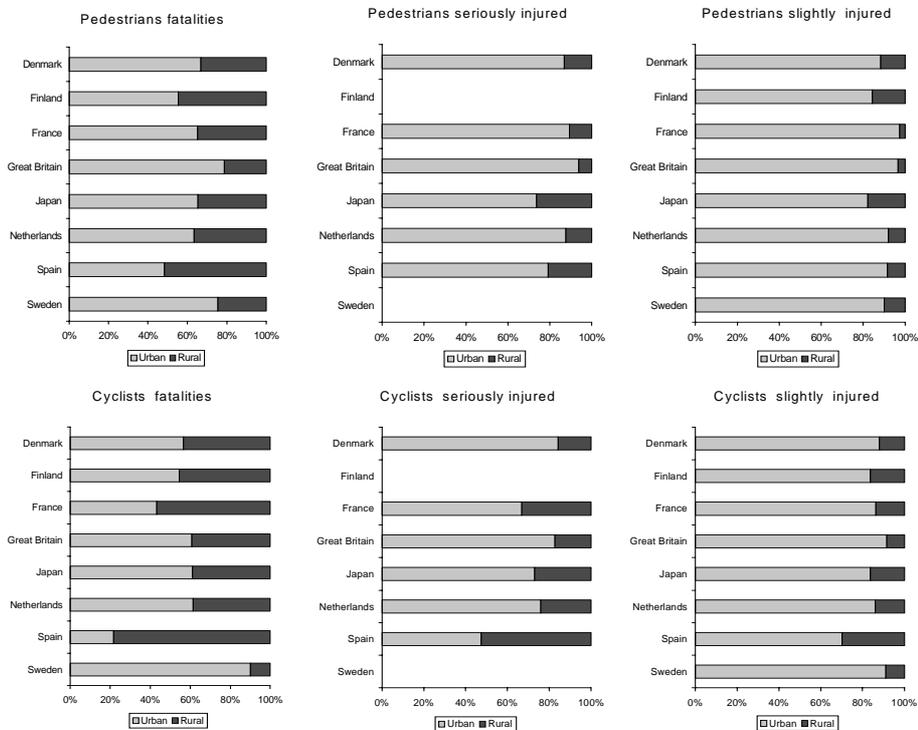
Some countries show larger numbers of pedestrian accidents on links than at junctions (see Figure IV.8). Bicycle accidents mostly occur at junctions, but accidents on links tend to be serious for both pedestrians and cyclists. Cyclist fatalities also show a similar tendency except in Spain and Finland, where more cyclist fatalities occur on links than at junctions.

The conditions under which accidents occur vary by type of junction.

- In the Netherlands, the change of intersections (signalised and non-signalised) into roundabouts resulted in a 30 per cent decrease in injured cyclists, a 50 per cent reduction in

the number of accidents, and in a more than 75 per cent reduction in the number of road accident fatalities.

**Figure IV.7 Pedestrian and cyclist accidents by road type**



Note: Slight injuries in Finland and Sweden include both slight and serious injuries

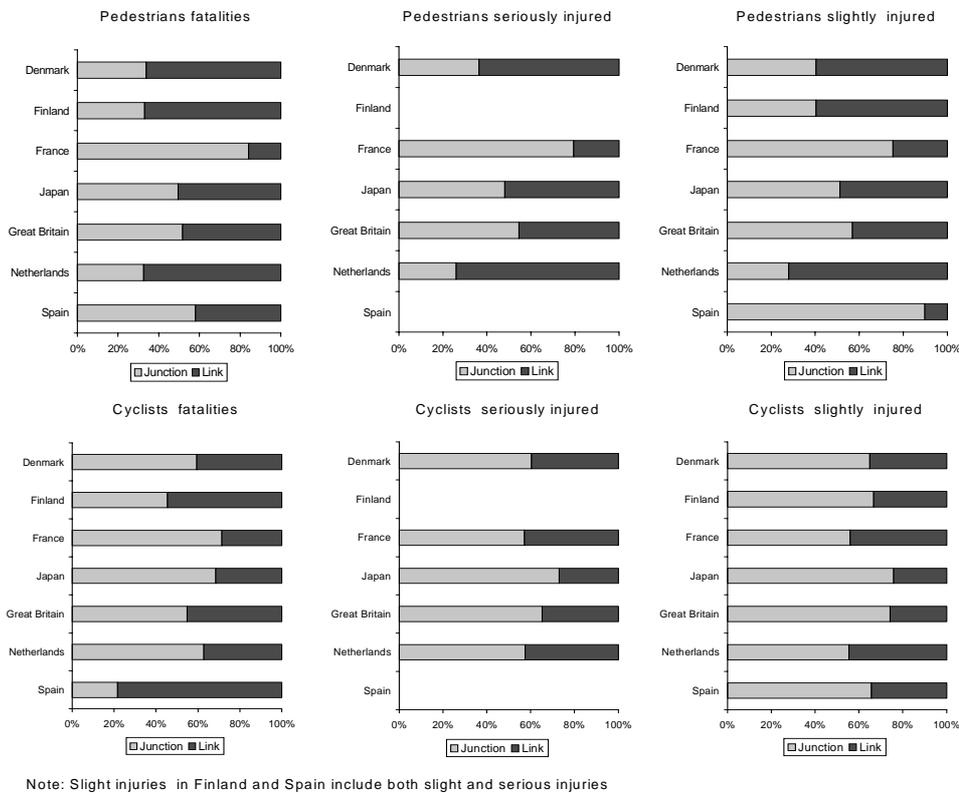
Source: OECD

Further, it is generally found that the accidents of vulnerable road users such as pedestrians and cyclists are more likely to occur on minor roads and at intersections where a minor road connects to an arterial road.

- In the United Kingdom, 72 per cent of child casualties occur on minor roads; 95 per cent occur away from crossings; 60 per cent are within a distance of 500 metres from their homes; 85 per cent happen away from crossings on main roads (year 1989).
- In the Netherlands, the safest roads for cyclists and mopeds are residential roads in traffic calming areas. Parts of these residential roads in traffic calming areas have a speed limit of 30 km/h. It could be said that the effect of traffic calming measures on minor roads is large.

It is also noted that the location of accidents differs for different age groups.

- In the United Kingdom, accidents involving children tend to be scattered across the road network while those involving adults tend to be more clustered.

**Figure IV.8 Pedestrian and cyclist accidents by location**

Source: OECD

Characteristics of the distribution of accidents to vulnerable road users on pedestrian crossings, cycle tracks and cycle lanes have been obtained from various group members. It should be noted that accidents to pedestrians and cyclists occur frequently at facilities designed for pedestrians and cyclists such as pedestrian crossings, cycle tracks and cycle lanes. This means that these facilities are not necessarily good enough to prevent accidents.

- In the United Kingdom, over 20 per cent of accidents happen at a place where people should be safe, such as on the pavement or at a pedestrian crossing.
- In Denmark, half of the accidents with cyclists occur at facilities for cyclists such as cycle tracks or cycle lanes.

Pedestrian accidents occur most often whilst crossing the roadway, especially for older pedestrians. Pedestrian accidents often occur when people are trying to cross the street on links outside pedestrian crossings or where no pedestrian crossings exist. One of the causes is the driver's difficulty in perceiving pedestrians because of darkness and/or parked cars.

- In the United Kingdom, nearly 90 per cent of the injuries to older pedestrians which are caused by motor vehicles happen under such conditions. In over 10 per cent of cases, the driver cannot see pedestrians because of parked cars. 67 per cent of pedestrians in the United Kingdom were killed or injured whilst crossing the road more than 50 meters away

from a pedestrian crossing. Three quarters of these accidents happen when they are unprotected by a crossing.

- In Denmark most pedestrian accidents with children and older people occur when these road users cross the road on links away from pedestrian crossings.
- In Japan, the most frequent accidents are those while crossing the road, especially on links where no pedestrian crossings exist. For cyclists, collisions at crossings occur most frequently, followed by accidents when cyclists turn or cross. In particular, collisions when crossing at non-signalised intersections occurred most often.

### *Personal characteristics*

Figure IV.9 shows the percentage of those killed, seriously injured or slightly injured for each age group. It is characteristic that where the proportion of accidents to children is larger, the proportion of serious accidents is smaller. This tendency is found especially among pedestrians. At the same time, the larger the proportion of accidents to older people, the more serious the injuries become. According to the time series data and the rate of injuries per population provided by Great Britain, Japan and Finland, the fatality rate for people aged 65 and over is extremely high in comparison with other age groups.

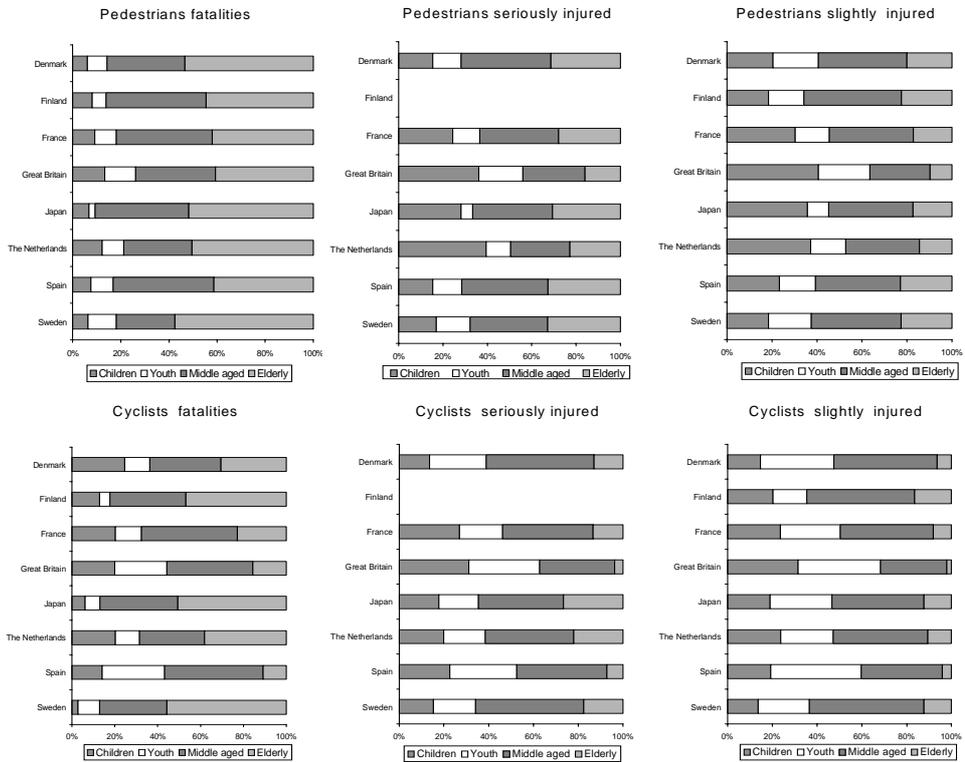
In Japan, fatal accidents to pedestrians aged 65 and over have increased. This trend will become more serious with an increase in the elderly population in the future. Fatalities to older cyclists have also increased.

There are few differences between male and female pedestrians. The proportion of male pedestrians is a little higher than that of females in accidents with personal injuries. Male pedestrians are more susceptible to fatal accidents than females in Denmark, Spain, France, the Netherlands and Great Britain. It could be said in general that the higher the proportion of male pedestrians the more serious the injuries become. Generally, male cyclists have a higher percentage of fatal accidents than female cyclists (see Figure IV.10).

It should be noted that the distribution of male and female varies by age group.

- For children in Great Britain, boys are more at risk than girls because it has been found that they tend to play more often in the street, especially between the ages of 6-10. After the age of 12, girl pedestrians do not show much lower figures than boys.
- Among older people in France, the proportion of casualties is equally distributed between males and females, but particularly in the case of slight injuries, the number of female victims is larger than that of males.
- In Finland, most bicycle accidents happen to young people under 15 years and to men over 65 years. Over half of the serious bicycle accidents happen to elderly cyclists.

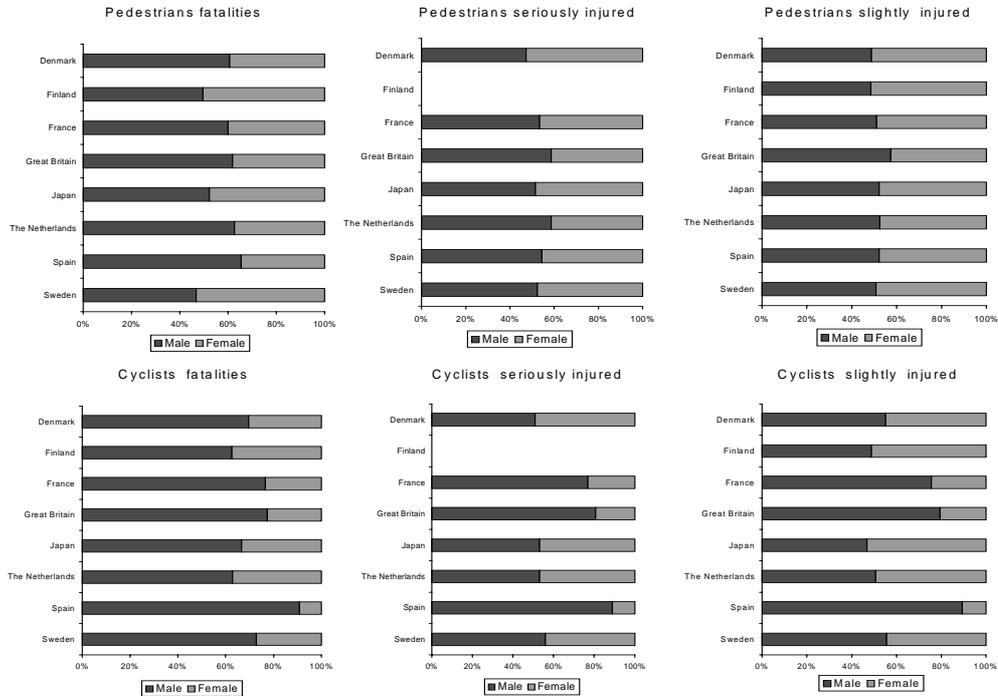
**Figure IV.9 Pedestrian and cyclist accidents by age group**



Note: Slight injuries in Finland include both slight and serious injuries  
 Children = 0-14; Youth = 15-24; Middle aged = 25-64; Elderly = 65+

Source: OECD

**Figure IV.10 Pedestrian and cyclist accidents by sex**



Note: Slight injuries in Finland include both slight and serious injuries

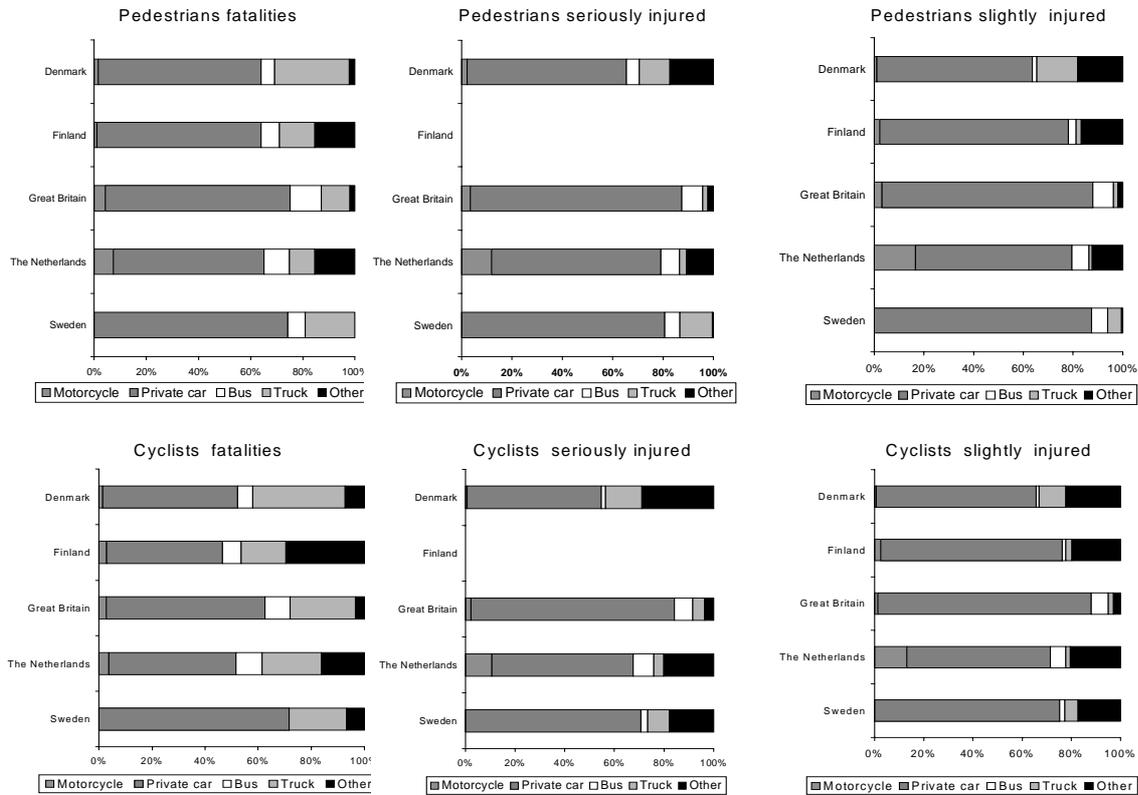
Source: OECD

*Type of vehicle*

Countries define types of vehicles differently, as illustrated in Table IV.3. However, it is fair to say that a passenger car is usually involved in accidents involving pedestrians and cyclists. It is also found that, in both pedestrian and cyclist accidents, the more often trucks are involved the more serious the accidents tend to become. In the Netherlands, motorcyclists are involved more in both pedestrian and cyclist accidents. This is because mopeds are included with motorcycles in these accident comparisons (see Figure IV.11).

**Table IV.3 Examples of definitions of type of vehicle**

<b>Country</b>	<b>Passenger Car</b>	<b>Bus</b>	<b>Truck</b>	<b>Others</b>
<b>Finland</b>	Motor vehicle with at least four wheels or tracks constructed with a maximum design speed exceeding 30 km/h.	Motor vehicle intended for carrying passengers and comprising more than 8 seats plus driver's seat.	Motor vehicle designed for carrying goods with a total mass exceeding 3.5 tones.	–
<b>Great Britain</b>		Coach, van.	Heavy freight vehicles.	Other motorised, non-motorised vehicles, bicycles.
<b>Japan</b>	Sedan.	Bus, minibus, 4-wheeled light bus.	Light truck, 3- and 4- wheeled truck, large-sized special truck.	Other motorised vehicles, bicycles.
<b>Spain</b>	Vehicles other than motor cycles, specially designed for the carriage of persons up to 9 seats (driver included).	Power driven vehicle designed for the transport of persons, with a capacity for more than 9 seats (driver included), including trolley buses (vehicles connected to an electric conductor and not rail-borne).	Power driven vehicle designed for carrying goods. Three-wheeled motor-cycles designed for carrying goods with a maximum authorised mass of 400 kg are excluded from this definition.	
<b>Sweden</b>	Motor vehicle with at least 3 wheels (other than motorcycles or mopeds), used for carrying persons (max. driver + 8 passengers).	Motor vehicle with at least 3 wheels (other than motorcycles or mopeds), equipped to carry more than 8 persons beside the driver even if the vehicle is equipped for other purposes.	Motor vehicle with at least 3 wheels (other than motorcycles or mopeds) that is not to be considered a passenger vehicle or bus.	Other motorised vehicles like tractors, terrain vehicles, motorcycles, mopeds and rescue vehicles, cycles, carriages drawn by animal(s).

**Figure IV.11 Pedestrian and cyclist accidents by type of vehicles involved**

Note: Slight injuries in Finland include both slight and serious injuries

Source: OECD

### *Injured regions of the human body*

Hospital based research provides detailed information on the type and severity of injuries as follows:

- Head injuries occur most frequently and are the major cause of death and hospitalisation for vulnerable road users.
- Injuries to legs and arms are the next most frequent injuries after head injuries. The most serious (non fatal) cyclist casualties are those with injuries to the lower limbs.

More detailed information based on hospital studies is provided in Chapter V.

### **IV.2.3. Accident risk -- Accident rate taking mobility into account**

Because car trips are dominant, and the trip length of the car is much longer than that of non-motorised transport such as walking or cycling, it is natural that the largest percentage of all accidents is that of car drivers and/or passengers. This shows that there is a need to introduce additional data to be able to interpret statistically the differences that exist between accident numbers for different road user types and in different situations.

Although this is usually expressed as “accident risk”, it might be clearer to use the term “accident rate” in order to avoid any misunderstanding when discussing the accident frequency probability, and not the severity or consequences of accidents. Accident rate could be represented by the following equation:

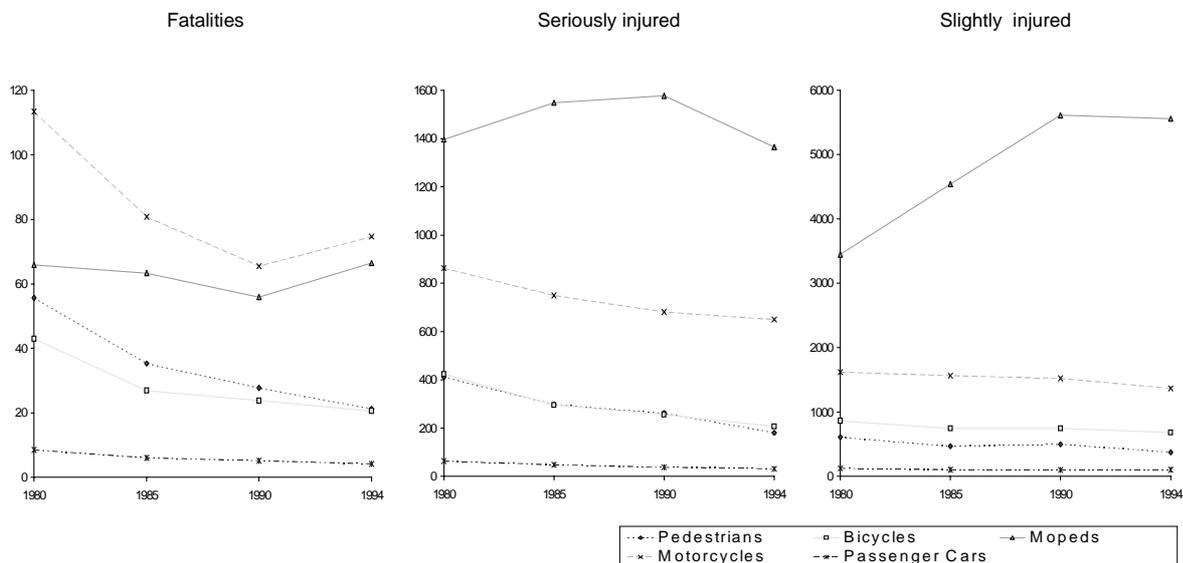
$$(Accident\ Rate) = (Number\ of\ Accidents) / (Exposure)$$

Unfortunately, as indicated in Chapter III, there are only a few countries where mobility and accident data are provided with a sufficient level of detail and consistency for such a purpose. The difficulty occurs because mobility data and accident data are not recorded using the same time periods or regions. It is hoped that analysis of accident rate, with well prepared data using the same year and regions will be carried out in further studies.

Figure IV.12 illustrates the trend in the number of accidents per trip length by mode based on a study conducted in the Netherlands. It was found that:

- the rates for motorcycle and moped riders are remarkably high;
- the rates for pedestrians and cyclists are lower than those of motorised two-wheeler riders, but higher than that of passenger car occupants;
- the rates for passenger car occupants are the lowest; and
- the rates for pedestrians and cyclists decreased between 1980 and 1994.

**Figure IV.12 Fatality and injury rate per billion kilometres travelled per year by mode (1980-1994, the Netherlands)**



Source: SWOV (BIS-V-CBS/VOR)

In Denmark and Sweden, the accident rate for vulnerable road users is higher in urban areas than in rural areas. According to accident statistics based on police reports the safety problems are higher for pedestrians than for cyclists, both in absolute terms and when related to distance travelled.

The accident risk for cyclists and pedestrians is higher on road links between junctions than at junctions. If hospital registrations are taken into account then cycle accidents increase by a third, because a higher number of single vehicle accidents are included. When data from hospital registrations are included the level of risk for cyclists becomes higher at junctions than on links.

### **IV.3. Problems of under-reporting of accident data**

The summary of accidents involving vulnerable road users which has been discussed previously depends on national accident statistics. The problem of under-reporting accident data always exists, except for fatal accidents, especially for vulnerable road users. It is thought that this problem results from the definitions of “traffic accidents” generally used in each country. These definitions are at present related to accidents involving motorised vehicles.

The least likely casualties to be reported to the police could be those where:

- there was no other motorised vehicle involved in the accident;
- the casualty was a child;
- the injuries were slight;
- an accident occurred in which the casualty contacted a doctor or casualty department on his own; and
- the accident occurred on a minor road.

There are many studies on this topic of under-representation which look at accident data reported to the police and compare it to hospital-based data.

A study in the United Kingdom shows that problems regarding under-representation consist of the following three possible sources of differences between hospital data and police reported data.

#### *Misclassification of severity*

- The police were more likely to under-estimate than over-estimate severity.
- The proportion of cases where severity was wrongly coded varied with road user type.
- The proportion of under-estimated cases was high for pedestrians, cyclists and motorcyclists.

#### *Under-reporting of casualties to the police*

- The proportion of casualties excluded is likely to be highest for cyclists and lowest for car occupants.
- Serious injury accidents were only marginally better reported than slight injury accidents.

*Under-reporting by the police of reported casualties*

- Levels of under-recording were higher for casualties with slight injury compared with casualties who were seriously injured.
- Under-recording also tends to be more likely for occupants of cars and other vehicles compared with pedestrians and motorcyclists.

The study estimates that, to take account of the effect of misclassification, under-recording and under-reporting the number of serious and slight casualties appearing in national figures should be multiplied by 2.76 and 1.70 respectively. Thus there are estimated to be almost three times as many serious casualties as are recorded in national casualty figures and nearly twice as many slight casualties.

Six hospital-based under-reporting studies carried out in Great Britain have been summarised in Table IV.4 to give an indication of the range of levels of under-reporting for different degrees of injury severity and for different road user types.

**Table IV.4 Percentage of casualties reported**  
(estimated from hospital-based studies in Great Britain)

	<b>Min.-Max. percentage reported</b>	<b>Average percentage reported</b>
<i>Vehicle occupant</i>		
Fatal	100-100	100
Serious	85-91	89
Slight	70-82	77
All injuries	75-86	81
<i>Pedestrian</i>		
Fatal	100-100	100
Serious	82-91	85
Slight	60-80	67
All injuries	73-85	77
<i>Motorcyclist</i>		
Fatal	100-100	100
Serious	67-73	70
Slight	42-63	51
All injuries	56-66	61
<i>Pedal-cyclist</i>		
Fatal	100-100	100
Serious	17-41	33
Slight	9-29	21
All injuries	22-34	27
<i>All casualties</i>		
Fatal	100-100	100
Serious	66-82	76
Slight	55-66	62
All injuries	50-72	62

In *Denmark*, only about 10 per cent of accidents with slight personal injuries and 50 per cent of the serious accidents involving cyclists are reported to the police.

In the *Netherlands*, hospital survey data compared with the accident data from the Traffic Accident Registration (based on police reports) of the Ministry of Transport, show that registration of recordable accidents accounted for only 20 per cent of accidents reported by those interviewed. However, accidents reported by interviewed casualties did also include pedestrian falls which are not considered registrable. Completeness of the registration appeared dependent on injury severity, age and modal split. The most under-recorded road users were cyclists (only 9 per cent), while the best registered group was car occupants (37 per cent).

A study carried out by the *Swedish* National Statistics in 1982-83, comparing an estimated number of injuries to adults aged 14 to 74 to the corresponding figures recorded in police reports, showed that only 37 per cent of injuries were recorded in statistics (32 per cent of the slight ones and 59 per cent of the serious ones). When considering separately the various transport modes, it was found that coverage of cyclist accidents by the police was particularly low (15 per cent), which may be in part due to the fact that cyclist falls without collision were not reported. Another study based on hospital data and police reports was carried out in 1992 on a sample of accident victims seeking treatment in Lund University Hospital. Police data included 1 514 victims, and hospital data 1 076; only 843 victims were found to have been recorded both by the police and the emergency department. Cyclists are shown to account for 15 per cent of the victims in police data, and for 35 per cent in hospital data. Information on pedestrians injured by falls is reflected in the hospital data alone (Berntman, 1994).

A study on bicycle injuries was carried out in *Finland*. It was based on information derived from the health care records (with additional interviews and questionnaires) in the town of Mikkeli and its surroundings in 1980, as well as from health care records of Mikkeli Central Hospital and of four hospitals in Helsinki in 1985-86, and from the national hospital discharge register in 1980. This information was compared to official police statistics. The results suggested that the incidence in the population of cyclists' injuries was 15 times higher than the figure derived from police data. It was estimated that, annually, about 1 per cent of cyclists suffered an injury requiring medical attention. Bicycle injuries accounted for 52 per cent of all traffic injuries. Non-motor vehicle related bicycle injuries accounted for 58 to 72 per cent of in-patients and 93 per cent of out-patients. Adults (over 14) accounted for 64 per cent of injuries requiring care, 72 per cent of hospitalisation and 86 per cent of fatalities. The incidence of non-fatal injuries was highest among boys under 15, school-age girls and elderly men (Olkkonen, 1993).

The level of under-reporting varies widely, as illustrated above. This results from differences in the collection systems and structures of accident data of the various countries as well as from differences in under-reporting study methods. The problem of accident under-reporting concerning vulnerable road users needs to be properly addressed in the future.

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## CHAPTER V -- IDENTIFICATION OF ACCIDENT FACTORS

### V.1. Methodologies and theories

#### V.1.1. Introduction

International comparisons of accident statistics and the analysis of accident data, as summarised in Chapter IV, provide a description of the main accident problems and characteristics as a basis to select priority targets for safety action, in terms of groups or categories of accidents to eliminate, types of location where accidents are particularly frequent or where the risk is high, etc. But in order to choose and design the safety measures or policies promising to be the most efficient in dealing with these priority targets, knowledge provided by standard statistics is not enough, as will be discussed below.

Accident statistics give a global image of a past safety situation. From this situation, it is inferred that, if nothing is done about it, future accidents of the same types can be expected to appear. Safety measures are designed to prevent part of these expected accidents or, at least, to limit the damage they are likely to cause. To design efficient measures, it is essential to understand what processes are going to generate the future accidents, and what factors should play a key role in them. It is by eliminating or neutralising the effects of some of these factors that the accidents that would have involved them can be avoided. Only the study of factors having played a part in accidents that have occurred in the past can yield information on those that could generate future accidents.

Accident research has shown, particularly through clinical methods of in-depth investigations, that accidents are the result of complex processes involving a number of factors related to the various elements of the road and traffic system (the road and its environment, vehicles and traffic, the road users) and to the way they interact. Accidents are thus indicators of malfunctions of the mobility system that usually associate several of its components. The search for factors that have contributed to generate a particular accident target is therefore not easy and requires sound methodology.

Accident occurrence is, in statistical terms, a random event. The factors generating the accidents are not usually random; the combination of factors resulting in accidents is random, but predictable. Refined statistical methods and epidemiological studies are used to distinguish between the random element and the other effects explaining accident occurrence, thus helping to pinpoint characteristics of the road and traffic system that may be accidents factors. Such studies do not involve identifying direct causal relationships between *would-be* factors and the accidents. For example, epidemiological studies of road accidents have pinpointed the presence of “alcohol” (i.e. one of the drivers involved had a blood alcohol content above the legal limit) in a substantial percentage of fatal accidents. This does not mean that alcohol has necessarily been a causal factor in all these accidents, but that it is likely to have played an active part in at least some of them.

Statistical accident data, as collected by the police or similar agencies, is most often based on a reduced number of variables describing accidents characteristics. The range of *would-be* factors that can

be detected and described on this basis remains therefore limited. Moreover, the quality of statistical accident data in terms of completeness and accuracy is not always satisfactory, especially with regard to vulnerable road users, which further biases the findings. Finally, police data provide very little information on the consequences of accidents (severity and types of lesions, resulting disabilities, etc.). This means that information useful to design measures to reduce the severity of accidents is not available.

It can be seen that the statistical approach based on standard accident data must be complemented by other approaches in order to find out a sufficient range of accident factors on which to base the design of safety measures. There are two possible avenues:

- One is to apply statistical and epidemiological analysis to accident files including a larger number of variables to describe each accident and its consequences. In what follows, this approach has been termed “intermediate” because the data collected are more detailed than in standard accident statistics -- although without actually getting into the complete description of the accident processes -- and because they are neither systematically collected on all accidents, nor limited to a very small sample of them.
- One is to identify accident factors through a clinical approach, based on a sample of investigation files of accident cases, and consisting in reconstructing each accident process in order to understand the causal relationships involved. The data needed must be accurate enough to make the reconstruction possible, and are usually obtained through ad hoc investigations carried out at the accident spot, although the full police reports (or the records supporting court cases) can often be used for more summary clinical analysis.

These approaches are based on one form or the other of accident data. As such, they do not allow taking into account all aspects of the accident processes as these have not been observed but, at best, reconstructed. They cannot either help to identify factors related to accidents that may occur as a result of changes (in the environment, in traffic, etc.), planned or spontaneous.

There are other problems connected to the use of accident data for traffic safety evaluation. Accidents are rare events, which means that for local everyday traffic safety work, it is not sufficient to use accident data only. To produce reliable estimates of traffic safety, additional information is usually needed. As seen earlier, there are also difficulties with the recording of accidents: not all accidents are reported and the level of reporting is unevenly distributed with regard to type of road users involved. Vulnerable road users are, for instance, heavily under-represented in the police accident statistics compared to what hospital registrations and other studies show. The *behavioural* or situational aspect of the situation is often not well covered by accident data. A major drawback of accident analysis is finally the total disregard of all these much more frequent elementary events that can be defined as safe or unsafe interactions between road users. The quality of traffic *interactions* is the basis of a proper assessment of traffic safety. In order to be able to perform more quality work in this field, the future challenge is to define and study the principles of safe interaction.

All this shows that there is a strong need for *intermediate* methods in road safety studies. Such methods, aimed at providing complements or *surrogates* for accident analysis, have thus been designed, based on the direct observation in traffic of events resulting from processes similar to those of accidents (*traffic conflict techniques*), or on the observation of particular characteristics of traffic behaviour and analysis of their determinants.

This chapter describes the four approaches introduced here, provides examples of applications as well as the main accident factors which have been identified and studied through them.

### *V.1.2. Accident analyses at an intermediate level*

#### *Principle*

“Intermediate” accident studies are so termed because they rely on data bases which contain more information than standard statistics, and whose scope must therefore be reduced, either in the geographical area covered, or in the types of accidents included, or in the time span devoted to data collection.

Intermediate studies have been designed either:

- to check the validity of existing statistics (assessing the amount of under-reporting, for example); or
- to complement the missing data on the consequences of accidents; or
- to provide more precise targets for action; or to widen the range of variables that may possibly explain the accident variations.

Data bases have usually been developed in view of one of these aims (or a combination of them).

Intermediate studies may thus be carried out at the national level, using data extracted from the more detailed police reports to provide some information on accident processes, or health statistics to provide information on accident consequences, or check completeness of casualty data. Only some particular categories of accidents may be considered (accidents involving vulnerable road users, fatal accidents, accidents followed by hospitalisation of victims, etc.). As data collection, linkage, and processing require time and effort, they are usually performed over a (large) representative sample of accidents, and over a given period of time, although some intermediate data bases have become permanent.

More detailed studies may also be carried out on limited geographical areas, which makes it easier to link data from different sources, collect additional data from observation or interview surveys, visit accident sites, etc. Such local studies are usually undertaken, either to check the quality of police reported data -- in which case they are most often based on hospital data -- to provide indications on the consequences of accidents in terms of injuries, or to improve knowledge of accident patterns and provide directions for local road safety action.

A large number of investigations also aim at examining particular features of the road environment and their effects on the safety of vulnerable road users. However, they consist more in evaluation studies and provide only very specific information on accidents factors. So only a few of them have been considered in this chapter.

#### *Examples of country-wide accident studies*

In *Denmark*, a survey of fatal cyclist accidents was carried out, based on the detailed analysis of 88 randomly selected police reports for the period 1986-90:

- accidents involving children, young and elderly cyclists were found to occur mostly at intersections, without turning or with a left turn in front of a vehicle;
- most of the accidents may be explained by the cyclist's lack of or inadequate perception of approaching traffic, resulting in failure to give way;
- in some accidents, the car driver had no opportunity for avoidance, while in others, the driver was too uncritical in his attention to the cyclist's behaviour;
- a number of accidents would not have occurred if the driver had chosen a reasonably low speed;
- accidents to cyclists in the age-range of 25-64 involved overtaking, or situations where the cyclist was hit from behind;
- cyclists were without influence on the accident, while car drivers were often to blame for poor lateral distance, inattention, high speed or drunk-driving;
- respect of right of way, both by drivers and cyclists, and the observance of speed limits appeared as key issues for countermeasures, as well as the necessity for the driver to pay special attention to children, young and elderly cyclists (Bernhoft et al., 1993).

In the *Netherlands*, Goldenberg (1992) studied 1 173 accidents involving cyclists aged 50 and above, using both the original police registration forms and accident reports obtained from the Dutch Association of Motor Vehicle Insurers. A random sample of 479 accident cases was selected for further analysis:

- Cars were shown to be the main collision partners (63 per cent of cases).
- Car-to-bicycle accidents at junctions occurred mostly at signalised junctions, when the cyclist approached from a side-road and either crossed straight ahead, or turned left, while the car used the main road.
- An increase in traffic infringements at intersections was observed amongst cyclists aged 75 and over. It was felt that elderly cyclist experienced difficulties with crossings and left turns due to the complexity of information-taking and decision-making processes preparing to such manoeuvres and to time pressure.
- The relatively high speed of vehicle traffic with the green light on the main road contributed to the time problem.
- In 18 per cent of accidents, elderly cyclists were hit by another cycle or a moped, and these collisions often led to serious injuries.
- Separation between mopeds and bicycles seemed to be advisable, in urban areas at least.
- Finally, there were indications that 10 per cent of the accidents involved inadequate control over the bicycle (cyclist startled by the other party and falling, not keeping a straight course, driving erratically), and that female cyclists were particularly prone to such behaviour.

A study was carried out in *Finland* on 6 245 accidents involving pedestrians, cyclists, and moped riders (8.6 per cent of all accidents on public roads) from 1986 to 1990:

- out of these, 5 074 accidents were severe or fatal and half of them occurred in built-up areas.
- most severe and fatal cyclist accidents occurred at junctions and were fairly evenly distributed between the different accident types.
- accidents involving a turning vehicle showed the highest severity level.
- 42 per cent of severe and fatal pedestrian accidents were located outside a pedestrian crossing and these accidents were also those with the highest severity level.
- pedestrian accidents showed the highest fatality rate in urban areas (Salonen, 1991).

Another study was carried out in *Finland* on the safety of public roads in built-up areas, based on the material gathered in 1990-91 in a survey of built-up areas conducted by the Road Service, and on the traffic accidents on public roads, documented by the police from 1986 to 1990. The study covered 17 312 accidents (24 per cent of all accidents on public roads), a third of which were severe or fatal accidents:

- the victims included 407 fatalities and 7 156 injuries;
- about 42 per cent of serious and fatal accidents in built-up areas involved pedestrians, cyclists and moped riders; and
- 52 per cent of fatal accidents involved these same road user groups;
- most cyclist accidents occurred at junctions, while pedestrian accidents occurred more often on road links outside pedestrian crossings (Salonen, 1991).

In Japan, 1 161 accidents involving cyclist fatalities in 1990 were analysed with regard to age, trip purpose, and traffic violations:

- The group of cyclists over 65 years of age accounted for 47 per cent of all cyclist fatalities.
- Children aged 7-12, young cyclists aged 13-15, and elderly cyclists (over 65) were found to be the most frequently involved in fatal accidents.
- Accidents did not occur at the same time of the day for different age groups, which implies that differences in trip purposes according to age were significant; children and the young tended to suffer fatal accidents when coming home from school and riding around, while the elderly were likely to get hit when shopping or visiting.
- Insufficient information taking was particularly frequent with children, young and elderly cyclists; in the younger groups (under 15), reckless riding, blocking the right of way, or failing to halt at railway crossings were also frequent.

- Crossing against red was comparatively common in the 25-64 age group. Cyclist fatalities occurred most frequently at non-signalised junctions, followed by road links and, finally, by signalised intersections.
- 28 per cent of fatalities were recorded in crossing collisions at non-signalised junctions. It was concluded that this type of accident can be considered as a representative category of bicycle accidents (Mitsui, Murata, 1992).

A study of pedestrian accidents was carried out in *France* on the basis of three types of accident files, all relying on police data: (i) the national accident statistics, (ii) a representative sample of police reports of one accident out of fifty over the whole country, and (iii) a very detailed data file on all fatal accidents for the year 1990 (information available on 1 289 fatalities):

- Pedestrian accidents were found to occur mostly in urban areas but to be much more severe on rural roads.
- A non-negligible proportion of rural accidents occurred on motorways, where walking is usually the consequence of an incident.
- In three quarters of fatal accidents, the pedestrian was hit by a car.
- Most fatal accidents occurred on road links, or at junctions against a vehicle on a straight trajectory.
- The risk to be involved in a pedestrian accident was found lower for a woman than for a man; young children were over-involved in accidents (with reference to their demographic share), but to a different extent for boys and girls; elderly people were particularly at risk to be killed.
- When examining the social background of the victims, it was found that both retired people and people under 60 without a profession (including the unemployed) accounted for a larger proportion of fatalities than of injured.
- A high proportion of the accidents happened during a shopping or a leisure trip.
- Fatal pedestrian accidents occurring while crossing only accounted for 53 per cent of cases; other situations included walking along the road, playing, running, or working.
- Only 15 per cent of fatal accidents were located at a marked pedestrian crossing, the vast majority occurring at more than 50 m from such a crossing.
- Elderly people were most frequently hit by vehicles when halfway across the street or further, while children were mostly hit when starting to cross.
- 28 per cent of fatal accidents involved a change of transport mode, from car (or bus) occupant to pedestrian or the opposite.
- The level of information on the blood alcohol content of pedestrians was relatively low (46 per cent) and was lower for women than for men. 35 per cent of adult pedestrians (over the age of 16) killed in an accident and tested for alcohol were found to have a BAC over the

legal limit. This rate was higher than that of drivers involved in a fatal accident (Fontaine et al., 1995).

A *Finnish* study focused on changes in the number of road accident injuries resulting in hospitalisation over the period 1970-1990. The effects of road safety measures on these injuries were also investigated. Hospital discharge records for the entire country in the years 1970, 1975, 1980, 1985 and 1990 were used as the material for the study:

- It was found that the total number of injuries resulting in hospitalisation declined during the 70s, but increased again in the 80s.
- Comparing the records for 1970 and 1990, injuries to cyclists increased by 26 per cent, while those to pedestrians decreased by 28 per cent.
- Over the same period, child injuries decreased by 51 per cent, but injuries to young moped riders or motorcyclists increased by 88 per cent; injuries to elderly people (over 64), both as pedestrians and cyclists, increased by 82 per cent.
- From 1970 to 1990, head injuries caused by road accidents decreased by 57 per cent; head injuries sustained by motorcyclists and moped riders decreased by 74 per cent, but head injuries sustained by elderly cyclists increased by 67 per cent.
- The number of serious cerebral injuries sustained by motorcyclists and moped riders decreased by 18 per cent, but increased in the cyclist group by 187 per cent.
- The reduction in head injuries was influenced mostly by the use of safety belts and crash helmets, speed restrictions and the improved traffic environment.
- The increased number of injuries among the elderly was probably due to the growth of their demographic share and to increased mobility.
- The minimum age limit imposed on moped riding was not able to prevent injuries among young moped riders.
- The study concluded that special attention should be given to the prevention of road accidents involving elderly road users, and that serious head injuries experienced by cyclists could be effectively reduced by bringing cycle helmets into general use (Liikenneturva, 1995).

In the *Netherlands*, according to the records of the principal diagnosis for hospital admission following a traffic accident:

- more than 2 300 cyclists suffer each year head or brain injury, including about 1 000 young cyclists (0-19 years of age);
- for cycle victims aged 0-19, the proportion with head or brain injury represents about 50 per cent of all hospitalised road accident victims;

- head or brain injuries sustained by cyclists are considerably more often the result of unilateral accidents, rather than the result of a collision with a motor vehicle (Goldenbeld & Wittink, 1993).

*Examples of accident studies on particular geographical areas*

A large number of studies have been examined in this section, and they were not easy to classify by theme or method used. They are therefore presented here country by country.

VicRoads conducted a bicycle-accident study in Victoria, *Australia*. One issue treated amongst others was conspicuity, and traffic movements were grouped according to their implications for this issue.

- The first grouping consisted of movements where the car and the bicycle approached from adjacent directions, and accounted for 24 per cent of accidents overall, 28 per cent of accidents at dawn or dusk, and 22 per cent at night. Frontal conspicuity of bicycles when approaching from the side would thus 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 per cent of accidents overall, 14 per cent of accidents at dawn or dusk, and 9 per cent of night accidents.
- The third grouping consisted of accidents where rear conspicuity was the issue, and included 9 per cent of accidents overall, 10 per cent of dawn or dusk accidents, and 17 per cent of the night ones.
- It should be noted that only 13 per cent of rear-end accidents occurred at night, so that accidents in which rear conspicuity was an issue were over-represented at night (VicRoads, 1990, cited in Cairney, 1992).

Cairney further commented that, taking into account accident numbers at night, dawn or dusk, or in the daytime, dawn and dusk conspicuity was a much greater issue than night conspicuity. However, this may be a direct effect of exposure patterns.

A recent study was carried out in *Denmark* on 1 021 cyclists injured after a collision:

- the young cyclists of 10-19 were found to be most at risk;
- three quarters of the collisions against cars occurred at road junctions;
- 42 per cent of collisions were located on the normal carriageway; and
- 44 per cent on cycle tracks;
- over a quarter of the cyclists injured were still sustaining physical inconvenience two years after the collision (Larsen, 1994).

Various *Danish* statistical accident analyses supplied with international experience have shown that:

- Bicycle paths as well as bicycle lanes in cities offer an overall improvement in traffic safety on road links.
- However, bicycle lanes appear to result in an increasing number of accidents involving parked cars. When the bicycle lane is too narrow (1 to 1.2 m), the accident frequency of mopeds tends to slightly increase.
- The traditionally constructed bicycle paths at signalised intersections (leading up to the junction) appear to cause major safety problems. There are indications that safety can be improved by replacing the bicycle path by a narrower bicycle lane about 20-30 m before the intersection.
- At 4-arm signalised intersections with constructed cycle paths leading up to the intersection, it is suggested that the cars' stop line be moved back 5 m from the cyclists stop line in all car lanes (Danish Road Directorate, 1994).

In a study on bicycle injuries carried out in *Finland* and based on health care records of hospitals in the town of Mikkeli in 1980 and of four hospitals in Helsinki in 1985-86, accident consequences and the incidence of some factors were assessed:

- the average duration of hospital stay was eight days for adults and six days for children;
- the mean duration of work disability was 82 days for all hospitalised patients, and 127 days among hospitalised patients injured in collisions with motor-vehicles;
- 32 per cent of in-patients and 5 per cent of out-patients reported persistent disability;
- persistent disability was recorded for 11 per cent of children, 47 per cent of adults and 67 per cent of elderly in-patients;
- the injury risk of an inebriated cyclist was found to be at least tenfold at BAC above 1.0 g/l;
- the role of health disorders might be more important in cycling injuries than previously thought;
- the estimates of the potential of the cycle helmet to protect against fatal injuries were equal in all age groups (58-68 per cent) (Olkkonen, 1993).

Another study carried out in *Finland* concerned the effect of the road and traffic environment on accident risks based on a database of the Finnish Road and Waterways Administration (RWA). The database consisted in a series of road links where provisions for unprotected road users were found by RWA to be in an unsatisfactory state:

- about one half of the 4 206 locations in the base were in urban areas and about one third in the outskirts of urban communities;
- a separate pavement or pedestrian and bicycle way existed only at 360 locations;

- the effects on safety of road and traffic characteristics were studied with the help of linear models explaining the numbers of accidents; the exposure measure was a function of the mileage travelled by motor vehicles and by unprotected road users;
- explanatory variables included location (urban, outskirts of urban areas, rural), size of the urban community, road class, street class (business, residential), speed limit, and average daily traffic of motor vehicles;
- on-site inspections revealed that the safety of unprotected road users could be improved in many locations by narrowing the road or constructing a refuge on the pedestrian crossing;
- advanced town planning solutions, and network planning taking into account unprotected road users, were typical of the safe locations;
- on local roads with low traffic volumes, there was often no need for the separation of unprotected road users, but this usually required speed reducing constructions (Kallberg).

A hospital-based study was carried out in Barcelona, *Spain*, for the purpose of assessing the one-year incidence of traffic injuries among residents aged over 13. Death certificates were examined and interviews performed:

- the incidence of injuries per 100 000 population was estimated to be 1.037;
- there were 108 admissions to hospitals and 15 deaths per 1 000 incident cases;
- admission/case ratios increased with age and were highest for pedestrians, who also accounted for the highest fatality/case ratio and highest severity of injuries;
- motorcycle accidents, however, produced half the injuries (Placència et al., 1995).

A study on bicycle accidents was carried out in the *United Kingdom*, using hospital data to provide detailed information on the types and severity of injuries. It was found that:

- head injuries are the major cause of death for three quarters of cyclist fatalities;
- over half of casualties received moderately severe facial or skull injuries which required an overnight stay in hospital;
- injuries to chest, abdomen and spine were relatively infrequent; chest injuries, when they occurred, were often severe, but abdominal and spinal injuries were minor;
- two-fifths of cyclist casualties sustained injuries to the lower limbs, including fractures of femurs, dislocated hips, knees or ankles;
- over half of casualties suffered injuries to the upper limbs, although these were rarely serious;
- three-quarters of cyclist casualties were detained for long stays in hospital, on average 21 days.

Another hospital based study of 776 cyclist casualties was conducted in the *United Kingdom*. 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 per cent of cases where the cyclist was involved in a collision with a motor vehicle or another 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) (Mills, 1989).

In the *United Kingdom*, accident records of 2 470 persons injured in Birmingham over a three-year period (1985-88) were analysed. In addition, very detailed records of HM Coroner in Birmingham were used to study 50 accidents involving 51 young pedestrians killed during a five-year period 1983-1988. This data set was enhanced by means of postal questionnaires, and interviews with 251 seriously injured pedestrians and 192 drivers. Findings from the various data sets were compared and showed relatively few contradictions. The detailed accident study showed that the distance of the accident site to the casualty's home increased with age, and that more than half of the pedestrians had crossed the road at the site three or more times per week prior to the accident. This was confirmed by the questionnaire survey:

- Two-thirds of all pedestrian casualties were going to or from home, a third were on a trip to or from school, and over a quarter going to or from shops.
- The questionnaire survey showed pedestrians to be predominantly from low socio-economic groups (26 per cent of heads of household were unemployed).
- Cars accounted for 92 per cent of striking vehicles. Like the pedestrians, the drivers knew the site and had travelled through it three to five times a week prior to the accident.
- Almost a third of pedestrians said that something made it difficult for them to see the striking vehicle, a parked car being the most common source of obstruction;
- Similarly, 42 per cent of drivers said something made it difficult to see the pedestrians, a parked car in more than half of the cases.
- The role of parked cars in child pedestrian accidents was confirmed by statistics.
- Police blamed the pedestrian for the accident in 93 per cent of occasions in the city of Birmingham.
- Detailed records showed that pedestrian risk-taking was indeed a factor in some accidents; also a third of the pedestrians aged 15-19 had consumed alcohol in excess of the limit prescribed for drivers.
- In half the accidents, the pedestrian was the sole contributor to the accident.

- Seven of the 50 drivers involved were “rat-running”, nine were travelling at more than 10 mph over the speed limit, two had consumed alcohol in excess, and 21 altogether were prosecuted.

### *V.1.3. Clinical studies of accident factors*

#### *Principle*

In order to provide sound directions for safety action, it is necessary to gain some knowledge of accident generating processes. To this purpose, detailed accident investigations may be undertaken, including specific data collection at a number of accident spots, followed by the reconstruction of each accident process and the identification of the elements of the road and traffic system (or of interactions between some of them), that have played an active part in the process and can be considered as accident factors.

On-site accident investigations usually take place immediately, or at least as soon as possible, after an accident has occurred, which means that a procedure has been set to call the team of investigators and gather them rapidly at the scene. For research purposes, the team is generally multidisciplinary, including well-trained scientists, such as specialists of the road infrastructure, of vehicle dynamics and design, and psychologists. Investigations include on-the-spot observations and measurements, performed on the road and its environment and the vehicles involved and addressing infrastructure characteristics and condition, position of vehicles and marks on the ground related to the collision, damage inflicted to the vehicles or the environment, etc. Simultaneously, interviews of the road users involved and of the witnesses are carried out. Secondary interviews may, in some cases, be performed at a later stage, after victims have had time to somewhat recover and to think over what has happened. Reconstruction of the accident process uses all the data collected, and often aids such as mathematical models, photographic libraries of crashed vehicles, etc. (OECD, 1988).

Detailed accident investigations are most often based on small samples of accidents: the smaller the sample, the more time can be devoted to each accident reconstruction, but representativeness of course decreases. Such studies usually need to be complemented by other approaches in order to get generally applicable results. But it is interesting to note that various studies of this kind, carried out in different countries, converge on similar findings.

As the amount of effort implied by in-depth accident investigations restricts their applications, some researchers have endeavoured to identify accident factors through other approaches, involving in general a combination of accident data analysis, field observations, and road user surveys. The accident data used are then the most detailed and reliable ones available, such as police or court reports.

#### *Examples of in-depth and on-site accident investigations*

In Denmark, an in-depth analysis of 22 accidents involving children as pedestrians or cyclists was carried out; the situations were assumed to be typical for children. The overall conclusions demonstrated:

- the children's inadequate knowledge of correct behaviour in traffic; and that
- in most of the accidents, the counterparts behaved adequately;
- in only a few cases, the driver was impaired or drove too fast;
- in most cases, the parents of the child involved agreed to his presence in traffic, but sometimes the children did not have parents' permission;
- recommendations have been made towards more education of children simultaneously with information of their parents;
- a higher age limit for walking and cycling alone has also been proposed (Engel, 1981).

In *Finland*, all fatal accidents involving motor vehicle occupants and some other specified accidents are investigated in detail by 13 multidisciplinary teams all over the country. Investigations are carried out on the spot and focus on the pre-crash phase, following a standardised method. After the data collection, the team analyses the information, reconstructs the accident and draws up the final investigation report. 300-400 accidents are analysed annually. It seems that pedestrian accidents have not at first been included in the data collection, as such types of collisions seldom kill a motor-vehicle occupant. However, the data collection has been extended to all accidents involving vulnerable road users. The full results are not yet available for these (Hantula, 1994).

Meanwhile, the same methodological framework was applied to a representative sample of 234 bicycle accidents that the Traffic Investigation Teams studied in four Finnish cities in 1990-94:

- Most accidents occurred during good driving conditions.
- 84 per cent of collisions between cyclists and motor vehicles occurred on roads whose functional class was at least collector road, and
- 75 per cent of accidents were on a main cycling through route.
- It appeared that bicycle accidents could be most effectively prevented by concentrating safety measures on the upper level of the bicycle network.
- Most collisions between a cyclist and a motor vehicle (63 per cent) occurred at a cycle crossing:
  - There were indications that this kind of facility is not well understood by drivers, causing inadequate scanning behaviour. In particular, among collisions with cars at cross-roads, the most frequent accident type was a driver turning right and a bicycle coming from the right along a cycle track.
  - Only 11 per cent of the drivers hitting a cyclist had noticed him beforehand, while
  - 68 per cent of cyclists had noticed the other vehicle (and a vast majority of them believed the driver would give way as requested by law).

- It also appeared that crossing accidents more than others involved cyclists familiar with the site, which would tend to show that daily cycling on the same site with the right of way may easily induce careless behaviour.
- Drivers involved in collisions against cyclists had omitted to give way in 66 per cent of the cases.
- Cyclists under 15 and over 54 more often omitted to give right of way than those of middle-age. Traffic environment seemed unclear as to who had the right of way (Räsänen, 1995, Räsänen & Summala, 1996).

In *France*, since 1981, a multidisciplinary team of INRETS has been carrying out an in-depth accident investigation, on a limited geographical area including all types of roads (25 km around the town of Salon-de-Provence). All types of serious accidents are analysed. As in Finland, investigations are carried out on-the-spot and focus on the pre-crash phase, following a standardised method. After the data collection, the team analyses the information, proceeds to additional data gathering, reconstructs the accident and draws up the final investigation report. Although pedestrian and two-wheeler accidents are normally included in the in-depth accident study, most research efforts have concentrated on accidents involving motor-vehicles. However, analysis of a few cases involving elderly pedestrians or drivers (aged over 70) indicated:

- problems with information taking, estimating speed, hesitating, performing an evasive action;
- moreover, environmental features always contributed to the accidents, either because they made information taking difficult, or because they did not clearly reflect the right of way;
- high speed of opposing vehicles also played a part, at both levels of information taking and of crash avoidance;
- such indications need to be confirmed by wider-scale studies (OECD, 1985, Ferrandez, Girard, 1995).

An in-depth study of 30 accidents involving pedestrians in the age groups 7-14, 18-27 and over 60 was carried out in *Spain*; in addition, interviews and site visits were performed:

- Field-dependency (i.e., children following persons they knew) appeared the major reason for accidents to children.
- Distorted perception of speeds or time-distance was an important factor in the older age group.
- In the 18-27 group, drugs and alcohol were the main factors generating reckless behaviour. Social problems, severe personality distortion and disabilities seemed to be relevant variables (Pacheco Calvo, 1996).

In *Sweden*, in 1993-94, the Swedish Road Administration carried out an in-depth accident investigation, in which each of the seven areas of the country concentrated on a specific type of accident.

Accidents involving vulnerable road users (mopeds, cyclists and pedestrians) were investigated in Skåne, by a multidisciplinary team. The sample analysed included 16 accidents:

- most of them occurred with traffic volumes lower than normal;
- three-quarters of the accidents were collisions between a bicycle and another vehicle and a quarter involved a pedestrian;
- two-thirds of the accidents occurred at a pedestrian or a bicycle crossing;
- in two-thirds of the bicycle accidents, the cyclist was cycling in the wrong direction on a two-way cyclepath or appeared somewhere where he was not supposed to be;
- in three-quarters of the cases, factors related to the road and traffic environment were judged to have contributed to the accident (Ahlcrona et al., 1994).

A study of urban injury accidents (occurring outside the central business district) was carried out in Leeds, *United Kingdom*. A sample of 1 254 injury accidents reported to the police in 1988 was selected; 1 863 drivers and riders, 128 cyclists and 463 pedestrians were involved. The study included collecting basic accident and background information, interviewing participants, visiting the accident sites, assessing contributory factors, linking all the data sources, and interpreting the results in view of policy implications. Of the immediate failures that precipitated the accident:

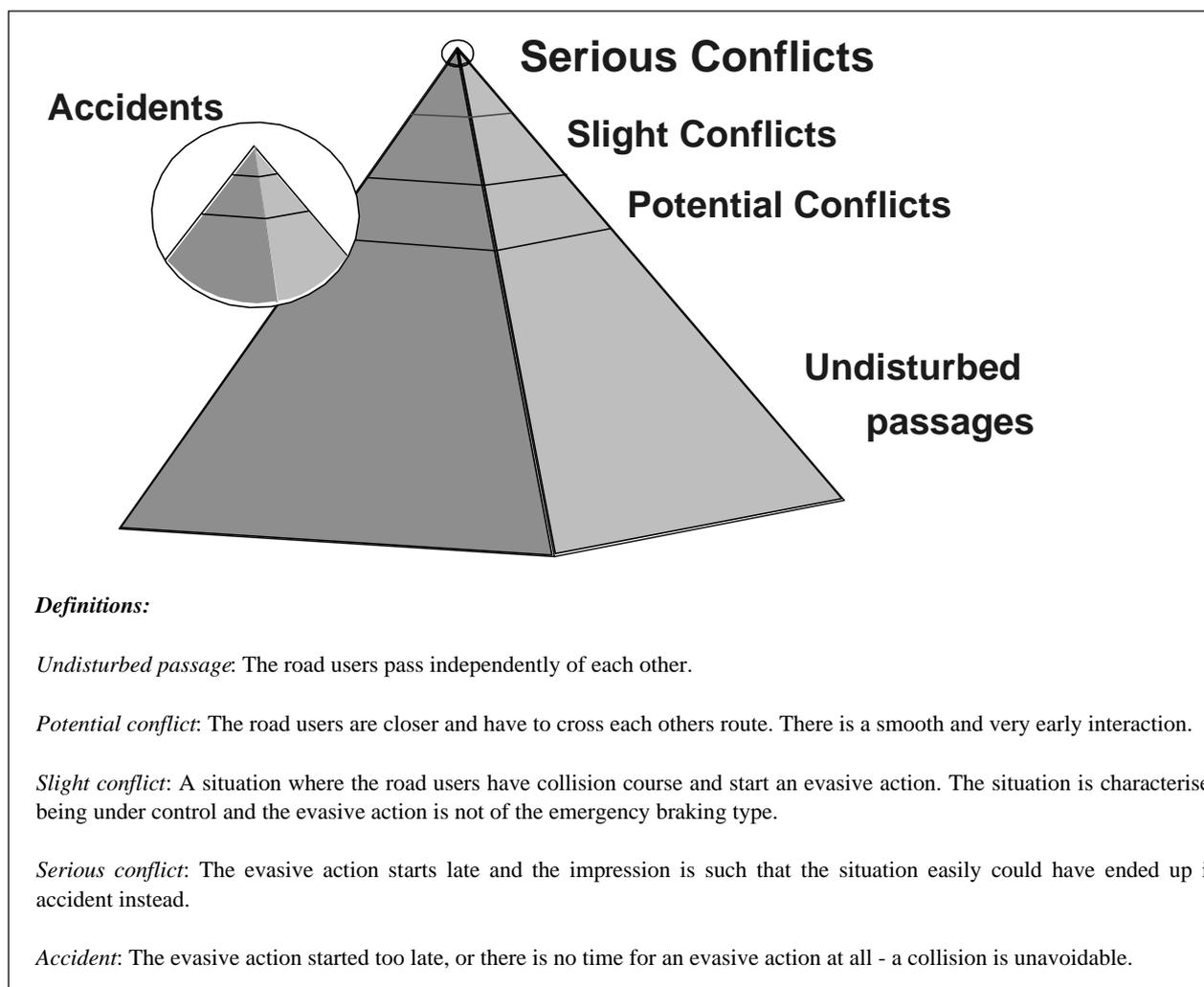
- “failures to yield” accounted for 16 per cent of the factors coded for adult drivers and riders, and
- “failures to anticipate” for 10 per cent;
- failure to yield to traffic accounted for 66 per cent of the factors coded for adult pedestrians and for 78 per cent of those coded for child pedestrians;
- only 23 per cent of adult pedestrians and 11 per cent of child pedestrians were found to be innocent victims of others’ mistakes;
- perceptual errors were the most common explanation of immediate failures, especially for child pedestrians;
- judgement errors were much less frequent and were more often attributed to female drivers and riders than to male ones;
- for drivers and riders, environmental factors accounted for 46 per cent of factors explaining failure of behaviour;
- alcohol was considered to be a probable contributory factor for only 4 per cent of adults, but this figure was substantially higher for pedestrians (11 per cent) than for drivers and riders (3 per cent);
- the figure for pedestrians may be underestimated as the availability of the information was much less than for drivers (Carsten et al., 1989).

#### V.1.4. Traffic Conflict Techniques

##### Principle

Conflicts are far more frequent events than injury accidents. Traffic Conflict Techniques, or TCTs, are based on the hypothesis that interaction between road users can be described as a continuum of events. If these events can be looked upon as different levels in a pyramid, as shown in Figure V.1, *accidents* are found at the very top and the “*normal*” driving situations at the bottom (Hydén, 1987). Between “normal” behaviour and accidents, serious conflicts describe the fundamental traffic safety problem, namely the breaking down of the interaction man-man and man-environment. This makes TCTs particularly suitable for basic traffic safety studies: while analyses based on accident data can only describe what happened at and after the critical moment, conflict techniques are tools that enable us to study the whole process ending up in an (near) accident.

**Figure V.1 The pyramid -- the interaction between road users as a continuum of events**  
(Hydén, 1987)



The first (known) conflict technique was presented in 1968 by Perkins and Harris at General Motors Laboratory in the USA (Perkins & Harris, 1968). It was designed with the purpose of studying junctions in order to see whether the GM cars performed differently in comparison with other car makes. This first definition of a conflict was mainly based on braking light indicators. Since then, a number of Traffic Conflict Techniques have been developed in a dozen different countries. At the first International Traffic Conflict Workshop, held in Oslo in 1977, a group of researchers from three continents decided upon a general definition of a traffic conflict:

*“a conflict is an observable situation in which two or more road users approach each other in space and time to such an extent that a collision is imminent if their movements remain unchanged”.*

The hypothesis about a continuum of events results in the conclusion that there exists a relationship between the number of serious conflicts and accidents, varying with regard to type of conflict and definition of a serious conflict. Based on the above definition, TCTs have been built as a set of procedures to identify, record, and analyse conflicts in a standardised way.

The use of a TCT usually requires human observers who have been trained to recognise, assess, and record traffic conflicts, according to a special training scheme. The training procedure often includes both indoor and outdoor activities. The most common way to carry out a conflict study on a given location is to post a trained conflict observer team on-site, for periods of two to three hours during two to five days, depending on the local traffic conditions and weather conditions, and on the general workload of the team. Observers have copies of a partly pre-printed data-sheet which they fill in for every conflict occurring at the site while they are observing. Some TCTs have been partly automated and field-observers are then replaced by a battery of film- or video-camera recording traffic; images are subsequently analysed, either manually or by computer (or a combination of both).

As TCTs make it possible to clarify on site the events that led to disruptions of the interaction process, they prove very effective to use for safety evaluation and for diagnostic purposes. As a diagnostic tool, conflict analysis shows what kinds of conflict types (e.g. categories of road users involved, and movements of road users involved) are most common, what causes the disruptions, and the severity of the incidents. In before-and-after-studies of the effects of safety measures, the result in terms of increased/decreased safety can be obtained within a relatively short period of time. Accidents are statistically rare events -- conflicts are 5 000 to 10 000 times more frequent. This means that conflict data provide a more valid basis for assessing safety variations. Even small changes in risk will be detected by conflict analysis. In addition, as the amount of data collected for conflict analyses are much larger than in accident studies, it is possible to disaggregate them into sub-categories: different types of road users, manoeuvres, places and so on, can be examined separately.

Reliability and validity are two issues strongly connected to the usefulness of TCT. External reliability is ensured when conflict observers are all able to discriminate serious conflicts from other events in the same way, and, of course, in accordance with the conflict criteria. Validity in this context means that conflicts are, to a reasonable extent, successful in describing the traffic phenomenon to be measured.

There has been some confusion as to the precise definition of validity. Some consider that validity of a TCT depends on the extent to which serious conflicts can be used in order to predict the number of accidents (product validity). Hauer and Gårder argue that trying to validate conflicts in the sense of accuracy in forecasting accidents is just as random as rolling a die. They overcome the problem by defining safety on some part of the transport system (for example, a road junction) as the expected

number of accidents per unit of time. On this basis, “the proper question to be asked is: how good is the TCT in estimating the expected number of accidents”. Comparisons are thus made between the variance of the estimates obtained through traffic conflict data and through other indicators, for example, accident data or exposure. Hauer and Gårder conclude that: “A technique (method, device) for the estimation of safety is ‘valid’ if it produces unbiased estimates, the variance of which is deemed to be satisfactory.” (Hauer & Gårder, 1986).

#### *Different existing Traffic Conflict Techniques*

The various TCTs developed in different countries vary from being purely “subjective” (when conflicts are detected by human observers) to being mostly “objective” (when conflicts are detected from recordings with the help of a computer system). Even though all techniques basically agree upon the common definition of a conflict (Oslo 1977), the operational specification of each of them focuses on different aspects: type of manoeuvre, location in time and space, speed, change in speed and direction. The category of road user is often included as well to indicate a difference in accident potential; in that case there is a distinction between serious and slight conflicts.

The more *subjective* methods such as the conflict techniques, developed in Austria, France, Germany, Great Britain, and the USA, have no quantitative measure to rely on. Instead, the observer acts as an expert who watches and judges whether situations developing under his eyes are conflictual or not. The observer takes his overall impression into account. These techniques use terms like “*unexpected behaviour*” and “*sudden evasive action*”. The more *objective* or more *quantitative* conflict techniques, developed in Canada, Finland, the Netherlands, and Sweden, use either the concept of Time-To-Collision (TTC) or that of Post-Encroachment-Time (PET), or both. TTC is defined as the time required at the onset of the conflict for two road users to collide if no evasive action is taken. The PET value is the time measured from the moment the first road user leaves the potential collision point to the moment the other road user enters this conflicting point.

There was a need to compare performances of the different TCTs in describing safety problems, as well as of recording a large amount of data to check validity of the techniques. Within the framework of ICTCT, the International Co-operation on Theories and Concepts in Traffic safety, created in Oslo in 1977, an international calibration study was carried out in Malmö, Sweden, in 1983. Its primary aim was to produce a detailed comparison of the agreement and disagreement between the various observation techniques currently in use. The comparisons were based on data obtained from simultaneous observations performed on the same sites by teams representing each a different TCT. During the study, traffic on the experimental sites was video-recorded. Estimates by each team could thus be compared with each other and with objective data. Teams from Austria, Canada (with the PET technique then in use there), Finland, France, Germany, Great Britain, the Netherlands, Sweden, and the USA, took part in the calibration (Asmussen, 1984). Although the different TCTs are not identical, they were found to give compatible results at recording conflicts. All techniques agreed upon the use of a severity scale, in relation to a probability of accident. Furthermore, once a conflict was detected, there seemed to be a high agreement in the severity ratings provided by each TCT. A general conclusion was that all the teams actually used, directly or indirectly, TTC, minimum distance between the road users involved, and conflict type as the most important cues (Grayson, 1984).

A complementary calibration study was carried out in Trautenfels, Austria, in 1985. This study also served diagnostic purposes. Two intersections were studied simultaneously by TCT teams. A diagnosis of the traffic safety situation was made through different TCTs. Appropriate measures were introduced, and the situation after the implementation was examined. Detailed comparisons comforted the

results of the Malmö study, and showed that the PET measure was of limited use on its own, but could be a valuable complement to the TTC value for severity assessments. The diagnoses drawn from the TCTs largely agreed with each other, and quick evaluation of the measures implemented proved possible (van der Horst & Kraay, 1985, Risser & Tamme, 1987).

International co-operation, and the encouraging results obtained from calibration and validation studies, contributed to the TCTs being recognised as an acceptable and useful tool to describe safety problems.

#### *Example of the Swedish Traffic Conflicts Technique*

The Swedish TCT, one of the first to have become operational, can be used as an example to illustrate what TCTs are. In the Swedish TCT, the chosen threshold between severe and slight conflicts is based on time and speed: Time to Accident (TA-value) is the time that remains to a potential accident -- on the assumption that the road users involved would continue with unchanged speed and direction -- from the moment that one of the road users starts an evasive action (TTC is assigned continuous values and TA is assigned one distinct value in that series). When collecting conflict data, a human observer on-site detects situations in which two road users find themselves on a collision course, estimates the distance to the predicted collision point, and the speed at the moment when an evasive action is started. From these data, the TA-value can be calculated. The observer also makes a subjective estimate of the probability that the conflict could have ended up as an injury accident.

The ability of traffic conflicts to describe safety problems was tested by comparing the processes preceding respectively accidents and conflicts, from the moment that one road user starts an evasive action. Analyses showed strong similarities between accidents and conflicts on the basis of TA-values and conflicting speed (or approach speed of the road user for whom the TA-value is estimated). Accidents and conflicts were equally distributed, accidents tending towards lower TA-values and higher speeds. The severity scale was found consistent from conflicts to accidents, which reinforced the assumption that accidents and conflicts are events in a time-based continuum. The study also showed that the distribution of different types of evasive actions was similar for accidents and conflicts (Hydèn, 1987). Another validation study, based on the statistical approach advocated by Hauer and Gårder, showed that at lower accident frequencies, it is preferable to use conflict data instead of accident data when estimating expected number of accidents (Svensson, 1992).

The reliability of the Swedish TCT was tested at the aforementioned Malmö international calibration study (Grayson, 1984). On average, the Swedish conflict observers' estimate of the TA-values showed a 0.05 seconds difference from the objective measurement. As for conflicting speed, the estimations were on average only 3 km/h lower than the objective figures. Analysis also showed that observers managed to detect 75 to 80 per cent of serious conflicts. The conclusion was that human observers are able to detect serious conflicts and make satisfactory estimates of speed and TA-value. The ability of the observer to detect and assess the severity of conflicts is not a problem when adequate training has been provided, but the need to post on-site a number of observers over a longer period of time is very resource demanding. In the longer term, this problem will be eliminated when a more automatic conflict technique based on image processing is available.

The Department of Traffic Planning and Engineering of the Technical University in Lund, Sweden, has frequently used the Swedish TCT for safety evaluation, particularly for the evaluation of safety measures addressing the physical environment. The TCT has, for example, been used with success to assess the effects of mini-roundabouts, advanced stop-line for cyclists at signalised intersections,

location of pedestrian and cycle crossings at junctions, two-way cycle tracks at signalised intersections, different signalising strategies, automatic detection of pedestrians at signalised intersections, four-way stop, humps, etc.

*Examples of application of Traffic Conflict Techniques for diagnostic purposes*

TCTs have been widely used, particularly for assessment of safety of vulnerable road users, either within research studies or in view of plans to improve the road environment in urban areas. A large number of studies were performed on the intermediate (or “process”) evaluation of new infrastructure facilities with a view to pedestrian and cyclist safety (roundabouts, speed-humps, junction design, etc.), particularly in Sweden and Great Britain; to safety diagnoses on rural roads, particularly in Finland and in Sweden; or to urban safety diagnoses for preparing traffic calming schemes, as in France and the Netherlands. Use of TCTs by local authorities and government agencies has been particularly encouraged in Sweden, Finland, Germany, the USA, the United Kingdom and France, where guidelines have been published. TCTs have been currently applied by the National Road Administration in Sweden and Finland, the Road Police in Germany, some State governments in the USA, etc.

Locally based diagnostic studies using traffic conflict analysis are obviously to be found at a decentralised level and cannot be easily inventoried. Those carried out on a purely operational basis, for example to design local safety measures, are even rarely documented. Examples available are therefore mostly from research, and most reports focus on the methodological aspects rather than on the findings in terms of probable accident causation processes and factors. The examples below do not therefore represent the whole scope of the diagnostic work carried out with TCTs, but indicate some of its directions.

- A survey of 300 pre-schools was carried out in Sweden, based on a combination of a five-month accident data analysis, conflict recording and analysis, and questionnaires to the schools’ personnel and to the parents. The school environment was considered dangerous in 15 per cent of the pre-schools, and the route to school in 25 per cent of them. Factors characterising a dangerous traffic environment included lack or poor quality of fences, lack of warning signs, obstructed vision, and too high a speed on roads surrounding the pre-school. Lack of proper pedestrian and bicycle paths were found a hindrance for the large groups of children going to or coming from school at the same time (Arnberg, 1979).
- The Swedish TCT was used for diagnostic purposes at three locations in Sweden. For each one of them, the problems experienced by vulnerable road users were compiled, including a description of probable accident causation processes. Proposals were made for relevant countermeasures, and estimates of probable safety effects were provided. The general problems for vulnerable road users on arterial roads were found to be the following:
  - Drivers travelling at too high speeds, given the traffic circumstances. This was the main conflict-causing factor where vulnerable road users were involved. Car drivers simply did not slow down in spite of the obvious risk of a conflict or an accident.
  - Overtaking just before a pedestrian crossing. Car drivers often did not comprehend the fact that they were creating a very dangerous situation.

- Short gap acceptance when crossing. This was normally caused by pedestrians, either mis-judging speed or distance, or consciously risk-taking, hoping to force the driver to stop in time.
- Both pedestrians and car drivers showing lack of attention. This was normally caused by a complex traffic situation where attention was focused on other road users.

Different countermeasures were subsequently implemented at all three sites. An evaluation of the effects was carried out, using before-and-after studies (Hydèn, 1981).

- A study was carried out in Helsinki, Finland, to assess the effects on pedestrian safety of different existing pedestrian crossing facilities. Crossings were classified according to the existence of refuges (generally with tram stops) and of signal control, and to the location -- at junctions or on links. Traffic conflicts were recorded at 13 crossings, in addition to accident data for a two-year period and traffic flow and speed data:
  - the highest accident and conflict risks were found at crossings without a refuge;
  - both accidents and conflicts were mainly caused by pedestrians crossing against red, or by vehicles overtaking other vehicles stopped before the pedestrian crossing at non-signalised locations;
  - overall, two types of measures were found useful: implementing signal control at the non-signalised crossings studied, and marking more distinctly the crossings on road links.

Effects of building new types of pedestrian crossings with refuges were later studied separately (Kulmala, 1981).

- Pedestrian-cyclist conflicts were studied in Vienna, based on the Austrian TCT (Risser et al., 1991). Conflict analysis was complemented with behavioural observations based on video-recordings, and by interviews in traffic situations. It was found that:
  - pedestrians adopted a more passive role and complained less than cyclists;
  - conflicts were generated mainly by narrow footpaths, narrow cycle-tracks, (relatively) high speed of cyclists, poor visibility, or considerable age difference between cyclist and pedestrian;
  - few conflicts were dangerous; however, danger increased when several of the factors mentioned were combined (Schmidt, 1991).

### ***V.1.5. Behavioural and interactional studies***

#### *Principle*

Behavioural studies are often used: either to check some findings from accident or conflict studies as to probable accident factors, and assess the frequency with which the incriminated items of

behaviour appear in current traffic conditions; or to explicit the determinants of such factors in order to be able to influence them through the appropriate design of countermeasures. Behavioural observations have also been used to check the way particular infrastructure facilities work, or within evaluation studies of the effects of safety measures or strategies. Finally, some observational studies may make a useful contribution to assessing safety of traffic situations for which little other information is available.

Behavioural studies are designed on the basis of an underlying model of road user behaviour suitable to the particular traffic conditions considered. They are based on observations, performed according to a well-defined plan. In this respect, traffic-conflict studies can be considered to be behavioural studies, for which a lot of research work has been devoted to defining standardised observation procedures, applicable in all traffic conditions. Other behavioural studies need to be defined for each case analysed, according to the particular questions raised and to relevant hypotheses.

Broad categories of behavioural studies include:

- *“In-depth” conflict studies:* Very often, conflict studies are combined with other types of behavioural studies, in order to broaden up and cover different aspects of the safety impact. For research purposes, it is for instance interesting to combine conflict studies with interviews of the road users involved. Compared to in-depth accident analysis, this method ought to be an improved way of finding factors contributing to accidents. For example, interviews with road users involved in conflicts have been done twice in Sweden, as well as in Austria, with encouraging results.
- *Speed measurements:* The level of vehicular speed is a crucial factor when it comes to accident risks and the outcome of an accident in terms of injuries. Speed measurements can serve as a diagnostic tool, for example to find the sites where vulnerable road users face a high accident risk due to too high speeds. For a rough estimate of the safety outcome of a countermeasure, speed measurement is a quick tool. Here the 85 percentage speed is usually used to compare the before situation with the situation after implementation.
- *Interactional studies:* The quality of the interactions determines whether traffic environment is safe or unsafe. It is logical to interpret good interaction between road users as safe interaction, and to assume that safe interaction should be characterised as early interaction, in which road users notice each other early enough to prevent late evasive actions from taking place in an emergency. There is no common nomenclature for the definition of good and poor interaction: each study has to clarify its own definition. In the same way as the distinction has been made in TCTs between serious conflict, slight conflict, and undisturbed passage, it is quite possible also to define and study the principles of safe interaction. With the right training, observers can thus correctly estimate the quality of interactions.
- *Interviews:* They can be performed in connection with accidents or conflicts, in what has been called “in-depth” analysis: the purpose is then to find out what happened a few seconds before the incident. This approach broadens the understanding of factors causing unsafe situations. Interviews can also be used in connection with other types of behavioural studies. For example, pedestrians crossing against red have been asked if they had realised that they were doing it, and why they did so; cyclists have been asked what their perception of safety was after improvement of a major cycling route. More general interviews can be carried out with a representative sample of a population of pedestrians, cyclists, etc., in order

to find out about their knowledge of rules, their feelings of insecurity, etc., and relate the findings to some particular behavioural patterns.

- *Behavioural analyses:* More classical behavioural analyses are conducted when a specific type of behaviour, or behaviour at locations with specific infrastructural design, is of interest. The studied behaviour has to have some kind of safety relevance, as a known or presumed relationship to accident risk, or a probable role as accident factor. Items of behaviour often studied include: walking or driving against red; scanning procedures of pedestrians, cyclists, drivers, at specific types of locations; positioning of the cyclists and drivers in the street as they are about to start driving at a green light; and many more.

*Some examples of behavioural and interactional studies applied to the diagnosis of safety problems*

Again, behavioural and interactional studies are often performed within larger diagnostic studies, either by researchers, often for practical purposes at the local level. It is not possible to draw a good representation of this kind of work in these pages. Only a few examples are therefore given here; some others can be found further on, in the discussion of particular accident factors.

- An “*in-depth*” *conflict study* was carried out in Sweden with the aim of establishing a relationship between conflict severity and degree of danger experienced by the road users involved, as well as to find additional personal and other factors explaining the appearance of conflicts or involvement in them. Of those involved in serious conflicts, 40 per cent declared having been disturbed by another road user or something else at the junction, just before the conflict situation arose. Among those involved in slight conflicts, the corresponding figure was 25 per cent. Furthermore, 26 per cent of those in the first group stated that they felt tired, overstrained or irritated, against 13 per cent in the second group. These figures confirm that road users’ state of mind can have a negative effect on traffic safety. When road users were asked to identify the conflict they had been involved in, two thirds of the road users involved in serious conflicts were immediately able to refer to the right situation, while among the road users involved in non-serious conflicts the corresponding figure was only one third. The reason that a large proportion of the road users involved in serious conflicts had such a good memory of the conflict situation had probably to do with the fact that they felt much more strongly to have been in a dangerous position than those involved in slight conflicts. This would strengthen the underlying hypothesis in TCTs that a serious conflict is a situation nobody puts herself/himself deliberately into (Hydèn & Ståhl, 1979).
- A *questionnaire survey* of 1 509 cyclists hospitalised after a fall was carried out in Denmark in 1988-90. The victims included 9 per cent of children under ten. Three-quarters of the accidents were located in urban areas. Most of the falls happened on road links. 90 per cent of the victims acknowledged some responsibility in the accident, which they attributed to insufficient awareness. Half the cyclists reported skidding, often because of gravel on the road surface. In many instances, cyclists had run into an obstacle, usually the kerb. Cycle defects were mentioned as a contributory factor in 5 to 13 per cent of cases, according to the age of the cyclist. One out of four adults reported having been under the influence of alcohol. Nearly a third of the children used a cycle helmet, which proved to have been helpful in half the cases (Larsen, 1991).

- In a study performed in Gothenburg, Sweden, cyclists using a continuous cycle track were interviewed before and after the improvement of the track. The *interviews* made it possible to find out what the cyclists experienced as a safe vs. unsafe design, a safe vs. unsafe type of paving etc. By taking these aspects into account, measures could be taken to increase flow and improve safety (Rystam, 1995)
- *Behavioural analyses* were conducted in the Netherlands with a specially designed methodology, in order to study the relationship between actual and intended behaviour at cycle facilities. The results showed discrepancies between the two. The cycle facilities were not used as intended by the planning engineers, and the safety benefits may not be obtained. The study pointed out the importance of analysing actual behaviour, in order to design infrastructural features that corresponded more closely to the needs and practice of cyclists, so that intended safety benefits could eventually be obtained (Twisk & Hagenzieker, 1993).

## **V.2. Accident circumstances and contributory factors**

### **V.2.1. Introduction**

Through the various methods of analysis described in this chapter, the circumstances of pedestrian and cyclist accidents have been widely studied, although a lot remains to be done in this field. Due to the variety of approaches and to the complexity of the safety situations to be studied, results obtained are neither complete nor homogeneous. However, it is useful to attempt to sum up present knowledge.

The first section briefly summarises the main accident circumstances and factors, that appear important through the studies reviewed, and that can provide future orientations for research and safety action. In the second section, more detailed discussions of some of the most prominent factors are provided, based particularly on the observational studies of road safety assessment. It is to be noted that the factors mentioned may not rank the same priority in all countries, as their respective influence on accidents depends on exposure, traffic conditions, and the physical, social, and regulatory environment: gathering general knowledge about them provides a framework that should be useful for comparison purposes, but does not make future analyses redundant.

### **V.2.2. Some detailed accident circumstances**

#### *Cyclist accidents*

Most reported severe and fatal accidents involving cyclists have been found to occur either at road junctions, or at crossings between a street and a cycle track. This is particularly the case in urban areas. The importance of falls of cyclists that do not involve any other vehicle, is grossly underestimated in accident statistics. There are indications that falls may occur more frequently on road links. A large proportion of cyclist accidents would seem to occur on the main cycling routes; if verified, this finding would justify a concentration of remedial measures on the routes most frequently used by cyclists. Accidents appear to be more severe when the cyclist is hit by a turning vehicle.

Elderly road users are, at least in a number of countries, over-involved in fatal cyclist accidents. Young cyclists are also a high-risk group. These two categories of road users perform cycling trips for different purposes, hence, one good reason to justify a differentiated treatment of the cyclist safety problem. Head injuries seem to be the most important lesion causing cyclist fatalities; they are particularly frequent in victims of single-vehicle accidents (bicycle falls). A large proportion of cyclists hospitalised after an accident sustain some permanent disability. The proportion is particularly high for elderly victims.

### *Pedestrian accidents*

Pedestrian accidents are less frequent on rural roads than in urban areas, but they are much more severe in the first case. Not much is known, however, on the conditions of rural pedestrian accidents. It seems also that a non-negligible fraction of pedestrian accidents occur on motorways, where walking takes place only in connection to accidents or other incidents. The most severe pedestrian accidents in urban areas seem to be those occurring on road links outside marked zebra crossings, or at junctions but involving a vehicle going straight ahead. It appears also that a large part of fatal pedestrian accidents do not involve any crossing patterns, but rather playing, running, working on the road, etc. Pedestrian accidents frequently occur during leisure or shopping trips. A significant proportion of pedestrian accidents seem to be related to a change of transport mode, in which the pedestrian has just left a car or, more rarely, a bus. In OECD Member countries, pedestrians are, in a large majority of cases, hit by cars. As for cyclists, falls of pedestrians are mostly ignored in statistics.

In many countries, young children are found to be over-represented amongst pedestrian casualties. The elderly are particularly at risk of being killed as pedestrians. The circumstances of the accidents involving the two groups of road users are different; in particular, in crossing accidents, children seem to be hit by vehicles mostly when they begin their crossing while the elderly are more frequently hit after they are halfway over. Pedestrians involved in accidents have been found in several countries to be predominantly part of the low socio-economic groups; in particular, the unemployed seem to be particularly involved.

### **V.2.3. *Some accident factors***

#### *Speeding*

Drivers' speeding has frequently been noted as a factor, both in pedestrian and cyclist accidents. The speed factor can be understood in two ways:

- speed may be in excess of the local speed limit; or
- speed may be too high with respect to local traffic and environmental conditions.

thus not leaving enough time for drivers to process information or to react to a possible incident with a vulnerable road user. In many cases, it has been noted that compliance with local speed limits could have been sufficient to avoid the collision. High speeds, or speeds higher than usual in the circumstances, make things particularly difficult for elderly pedestrians or riders, as they do not estimate well enough the length of gaps in traffic, and have less time for information taking and for decision-making.

### *Social problems*

A high incidence of alcohol consumption among pedestrians involved in accidents has been observed in several countries, where it seems to be largely a middle-aged male problem. However, this finding needs to be further checked, due to the fact that BAC tests are not systematically performed on pedestrian casualties. There may be social problems underlying drinking patterns of pedestrians, an assumption backed by the fact that, in a number of countries, injured pedestrians are among the underprivileged groups of the population. In some OECD Member countries, it has also been found that the risk of injury to a cyclist with a BAC over 1.0 g/l was multiplied by ten. This is particularly a problem for cyclist single-vehicle accidents. Conversely, drunk drivers cause a substantial proportion of pedestrian and cyclists accidents. It is one aspect of the wider problem of drinking-and-driving.

Unemployment and other forms of social problems frequently appear among adult pedestrian victims of accidents. This may reflect an exposure problem rather than an actual behavioural factor, but the question remains to be investigated.

### *Risk taking*

Reckless riding seems to be a factor in accidents for cyclists, particularly for the young ones and those using a route they are familiar with. In particular, cyclists have often been observed, in some countries, to have been hit by a vehicle while they were not cycling on the proper part of the road or were cycling in the wrong direction, thus providing an element of surprise. Among young cyclists, reckless riding may be related to alcohol. Young adult pedestrians also do take risks, for example when crossing against red, or running across the street using small gaps in traffic (similar behaviour by children cannot be really considered as risk taking as their understanding and awareness of risk are not yet fully developed). Conversely, drivers inflict risk, for example leaving poor lateral distance when passing or overtaking a cyclist, which often results in the cyclist hitting the kerb and falling.

### *Non-compliance with the right-of-way*

Cyclists are often noted in accidents to have blocked the right-of way, either by ignoring the priority system, or by stopping in the wrong place, or by performing sudden manoeuvres or cutting in front of other vehicles. This may be particularly true for both the young and the elderly. Crossing a junction against red may also be for cyclists a non-negligible accident factor. Drivers frequently omit to give way to cyclists, particularly to child cyclists. The same appears to be true for pedestrians on various types of crossings; in particular, right of way of pedestrians on side roads is often not respected by turning vehicles. Non-compliance with the right-of-way is, in fact, a complex factor, including several situations: right-of-way may have been ignored by a road user, either because of insufficient knowledge of the traffic rules or the local dispositions, or because of insufficient information taking, or because of perceptual problems, or again because of ill-designed road features that convey the wrong message.

### *Insufficient information taking*

Insufficient information taking by the vulnerable road users, especially by child and elderly pedestrians and by young and elderly cyclists, has been found a frequent factor in pedestrian and cyclist accidents. Cyclists in general display inadequate scanning behaviour when crossing. Pedestrians as

cyclists have been found to take insufficient information particularly when they are travelling on a familiar route. Insufficient information taking is also the fact of drivers, who frequently give too little attention to vulnerable road users in traffic, both to pedestrians and cyclists.

#### *Perceptual problems*

The elderly as well as child pedestrians usually find it difficult to estimate speeds of approaching vehicles, as well as gaps and distances. This leads to short gap-acceptance, a pattern of behaviour that tends to be classified under “*risk-taking*” although risk assessments are erroneous. Similarly, young and elderly cyclists have trouble anticipating approaching traffic. The problem may be worse at night, or in urban areas when speeds are higher than usual.

Lack of conspicuity of cyclists and pedestrians is a factor of accidents. The fact that vulnerable road users are not easily detected in the midst of traffic plays a part, even in the daytime. Lack of conspicuity is, of course, aggravated at dusk, dawn, and night, especially when public lighting is weak. The most serious problems seem to be detection of cyclists by drivers approaching alongside or from behind.

#### *Infrastructural problems*

Although cycle tracks have been found a good safety measure on road links -- provided width of the track is sufficient and dispositions have been taken to prevent accidents with vehicles parking -- it appears that they tend to create safety problems at signalised intersections. Particular attention has to be given to the design of cyclist routes at these locations. Crossings between cycle tracks and streets do not always seem well understood by drivers, in particular, when environmental features do not clearly reflect the right-of-way, thus creating confusion among drivers and vulnerable road users alike. Narrow cycle-tracks, where they follow a pedestrian path or pavement and where flows of cyclists or pedestrians are high, tend to generate pedestrian-cyclist collisions. Slippery surfaces may cause cyclist accidents (for instance, when there is gravel on the carriageway). Other road defects may play a similar part.

Marked pedestrian crossings are not as safe as expected, at least in situations where drivers do not respect the rules, as pedestrians tend to develop a false sense of security. Non-signalised crossings on urban arterials are particularly dangerous for pedestrians when there is no central refuge. A narrow pavement appears as a factor in pedestrian accidents in places where pedestrian flows are particularly high at some times of the day, for example in the neighbourhood of schools. Poor visibility at junctions or crossings is a factor both in pedestrian and in cyclist accidents. In general, environmental features or safety facilities which are not used in the way they were intended to be are more dangerous than useful. This is the case of facilities that have been designed without taking sufficient account of the needs and behavioural patterns of vulnerable road users.

Weak street lighting is a contributory factor in accidents to vulnerable road users, who are, in general, too inconspicuous in traffic.

#### *Parked cars*

Parked vehicles have been identified as a significant factor in a substantial proportion of pedestrian accidents when obstructing visibility of both pedestrians and drivers. This is particularly

important when children are involved. Similarly, ill-located bus-stops create problems when pedestrians tend to cross behind the stationary bus, where visibility is poor.

#### *Particular factors related to the most vulnerable road users*

Very young children are often present on roads with traffic conditions they have not the abilities to cope with. This may be with or without approval of their parents, which calls for specific measures addressing families. Other factors are more directly related to the road and traffic environment. The main one is speeding, which is often associated with insufficient attention paid by drivers. Another one is masking, in particular by parked cars, sometimes by other roadside features.

The elderly pedestrians and cyclists are over-represented in fatal and serious injury accident statistics. Only a limited number of in-depth accident studies have been conducted to specifically investigate particular accident circumstances of this road user group. Results showed that cyclists tend to be over-involved in accidents in urban areas, at intersections and when turning left. Due to the ageing process, perceptual, cognitive and motor skills deteriorate, complex situations are more likely to cause problems in the selection of information and in decision making. In addition, with increasing age, biological processes result in a reduction of resilience to trauma (i.e. greater vulnerability). However, research relating to age-related diminutions to pedestrian and cyclist behaviour is very scarce. Also, a clear relationship of the diminution of functions with the occurrence of traffic accidents is not yet demonstrated (Hagenzieker, 1996; OECD, 1985).

More research on the particular factors affecting the safety of disabled road users is still needed.

#### **V.2.4. Discussion of some accident factors**

##### *Generalities*

What causes traffic safety problems? In this area, almost everybody with a connection to traffic has his/her own opinion. The opinion varies depending upon whether one is a civil engineer, social scientist, psychologist, traffic engineer in a local authority, or simply a person with driving experience. Even among traffic safety experts, there is no general agreement about factors contributing to the occurrence of unsafe situations. One reason for the lack of a common traffic safety theory is the lack of good and reliable data. It is seldom possible to carry out real experiments in traffic in order to test and verify hypotheses. Researchers are usually confronted with historical data and have to reconstruct the scenes afterwards in order to find out what happened. One way to keep track of all parameters and change one at a time would be experiments in the laboratory, but this method still struggles with validity problems (OECD, 1997). So, no findings are ever sufficiently ascertained to suffer no contradiction.

Despite these reservations, enough elements of research have been gathered for us to discuss some factors affecting safety of vulnerable road users. The main sources of information in this part have to be observation studies based either on traffic conflicts or on behavioural analyses. Accident studies are, of course, also relevant, although insufficient in themselves. Most of the traffic safety discussion exposed here is, in any case, quite unanimous, whichever type of data the analysis is based on. The underlying assumption, as a common denominator to most recent road safety work, is that it is impossible to extract one single cause and recommend one single solution to any safety problem. It is always a combination of factors, behavioural and environmental, that prepares the ground for unsafe situations.

From a general traffic safety point of view, and especially from the vulnerable road users' point of view, the traffic environment must allow the road users to make mistakes. Making a mistake should not inevitably result in being killed or severely injured. Low speed is the fundamental principle for a safe environment, as will be discussed below. When sufficiently low speed has been ensured, additional principles to improve safety of vulnerable road users can be considered. Some of the following traffic safety principles have been tested in real traffic environment, others are logical conclusions based on considerable hours of behavioural studies, and ought to be easily tested. They deal with expectations and the balance between complexity and simplicity:

- *Easy to make decisions*: It must be easy to understand how to behave at an intersection. Too complex a signal strategy, for instance, runs the risk of being misunderstood and causing road users to make errors.
- *Enhanced attention in critical situations*: There must be a clear message in the environment when enhanced attention is needed. For instance, if a driver approaches a two-way cycle crossing and there is a risk that a cyclist might appear from an unexpected direction, then the driver must get that information.
- Road users should not get *too strong a feeling of having the right of way*: It makes them less prepared for unforeseeable situations, and it increases the speed.
- *Awareness of coming events*: It makes road users better prepared if something unforeseen happens, provided they are not conscious of possible unexpected events to the point of being stressed. However, there should be no uncertainty at all when it comes to identifying hazardous situations.
- *Good visibility, conspicuity*: Road users should be able to see each other in time, and adjust their movements accordingly.

Alexander & Lunenfeld summarise the principles above in a slightly different way. They state that driver errors contribute to accidents, and that the most common causes of errors are drugs, alcohol and fatigue. In this context however, they find the following factors most important: (i) wrong expectations, (ii) stress and mental overload, and (iii) too little demand put on the driver, resulting in a lack of alertness (Alexander & Lunenfeld, 1986).

### *Speed*

There is a close relationship between vehicle speed and safety, that materialises under two aspects:

- the probability of an accident taking place increases with speed; and
- the outcome of the accident strongly depends on the collision speed.

As the words “vulnerable road users” imply, cyclists and pedestrians are more likely to suffer from a collision than car drivers and passengers. A number of studies support this view. Eero Pasanen, for instance, applied a mathematical model to assess the relation between driving speed and the risk of pedestrians being killed in an accident. Risk included both the probability of pedestrians getting hit by a vehicle and the probability of being killed when hit. The explanatory variables were vehicle speed,

driver's reaction time in braking, deceleration, and the time the pedestrian remained on a collision course with the vehicle. A speed of 50 km/h meant a risk of death almost eight times higher than a speed of 30 km/h. With a collision speed lower than 30 km/h, injuries to the pedestrian were often moderate. Conversely, with collision speeds exceeding 60 km/h, a pedestrian would most probably die (Pasanen, 1992).

Eero Pasanen also analysed 18 video-recorded traffic accidents, ten of which involved pedestrians, at two intersections in Helsinki. Comparison with police statistics showed that 80 per cent of the injury accidents were captured on the tape. A vehicle was defined as "free" when the time gap to the previous one exceeded three seconds. All pedestrian accidents involved a free vehicle, though only 40 per cent of traffic consisted of free vehicles. In eight of the ten pedestrian accidents, vehicles were on a straight trajectory; their average speed was 9 km/h higher than the average speed of all vehicles, and 4 km/h higher than the average speed of free vehicles in the reference traffic. It was estimated that the probability of a vehicle getting involved in a collision with a pedestrian at a speed exceeding 50 km/h was twice as high as with a speed below 50 km/h (Pasanen, 1993).

A report by Ashton and Mackay, while also supporting the general fact that severity of injuries to a pedestrian hit by a car increases with impact speed, concluded that there are, however, considerable variations in the injury severity for the same impact speed. Other variables influencing injury severity include:

- Injury tolerance of the body is different at different ages: bone strength tends to decrease with age, which means that elderly people sustain more serious injuries than other age groups for the same violence of impact, while young children, on the contrary, have more resilient bones.
- Height and weight differ: the same impact speed causes injuries to different parts of the body, depending on whether the pedestrian is a child or an adult (Ashton & Mackay, 1979).

In-depth accident analysis shows that contact with the car is the main cause of non-minor injuries. The severity of these injuries increases with impact speed, while injuries resulting from contact with the ground are, on the contrary, practically independent of the impact speed. Another result is that the injuries to the pedestrian being hit depend on the shape of the car front. Further experimental tests suggest that the energy-absorbing properties of the front is even more important for the injuries sustained than the shape of the front. It is therefore highly recommended to introduce pedestrian-friendly front structures in vehicles.

Most of what has been illustrated here on the influence of speed on accident and fatality risk to pedestrians can be extended to other vulnerable road users.

### *Interactive behaviour*

In most industrialised countries, society has, over the years, gradually adapted to the use of cars as the main means of transport. Vulnerable road users have step-by-step been deprived of their earlier travel space, to become uninvited guests in the traffic environment. Mobility of vulnerable road users has been restricted by legislation or other forms of control, usually under the consensus that they should not interfere with motorised traffic. Naturally, as motorised traffic became heavier, the problem of vulnerable road users was met with separating solutions. It is therefore not surprising at all that communication between vulnerable road users and drivers has become so poor. Two arguments can be formulated to

characterise poor interactive behaviour: misunderstandings in communication (for example, misunderstanding of signals); and lack of respect for vulnerable road users, due to different norms and values.

A safe traffic environment for the vulnerable road users presupposes safe interactive behaviour, and good communication with drivers in motorised vehicles. Deliberate neglect of rules, resulting in offending others' rights and feelings, indicate lack of willingness to communicate. Patterns of behaviour such as competing or "fighting" for the right of way, showing one's strength by reacting very late, or even increasing the speed in critical situations, also indicate unsatisfactory communication. In other social situations, the possibility of discussing and thereby solving disagreements is almost always there. In traffic the possibility is absent or has at least substantially decreased, and threat is often the main piece of information conveyed by drivers and their vehicles.

Unsatisfactory interactive behaviour is often the consequence of anonymity as well as of the priority given to one's own mobility at the expense of safety. It is interesting to raise the question of who dares to put one's own mobility before safety: up to a certain level, a majority of road users. But when risk exceeds what is acceptable, given one's instinct of self-preservation, then vulnerable road users become too conscious to continue with the trade-off. At this point, if vulnerable road users still give priority to mobility, it must be assumed that they are not fully aware of the risk they expose themselves to. This is for instance the case for pedestrians and cyclists crossing against red. The main responsibility for unsatisfactory interaction most often lies with drivers. Car drivers are protected by a hard shell, and are therefore in a better position of trading off between safety and mobility at high risk levels. Due to all the passive safety measures introduced in vehicles nowadays, drivers easily get the feeling that they cannot be injured. The large number of red-running cars is a good example of this, and causes a major safety problem for pedestrians.

Good interaction is achieved when drivers of motorised vehicles, either voluntarily or through imposed restraints, grant to vulnerable road users a more equal position in traffic. Restraint appears to be the best way of achieving this, at least in the short run. It is unavoidable to mention the significance of speed once again: high speeds make communication between road users difficult, and therefore increase the probability for unsafe situations to appear. On the contrary, if speeds are low enough, the physical threat falls to a low level for both vulnerable road users and drivers, and it becomes possible to further improve communication by letting the road users get physically closer in space.

### *Expectations*

Difference in expectations can cause dangerous situations. This includes a difference in expectations between different road users, and a wrong expectation of the prevailing situation.

How the difference between different road users' expectations may cause safety problems is best illustrated by the following case:

- In Sweden, the most common measure to promote safe crossing has been to introduce marked pedestrian crossings. However, no safety evaluation was ever conducted to establish their true safety potential. It seemed so obvious that pedestrian safety must increase if pedestrians were provided with an area of their own to cross at. Moreover, painting white stripes on the road and putting up signs was very cheap compared to other more sophisticated measures. Since everybody believed in its safety potential, the measure also

turned out to be very good when it came to calming parents concerned with their children's safety. Until 1988, nobody questioned the benefits of marked pedestrian crossings.

- Then, a study by Ekman comparing pedestrian risks on marked pedestrian crossings to risks at other locations produced much debated results. Ekman concluded that risk was higher for a pedestrian when crossing on a marked zebra or at a signalised marked crossing than at other crossing points located at junctions. Controls were introduced for car flows and the presence of children and the elderly, but that could not explain the poor performance of marked pedestrian crossings. One explanation could be that pedestrians' expectation of the marked crossing's safety effect was higher than the respect car drivers showed for the rules implied. This is a clear case of different road users' expectations. In Sweden, everybody has been taught from childhood that marked pedestrian crossings are the place for pedestrians to cross at, which gives pedestrians a sense of security. They are not so attentive to potential dangers as they should, according to statistics. Drivers, on the other hand, consider the road as their territory, and think that pedestrians should not attempt to cross until motorised vehicles have passed by. At locations where pedestrians feel less safe -- i.e. at locations with no crossing facilities -- they act more cautiously. The pedestrians know that they cross the road "at their own risk" and are therefore more attentive to possible danger (Ekman, 1988).

Wrong expectations of the prevailing situation occur when there is a difference between the normal, most frequent, situation which has been handled in a safe way many times before, and a prevailing situation that happens to be extreme or leading to unexpected hazard. Then, expectations are not in accordance with the prevailing situation, which has sometimes been termed a "violation of expectations". According to traffic safety principles, safety benefits from awareness of coming events, as it makes road users better prepared to react to anything unforeseen. Wrong expectations reduce this awareness. To expand this a little, the "normal" situation can either be site- and time-specific, or situation- specific.

- *Site- and time-specific:* For example, a car driver goes to work every morning at 7 O'clock. Every morning, he passes through a certain intersection, where he never meets any cyclist or pedestrian. But it so happens that once, he passes through the intersection at another time of the day, knowing from experience that there is nothing there that demands particular attention. His feeling of security is high. Then the extreme situation arises: suddenly, a cyclist appears right in front of him. The buffer for handling the situation in a safe way is bound to be very low.
- *Situation-specific:* A good example is a Finnish study that connected bicycle accidents and drivers' visual search during left and right turns. Analysis indicated a higher accident risk between vehicles crossing a cycle path when preparing to turn right and cyclists coming from the right, than for vehicles turning left. Following this, drivers' scanning behaviour was studied from video recordings at two T-junctions, where a two-way cycle path was situated along the main road and across the minor road. The drivers studied had to cross the cycle path before entering the main road. The results supported the hypothesis that right turning drivers scanned the left arm of the junction more frequently than the right arm, thus failing to notice the cyclists coming from the right. There was no difference in approach speed between right turning and left turning vehicles (Summala et al., 1995). This finding supports the basic hypothesis that there is a difference between the normal situation at a

junction, that road users have found a strategy to handle, and the abnormal situation that creates a dangerous outcome.

In the examples presented here, the traffic environment has failed to give the correct message to the driver. Nothing called for enhanced attention, and drivers are therefore not prepared to handle the prevailing situation.

### *Conspicuity*

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.

- Visibility can be defined as a 50 per cent 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 increases. This means, in general, that 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 is decreased).
- When it comes to detecting something among other elements, or to identifying something in particular, for example a pedestrian or a cyclist, one can speak of conspicuity. Visibility does not necessarily imply conspicuity. A particular object may be visible between other objects (i.e. be detectable) without necessarily being conspicuous. Conspicuity implies that a particular object must “compete” with other objects to attract attention. Various researchers (Hughes & 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 (Theeuwes, 1992).

This shows that it is not easy to study conspicuity issues. 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 (who should not always search for bicycles or pedestrians). Experiments, for example, in which detection is measured, where empty backgrounds are used, and where 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’ expectations 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. Olson (1996) states that “*driver’s expectations 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*”.

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 non-existent.

### V.3. Literature

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## CHAPTER VI -- NON-INFRASTRUCTURAL SAFETY MEASURES

### VI.1. The effects of non-infrastructure safety measures on safety of vulnerable road users

#### VI.1.1. *Introduction*

Measures to improve safety of vulnerable road users can be roughly separated in two complementary groups. Those which are based on road and traffic engineering or environmental planning, and can be termed “physical” or “infrastructural” measures; and the others, which aim at influencing road user behaviour without any intermediate action on the physical environment. The “non-infrastructure” measures are examined in this chapter.

Among non-infrastructure measures, only three selected areas are discussed here: education and training, measures to enhance visibility and conspicuity, and protective devices for cyclists. This does not mean that other types of non-infrastructure safety measures are not considered important. The topics of conspicuity aids and bicycle helmets were primarily selected for the large amount of research published recently on these measures. Education and training were selected because they are traditionally considered important measures, but only a few of recent examples of evaluations of programmes addressing children and elderly people are presented. Other types of non-infrastructure measures, such as rules and regulations, enforcement, telematics, and improved car designs, are briefly discussed.

The review of measures was mainly based on available literature, and on documents obtained through the Members of the Group, and should be representative of present international experience. The evaluated effects of safety measures include safety effects (e.g. accident reduction), behavioural effects (e.g. usage of safety devices), or effects on attitudes and/or opinions.

#### VI.1.2. *Education, training and publicity*

##### *Introduction*

Traditionally, education, training and publicity are considered important measures to help increase safety of vulnerable road users. A large number of reports have been published in the past two decades on this topic. Two previous OECD reports on *Traffic safety of children* and on *Effectiveness of road safety education programmes* focused on the evaluation of education, training and publicity activities aimed at various target groups, including pedestrians and cyclists (OECD, 1983, 1986). In addition, an OECD report on *Safety of two-wheelers* (OECD, 1978) paid some attention to the education and training of cyclists. More recently, the OECD report on *Improving road safety by attitude modification* (OECD, 1994) reviewed some evaluation studies on traffic safety campaigns aimed at children and pedestrians. With these reports available as a reference, no attempt has been made to provide here a complete review of measures based on education, training and publicity. Instead, a few recent examples of evaluations of

programmes addressing children and elderly people, either as pedestrians or as cyclists, are presented. These examples were not yet covered in previous OECD research reports.

### *Evaluation strategies and criteria for effectiveness*

It is important to stress that different types of evaluation methods can be used to assess the effects on safety of education, training, or publicity programmes, based on different criteria of effectiveness and serving different purposes (for example, product or process evaluation, summative or formative evaluation). Given the variety of evaluation methods and 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 on Traffic safety of children (1983), 17 studies of the effectiveness of education programmes were discussed. It appeared that the evaluation of programmes was based on the assessment of either knowledge, behaviour, or accident frequencies. Behaviour was the most commonly used evaluation criterion. Changes in knowledge were assessed in half the studies, while the effects on accident frequency were considered in only four of them. The most significant fact is perhaps that studies usually examined only one criterion: only two of the investigations considered changes in knowledge, behaviour, and accidents.

### *Programmes aimed at children*

Traffic education is brought forward as an important safety measure for the younger age group. A large number of programmes have been evaluated in terms of behaviour of children. Several studies showed that practical training of children in real traffic improves their traffic behaviour. Theoretical teaching of children was shown to improve their knowledge, but to have limited effect upon behaviour (Gregersen & Nolén, 1994; OECD, 1986). The influence on accident figures is less clear. Doubts exist about the effect on accident risk of this teaching and training strategy, based on knowledge of child psychology. Children have a number of psychological and physiological limitations. They can learn how to behave, but they can never be relied upon to use their knowledge when necessary (Vinje, 1981; Rothengatter, 1984). Evaluation studies of teaching and training programmes for children are seldom based upon effects on accident risk. There is thus no guarantee 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).

There are very few evaluation results of traffic education programmes in schools, except in terms of children’s understanding and knowledge. But Levelt (1994) made a recent inventory of the methods by which traffic education is taught to very young children (aged less than six). He concluded that two recent surveys form an exception in that the evaluation criteria included accident data:

- 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-type Traffic Club is to reduce accident risks in traffic for its members. However, no controlled studies of the club have been made so far, and it is

therefore not known whether it has reached its goal. An evaluation of the Norwegian club showed that members had fewer accidents than non-members, but since the study had no controls, drawing definite conclusions is difficult. For example, it was demonstrated elsewhere, that parents tended to restrict their children's exposure to traffic as a result of such programmes (Schioldborg, 1974; Rothengatter, 1985; cited in Gregersen and Nolén, 1994). In uncontrolled evaluations of the English Tufty Club, no improvements in knowledge or behaviour could be shown (Firth, 1973; Antaki et al., 1986; cited in Gregersen and Nolén, 1994).

The primary aim of Gregersen and Nolén's pilot-study was to investigate whether differences exist between a group of members of 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 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 the difference even more. 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 per cent).

Results showed that the member and non-member groups did not differ in background variables. Regarding exposure, the two groups were found to be outdoors for the same length of time; however, members were less exposed to traffic environments than non-members. Comparing the total traffic accident risk (traffic accidents/100 hours), members were found to have a significantly higher risk, especially as cyclists. According to what was reported by parents, non-members were found to spend a little more time in traffic on their own. Concerning the use of safety equipment, it appeared that the members used bicycle helmets considerably more often than non-members, and child restraints in cars a little more often.

The conclusion was that the club had some effect, however not on the most important aspect: traffic accident risk. Gregersen and Nolén offer some hypothetical explanations for these findings. For example, one possibility was that member parents were more likely to report minor accidents. The assumption that member parents overestimated the effect of the club, which led to a higher degree of exposure, had to be discarded as exposure was lower in the member group. The overestimation of the skills of children as road users might, however, have led to a higher degree of risk taking in traffic, a qualitative aspect of exposure which could not be checked through the quantitative variables used in the study. Finally, a possible explanation may have been that club-membership led to less teaching and training than the children would have received if they had not become members, because the parents shifted the responsibility onto the club. The results may be interpreted this way, since each member child was found to receive less training than a non-member child. Gregersen and Nolén (1994) were careful in drawing conclusions as methodological problems were involved in the study. However, they stated it could be reasonably assumed that the Swedish Traffic club did not have any effect in reducing accident risk.

- British Traffic Club

Another recent study into the effects of a Traffic Club on accident risk arrived at a more encouraging 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 on child casualties of the Traffic Club implemented in Eastern England.

The accident study compared a region with members (50 per cent of all children) with some regions without members, and was designed to reveal differences in the incidence of casualties in the experimental region compared to the incidence in the control region, over three-year before and after periods. A total of 11 514 casualty records -- 6 191 from the experimental region and 5 323 from the control one -- were used for a detailed analysis.

Results showed that the number of casualties occurring when a child was masked from the driver's view had fallen in the experimental region compared to the control region. The average change from the 'before' period to the 'after' period was approximately 20 per cent, a difference that was statistically significant. Similar differences were not observed with regard to child casualties who were not masked from the driver's view. To check whether the reduction obtained was a true 'Traffic Club effect' or was caused by some other factor, pedestrian casualty data were also collected for seven and eight year old children, too old to be eligible for membership of the Traffic Club and presumably not influenced by it. No significant change could be shown for this age group in the number of casualties masked by a parked vehicle. It seemed safe to conclude that the effect observed for the younger children was a genuine Traffic Club effect.

The 1993 data showed that, in Great Britain, 1 690 children aged between three and six were injured as they emerged from behind a masking vehicle. Bryan-Brown (1995) noted that, if the 20 per cent 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 3-6. Based on the pilot study findings, the British Traffic Clubs have rapidly grown.

### *Programmes aimed at older persons*

As seen in earlier chapters, abilities of elderly people to cope with heavy traffic and a complex physical environment tend to deteriorate with age, and their behaviour in traffic is consequently altered. Practice and routine help to slow the loss of function. From a traffic safety viewpoint, it should be useful to help the elderly adapt their behaviour in order to compensate for their relative loss of abilities, an additional and indirect effect being that they should feel more confident and retain their full mobility, thereby slowing down the effects of the ageing process. Traffic education aimed at elderly road users can also discourage hazardous compensation strategies.

Very few education programmes for the elderly have actually been implemented, even less of them evaluated. One large scale evaluation study of an education programme specifically designed for elderly pedestrians can however be used as an example.

In 1993, a 'Promotion programme of participation and practical traffic safety education for the elderly' was introduced in Japan (Morifuji, 1995). The programme was characterised by an emphasis on practice and experience in traffic situations, as opposed to more theoretical approaches, the elderly playing an active role in discussing their own capabilities and limitations. The objective of the programme was that elderly people should gain better understanding of hazardous traffic situations and learn practical ways to cope with them. The programme consisted of various "modules", such as an outdoor pedestrian course, a practical course of bicycle riding, and a course to prevent night-time 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, 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 these areas was compared to the total number of accidents involving elderly pedestrians in Japan during the same two years, and during one year before the application of the programme (Morifuji, 1995). The data indicated a decrease in the number of accidents in the areas in which the programme was carried out, whereas such a trend was less noticeable for Japan as a whole. However, the differences were not statistically significant, perhaps partly because of the relatively small number of accidents in the experimental areas.

A questionnaire survey (2 211 respondents) showed that 90 per cent of the participants found the programme “*very informative*” (Morifuji, 1995). Almost 40 per cent of the respondents thought that the traffic safety course for the elderly was a necessary tool to help prevent accidents. Results of the survey also showed that the participants particularly valued the elements of “*experience in traffic*” and the “*practical instruction*”, which were important characteristics of the programme.

### **VI.1.3. Measures to enhance visibility and conspicuity**

#### *Introduction*

Although in general the majority of accidents involving pedestrians and cyclists occur during daytime, the proportion of these accidents resulting in fatalities and severe injuries seems to be relatively high during night-time. When pedestrians and cyclists are compared, it seems that pedestrians are more vulnerable than cyclists during night-time: they show the largest share in fatal accidents.

Bicycle conspicuity has been recognised as a major safety issue for a long time, in particular, night-time conspicuity. This is more because of the very evident nature of the problem and the high risk associated with night-time riding, than because of absolute numbers of casualties (Cairney, 1992). A similar reasoning can be applied to the issue of pedestrian conspicuity. Taking into account that cyclists travel much more during daytime than during night-time, the risk associated with night-time travel was found to be about four times the risk associated with daytime travel (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.

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

#### *Bicycle lighting: head and tail lights*

Road lighting is an efficient way to improve visibility for cyclists and pedestrians. Public lighting being an infrastructural measure, its effects will not be discussed here.

In general, vehicle lighting is related both to how a vehicle is seen by other road users and to how the vehicle illuminates its surroundings. Contrary to motor-vehicle headlights, the function of bicycle lighting is not so much to light the surroundings, allowing riders to see properly -- bicycle headlights are usually too weak to fulfil this function -- as to allow cyclists to be better seen by others (Noordzij et al., 1992). Evaluation studies of bicycle lighting include two main groups: those focusing 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 with regard to bicycle lighting. A third, and complementary, group consists of observation surveys to determine the *use of bicycle lights*.

- 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. The circuit was arranged along suburban streets, so that measurements took place under real traffic conditions in rather light, night-time 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 at least two locations with different ambient lighting conditions. Each configuration was shown to three to 12 observers. All tail lights tested were seen by 85 per cent of the subjects at a distance of more than 100 m. Most of the tail lights were visible at distances considerably greater than those required for comfortably stopping a vehicle with a 60 km/h speed.

Cairney concluded that a flashing light-emitting diode (LED) device with a wide spread of light was particularly effective, especially against a cluttered background. 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 recommended 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.

Testing a device would mean nothing for road safety without any indication of the amount of use it is going to be put to.

- In the United Kingdom, Watts (1984; cited in Cairney, 1992) conducted an observation survey of over 2 500 cyclists riding at night in towns. 9 per cent of cyclists had no lights at all, 6 per cent had a missing tail light, and 6 per cent a missing front light.

Of the lamps observed, 21 per cent were judged to be too dim for the conditions, a further 3 per cent were flickering, and 9 per cent were off, the percentage of battery powered lights which were off being about double the proportion of dynamo powered lights.

- In the Netherlands, a higher proportion of cyclists use their lights, as shown from observations made of moving bicycles in darkness in 1985-1988 (Blokpoel, 1989). Approximately 1 500 to 3 000 bicycles were observed at five sites. It appeared that 55 to 70 per cent of bicycles used their headlights (ambient lighting conditions were < 25 lux).

Increasing the use of lights appears to be difficult. For example, a programme to encourage use of bicycle lights in a New Zealand city was not successful (Ferguson and Blampied, 1991).

- The effects of three different techniques to encourage the use of lights at night were studied.

The first technique consisted in prompting by means of posters, first on their own, 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 using satisfactory lights being entered in a prize draw. The third consisted in providing feedback in a form that had previously been showed effective in reducing speeding.

All three programmes were basically ineffective in increasing use of lights.

In the Netherlands only part of the cyclists use their lights (although it is compulsory), and maintenance is generally poor. During a campaign in Amsterdam, the two main offences by cyclists were found to be riding against red traffic lights and the absence of adequate cycle lights, each accounting for almost 50 per cent of the total amount of offences (Twisk, 1993).

- Concerning cycle lights, police activities were essentially preventive. Fines were dropped if cyclists could show within one week after being stopped that they had actually repaired their lights.

Although not systematically observed, this approach seemed successful in the sense that cyclists were more often using their lights after the campaign ended.

### *Reflectors on bicycles*

In the Australian study by Cairney (1992) mentioned earlier, various reflectors were tested.

- Laboratory tests showed that all of the reflectors used in the study had lower performance than that specified by 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, it was assumed that bicycle would become more easily recognisable as such when viewed from the side.

- 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 per cent relative reduction of the number of victims among cyclists at dawn and dusk and in darkness, as compared with the number of victims during daytime in the period after the law came into effect. As a control, the numbers of pedestrian victims in the same periods and circumstances were examined, the relative reduction in this group was 1 per cent.

Although the decrease of victims among cyclists was statistically significant when comparing “before” and “after” periods as well as when comparing with the trend in pedestrian casualties, the assessed effect of side reflectors in the form of wheel circles was found rather small. A complicating factor was that observations showed that cyclists equipped with wheel circles also used their headlights more often (70 per cent) than those

not equipped with wheel circles (36 per cent). It is unknown in what proportion of cases the wheel circles played a conclusive role in preventing cyclist accidents.

Observations carried out in the United Kingdom showed that 12 per cent of bicycles had rear reflectors which were damaged, misaligned or obscured, and 17 per cent had no reflectors (Watts, 1984; cited in Cairney, 1992). A series of tests was performed in an off-road situation to determine the detection distance for some lamps and reflectors to improve conspicuity from the rear.

- The cyclist could be either close to the kerb or near the centre of the carriageway. A pair of headlights to the right of the cyclist simulated 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 the greatest detection distance. All devices gave the shortest detection distance in the kerb position viewed against high beam. Further tests were carried out with the cyclist in the kerb position viewed against low beam.

A combination of rear lamp and small reflector gave a detection distance of 650 m and a recognition distance of only 54 m. Although a very bright reflective jacket and pedal reflectors had much shorter detection distance, they were of benefit in delineating the object as a cyclist and had relatively long recognition distances. Reflective cross straps and a reflectorised spacer were less effective.

#### *Fluorescent and retro reflective materials for pedestrians and cyclists*

A popular approach to increasing night-time 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 markers increase the visibility distance of pedestrians at night (Rumar, 1976, cited in Luoma et al., 1995). Sufficient reflectivity, contrast, area, and durability of retro-reflective markers have been considered the key variables affecting pedestrian visibility.

While providing a substantial improvement in the distance at which pedestrians are detected, good retro-reflectors, as such, may not ensure that a driver recognises the bright target as a person.

- In the study by Cairney (1992), reflective garments were tested. These were generally seen by 85 per cent 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 equipment of bicycles at night. The reflective garment was generally not visible until well after the tail-light had been seen. Its most appropriate function seemed to be as a supplement to lighting, especially as an aid to recognition.

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 cyclists 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 equipment 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. Table VI.1 below shows the basic results (Cairney, 1992).

Table VI.1 **Conspicuity aids -- Detection, recognition distances and visibility index**

	Detection distance (m)		Recognition distance (m)		Visibility Index (m)	
	Mean	SD	Mean	SD	Mean	SD
Baseline bicycle	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 metre. Visibility Index is a measure of visibility which takes into account both visibility and detection distances, derived by multiplying detection by recognition then finding the square root.

\* The “fanny bumper” is a large triangular panel of reflective sheeting.

Source: *Blomberg et al., 1984, in: Carney, 1992*

Blomberg et al. (1986, cited in Luoma et al., 1995) compared the detection and recognition distances of five different pedestrian targets in night-time driving.

- They found that flashlights produced the longest detection distance (420m), followed by retro-reflective bands on the head, waist, wrist, and ankles (232 m), a jogging vest (227 m), dangle tags (162 m), and a baseline pedestrian wearing a new white T-shirt (68m). However, the mean distances for recognition were 96, 133, 98, 44, and 32 m, respectively.

Results showed that white clothing was not a sufficient conspicuity aid for pedestrians. The authors suggested 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 showed that positions of retro-reflective markings were probably important.

Owen et al. (1994, cited in Luoma et al., 1995) conducted two simulation experiments to evaluate potential benefits of different retro-reflective markers for night-time 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 markers of all the major joints would create a biological motion phenomenon whereby the recognition of moving persons would be

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 markers, and were asked to respond as quickly as possible when seeing a jogger.

Results showed that performance was better with markers of the limbs than of the torso. Furthermore, when a secondary task was included, performance was better for markers that incorporated biological motion than for a vest or for arbitrarily positioned stripes on the limbs.

As a follow-up, Luoma et al. (1995) conducted a field experiment:

- The subjects' task was to press a response button whenever he or she recognised 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.

Results showed that the mean recognition distance was 40 m when there were no retro-reflectors, 96 m for torso reflectors, 156 m for wrist and ankle reflectors, and 169 m for reflectors on major joints when a pedestrian was approaching the car. When a pedestrian was crossing the road, the corresponding recognition distances were respectively 35, 136, 241, and 249 m.

Older subjects needed shorter distances to recognise a pedestrian. This difference may be partly caused by decreased visual acuity, or by slower information processing. In addition, Luoma et al. assumed that older subjects preferred to get more information to decide whether a given target was a pedestrian.

The main implication of this study was that retro-reflective markers on the limbs, in comparison to those on the torso, significantly increased (by about 60-80 per cent) the night-time recognition distance of pedestrians, thereby confirming the results of Owen et al. (1994).

However, the data were inconclusive as to the differential effect on recognition distance of the biomotion/major joints configuration and other configurations on the limbs. Luoma et al. remarked that retro reflectors on the wrists and ankles were anyhow more practical than on the major joints.

Shinar (1985; cited in Aylward and 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 night-time 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 markers to accident rates is not conclusive.

The actual use of retro-reflective devices in traffic was also investigated.

- 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 aide to visibility at night. Adult commuters in Melbourne showed the highest wearing rate (10.7 per cent), followed by cyclists at primary school sites in country centres (4.8 per cent). Cyclists at recreational sites and at secondary school sites showed the lowest rates (0.2-1.9 per cent).
- Of regular cyclists in Western Australia, 2 per cent reported using a reflective garment or bag, 24 per cent reported wearing white or brightly coloured clothing, and 3 per cent reported wearing reflective tape bands (Cairney, 1992).

In some parts of Sweden, peaked caps of highly conspicuous, fluorescent colours were given to all pupils when they began 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 indicated some deficiencies in the way caps had been introduced.

The study of car driver behaviour showed that, at least at some locations, the caps contributed to a somewhat lowered approach speed to the crossing. The caps also seemed to make the drivers observe the children significantly better (Dahlstedt, 1995).

#### ***VI.1.4. Protective devices: Bicycle helmets***

##### *Introduction*

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. A literature review by Royles (1994) showed that a large number of published papers, in particular from Australia and the USA, reported that at least two-thirds of the cyclists killed in accidents had head injuries which either contributed to or resulted in death. In three Finnish provinces in 1982-1988, over 70 per cent of bicycle fatalities had head injuries diagnosed as the principle cause of death (Olkkonen, 1993). In Canada, Cushman et al. (1992) similarly reported that head injuries were the reason for 70-80 per cent of cyclists' deaths and long term disabilities. Of 300 cyclists killed on the road in the United Kingdom every year, over half die because of a head injury, of which 29 per cent are received to the cranium, the area of the head which can be protected by a helmet (Mills, 1989).

*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, a reduction by a factor of eight in the annual number of cyclist victims with brain injury could be achieved if all cyclists were wearing 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 was 3-10 times greater for unhelmeted cyclists, depending on the helmet type.

In Denmark, Bernhoft et al. (1993) estimated from an in-depth analysis of 88 fatal accidents involving cyclists, that in one third of the accidents involving children, adults and elderly cyclists, the cause of death was exclusively head injuries (for children in particular), or involved serious head injuries. These authors concluded 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) reviewed a number of studies addressing 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, in the USA from 1984-1988, 84 per cent of deaths of which head injury was the principal cause and 83 per cent of head injuries could have been avoided if all cyclists had been wearing helmets. In Sweden, Lind and Wollin (1986; in Royles, 1994) carried out a questionnaire survey, and concluded that more than 70 per cent of the accident victims for whom the head was recorded as the main site of injury would have benefited from the use of a helmet. Olkkonen (1993) investigated the injury severity of bicycle accident victims in three Finnish provinces from 1982-1988, and estimated that almost 50 per cent of the 200 fatal injuries could have been prevented if a helmet had been worn. Wasserman and Buccini (1990; in Royles, 1994) analysed 191 questionnaires from recreational cyclists who reported having fallen and struck their heads: 57 per cent of them were wearing helmets. The helmet wearing cyclists reported significantly fewer skull fractures and fewer facial soft tissue injuries than the non-wearers.

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

*Stimulating the use of bicycle helmets*

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

**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, which 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) described 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, multiple 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 be worn in all school bicycle activities, and schools were allowed to buy helmets at a 33 per cent discount.

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, using 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 (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 was carried out in Victoria.

- Depending on the age (children, adults) and type of cyclists (commuters, recreational), wearing rates increased from less than 10-30 per cent in 1983 to more than 40 per cent in 1989 (Vulcan et al., 1991). After the law came into effect in 1990, usage rates further increased to 70-90 per cent. The highest wearing rates were observed among primary school children, followed by adults (in particular 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 cyclists with head injury was found in Victoria (37-51 per cent). The mechanisms by which this reduction was achieved seemed 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) reported the results of an observation 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 16 years-of-age and older; on 1 July 1991 the law was extended to the younger cyclists. Three months after the law came into effect, 77 per cent of cyclists aged 16 and over and 84 per cent of cyclists over 20 were wearing a helmet. The wearing rate of cyclists aged 16-19 was considerably lower (46 per cent).
- The legislation and promotional campaigns in Western Australia (Healy & Maisey, 1992; cited in Goldenbeld & Wittink, 1993) also resulted in substantial increases in the wearing rate of bicycle helmets.

However, in a recent review by Robinson (1996), it was reported that the new legislation resulted in a general decline in the use of the bicycle. Some cyclists had been discouraged from cycling because they did not own or did not wish to wear a helmet.

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 14, 16 or 18 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 per cent to 47 per cent after law enactment. 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.

#### Voluntary usage

In Sweden, bicycle use has strongly increased for the past 15 years. Ekman et al. (1992) reported an increase of 40 per cent from 1978 to 1984 among cyclists aged 15-84. 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, to be compared to 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, observation studies of bicycle helmet usage have been carried out annually. The results for 1994 (Nolén, 1995) indicated a wearing rate of 47 per cent for children under 11, and of approximately 25 per cent for school pupils aged 7-15. The wearing rate for adult commuters was 6 per cent, and 7 per cent for cyclists on public cycle paths.

Compared to the figures for 1988, all cyclist categories substantially increased their wearing rates. Global wearing rates were estimated (by weighting the wearing rates of children and adults) to be between 10-15 per cent, following a slightly upward trend.

However, since 1990, usage rates hardly increased further. Briese (1992) presented the following reason to explain part of the stagnation 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".

- A forum of experts ("Swedish Bicycle Helmet Initiative") sponsored by the Swedish government has launched a campaign targeted at children aged 6-12, and is planning campaigns targeted at teenagers and elderly cyclists. The preparation of legislation is also discussed, the focus is more on when bicycle helmet use should be made compulsory (as soon as possible or only when wearing rates are sufficiently high) than on whether 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 reaching at least

90 per cent helmet use among cyclists aged 12 and under in the year 2000, and at least 70 per cent among older cyclists (Ekman et al., 1992).

In Denmark, only minimal attention has been paid to the issue 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 included competitions to identify school classes where cycling helmets were used the most. The campaign stressed that it was “cool” to wear a helmet. As a result, 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 per cent 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 publicity material in schools, and the “Children’s Traffic Club” (40 per cent of the parents of children aged 3-6 are members of the club).

In 1991, a similar campaign took place, aimed at children between seven and 13. New bicycles could be won by all pupils of the school with the highest wearing rate. About half of all schools in Denmark participated in the competition. No effects on actual helmet use are known, but according to studies of travelling habits focusing on children cycling, 68 per cent of children between six and 15 had a bicycle helmet. However, helmets were worn only in about a quarter of the trips made by children on an average day in 1993. As in Sweden, only a few adults in Denmark wore a bicycle helmet: only 4 per cent of those aged 16-74 reported that they ‘almost always’ wore a helmet (Danish Ministry of Transport, 1993).

- Following a Danish campaign involving additional local activities in 1994, the wearing rates increased from 49 to 73 per cent for school children aged six to nine, from 11 to 50 per cent for children aged ten to 12, and from 0 to 7 per cent for children above 12. In areas where only the standard nation-wide programme had been held, helmet usage only increased significantly for 10-12 year olds, from 8 to 25 per cent (Behrendorff & Arndal, 1994).

In Finland, the Central Organisation for Traffic Safety has collected measurements of bicycle helmet use yearly since 1990 (Tanttu, 1996). The results show a steady increase of bicycle helmet usage, from 4 per cent in 1990 to 21 per cent in 1996 (see Table VI.2 below).

Table VI.2. **Trend in helmet wearing rate in Finland (1990-1996)**

<b>Year</b>	<b>Number of observations</b>	<b>Bicycle helmet use in Finland</b>
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%

In Canada, 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 5-14 and their parents. Leaflets were sent to more than 20 000 physicians and paediatricians, and included order forms to purchase bicycle helmets at reduced prices.
- In 1992, another campaign was launched by the Canadian Standardisation 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 pre-teen/teen audience (Focus, 1992; in Goldenbeld & Wittink, 1993).

Cushman et al. (1992) described 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 per cent to 44 per cent, an increase of 14 per cent to 32 per cent among recreational cyclists was observed, as well as an increase of 2 per cent to 21 per cent among students.

- Morris and Trimble (1991) evaluated the effects of projects to stimulate helmet use at primary schools in Ontario, Canada. They concluded that such programmes should be more than just information campaigns, and that the presence of rebate schemes was crucial for success. Helmet use 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 United Kingdom, very low usage rates have been reported. In 1987 Colyer et al. (cited in Royles, 1994) found that only 4 per cent 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 has remained low (11-13 per cent; Royles, 1994).

- A television advertising campaign aimed at drivers and parents was launched in Autumn 1990 in the United Kingdom, 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 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 per cent (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, 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 12 years is as high as in Sweden, and there are very few bicycle racers and tourers who do not wear helmets.

Except for some local initiatives, usually in primary schools, no large-scale activities to promote bicycle helmets have taken place in the Netherlands. Seijts et al. (1995) studied the determinants for not wearing a bicycle helmet for children aged 7-13 in the Netherlands.

- 279 children used a helmet during a 6-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.

In 1996, a campaign to promote the voluntary use of bicycle helmets and to enhance social acceptance of helmet use took place at two primary schools in the Netherlands. The campaign was aimed at children aged 4-12 and their parents. A social marketing approach (see OECD, 1993) was adopted, 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 helmet use (Goldenbeld, 1996).

#### *Attitudes to bicycle helmets*

In an interview study held among some potential cyclist target groups in the Netherlands, Goldenbeld and Wittink (1993) found that two types of cycling can clearly be distinguished: everyday cycling, which is only intended for the practical purpose of transport, and recreational cycling, which places great emphasis on sportiness, adventure and physical relaxation. Regarding everyday cycling, people believed that helmets represented an outward symbol of ineptitude, weakness or exaggerated fearfulness. They suspected the helmet would be uncomfortable, said they would feel stupid standing out in a crowd wearing the helmet with ordinary clothes, and were not interested in trying it out. For sport or for adventurous cycling, the helmet was considered a standard and useful part of cycling equipment, it represented an outward expression of skill rather than ineptitude, and fitted into the image that one wanted to present to others. People felt “tough” or “sensible” wearing the helmet rather than “stupid”, and persons who had never worn a helmet felt some inclination towards trying it during holiday trips or rough terrain cycling. Goldenbeld and Wittink concluded that adults and children had no, or hardly any, intention of wearing a helmet for everyday cycling, while for more adventurous forms of cycling, they were more inclined towards helmet use, in association with riding a special cycle and 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 USA, DiGuseppi et al. (1990) reported that 24 per cent of a sample of 931 third-grade children in Seattle owned helmets, but that only half of them said they wore them. They did not wear helmets because their friends did not, because they had never thought of it, or because they found them uncomfortable. In the United Kingdom, respondents to a postal survey were asked why they did not own a bicycle helmet (Colyer et al., 1986; in Royles, 1994); 44 per cent stated that risk was not high enough, 30 per cent based their decision on cost, poor looks or lack of comfort, and 24 per cent stated that helmets were inconvenient. In a Finnish interview study to find out why cyclists did not wear helmets, it was reported that most of the interviewees who rode without a helmet (76 per cent of a sample of 287 cyclists) mentioned the inconvenience to carry or leave a helmet somewhere as a factor influencing their decision not to buy one. Especially adults and elderly people were of this opinion. One in four of the respondents thought that only legislation making use of cycling helmets compulsory would get them to wear one. While 42 per cent of the respondents were opposed to such legislation, one in three favoured it. Women and elderly persons were the groups most favourably disposed towards compulsory use. A quarter of interviewees favoured a limitation of compulsory use to certain age groups. Generally, the age groups suggested did not include the age group of the interviewee in question (Sipinen, 1993).

Taylor and Halliday (1996) conclude from an attitudinal survey conducted in the United Kingdom 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 14) were shown to be very acceptant of helmet wearing, being attracted by the colour and design of the helmet. On the contrary, 12-17 year olds were much more self conscious wearing a helmet, and whilst a few said that they felt safer or more conspicuous, many others stated that they liked nothing about it. The results presented the cyclist aged 18 or more as the one who attaches much greater importance to the practical and functional aspects of helmets, such as cost and fit. In a study conducted in Canada, Otis et al. (1992) concluded that a positive image of the bicycle helmet and good marketing techniques were 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”*. Stevenson and Lennie (1992) reported 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 were considerably lower than in other States in Australia: about 5 per cent of school children up to 12. According to the 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”*, 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”*.

The reasons for not 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 have often not thought about bicycle helmets, have not thought them necessary or have decided that they were too expensive (cf. Royles, 1994).

On the other hand, when (Finnish) cyclists wearing 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. Helmet-wearing cyclists used their bicycles every day. Almost all of them said that they nearly always wore a helmet while cycling: helmet wearing had become an established habit for them. 71 per cent 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 had to justify their use of a bicycle helmet to others.

Besides cyclists' 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 of) wearing helmets. They argue that it could have a negative side effect in that an unjustified link may be established between cycling and danger, and bicycle use may drop, and that 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) suggested that cyclists wearing helmets may think that they are better protected and could therefore adopt riskier riding techniques (OECD, 1994).

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

- the spontaneous activities and efforts of civil activists and volunteers;
- attention to the bicycle helmet in local projects, with collaboration of government and private organisations;
- funding schemes where helmets are offered at reduced prices;
- a broad range of attractive, colourful and sporty cycle helmet designs;
- clarity about the safety standards which a bicycle helmet should meet.

#### ***VI.1.5. Other non-infrastructure measures***

##### *Motor vehicle characteristics*

Most of the vehicles involved in accidents with pedestrians and cyclists are cars. Some improvements in car design might lead to reduced injuries in collisions with unprotected road users. A study conducted in the United Kingdom 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, giving a benefit to cost ratio of over four to one (Lawrence et al., 1993). For instance, modifications of the design (e.g. the shape, length, and stiffness) of car-fronts can reduce the severity of injury markedly (Janssen et al., 1990; van der Sluis, 1993; Otte, 1994). Although trucks and heavy goods vehicles less frequently hit pedestrians and cyclists, the outcome of accidents involving them are particularly severe. Side guards can

help prevent cyclists and pedestrians from being run over by the rear wheels of lorries (Riley et al., 1985). It is to be noted, however, that all evaluations of motor-vehicle characteristics were carried out on the basis of simulation or laboratory tests.

### *Rules and regulations*

An example of a safety effect that can be attributed to a change of a rule can be found in the Netherlands, where, in a pilot-study in three cities, moped riders, originally subjected to the same rules as cyclists, were made to use the carriageway instead of the cycle track. In practice, approximately 70 per cent of the moped riders exceeded the speed limits; therefore, particularly in built-up areas, the speed differences between mopeds and bicycles were much larger than those between mopeds and other motor-vehicles. The idea was that it could be safer, for cyclists and other road users, to have mopeds using the carriageway. It was indeed shown that the measure exerted a favourable effect on injury accidents (Hagenzieker, 1995). A reduction of 70 per cent of moped accidents and of moped victims was found in the experimental areas, against a 20 per cent reduction in the control areas (a trend similar to the national accident figures). Both, accidents between mopeds and cyclists and between mopeds and vehicles were 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.

Another example is the change of speed limits in urban areas from 60 km/h to 50 km/h. When this was done in Denmark in 1985, an evaluation study was carried out, on the basis of a before-and-after accident analysis with a control group (accidents in rural areas). The accident reduction in urban areas, related to lowering the speed limit, was estimated to 8.7 per cent, while the number of fatalities was reduced by 24.1 per cent. Although the reduction of fatalities to vulnerable road users was not specified, they were expected to be among the main beneficiaries of the measure. Speed measurements were also performed in the before and the after periods. Changes in mean speeds were shown to vary considerably from location to location, but the most common reductions were of 3 to 4 km/h (Engel & Thomsen, 1988). Over the last ten years, the 50 km/h speed limit in urban areas has been adopted in a growing number of countries, in Europe in particular. Results of the few evaluation studies carried out, as for instance in Switzerland, provided similar results to those of the Danish study.

All other traffic rules are assumed to exert an influence on safety. However, there hardly seems to be any research investigating the effects of changes of rules and regulations specifically intended to better protect vulnerable road users.

### *Police enforcement*

Police enforcement activities might also affect the safety of vulnerable road users, so long as enforcement strategies focus on behavioural patterns that are recognised as contributory factors in accidents. Two types of enforcement policies can be distinguished in this regard:

- those directed at the behaviour of vulnerable road users themselves, such as prevention of red light violations; and
- those directed at the behaviour of motorised road users, such as enforcement of speeding laws.

While an abundant amount of literature on the topic of enforcement exists (see Zaal, 1994 for an overview), effects of enforcement on safety of pedestrians and cyclists have not been properly investigated. A small scale study in the Netherlands suggested that enforcement activities aimed at preventing cyclists from riding through red lights did not affect the behaviour of cyclists, whereas the same activities did affect the number of violations by car drivers (Twisk, 1993).

## **VI.2. Prospective measures**

### ***VI.2.1. Education and training***

#### *Introduction*

Education is a widely accepted tool for the improvement of safety of children and young people, as evidenced by the national efforts within OECD Member countries to increase and improve the provision of road safety education, and by the recommendations adopted by the ECMT on Road Safety Education for Young Children and Teenagers (ECMT, 1994), and the drafting of a resolution by UNECE regarding the traffic safety education of children (UNECE, 1996).

The UNECE resolution presents recommendations for the development and maintenance of effective, progressive, and planned road safety education programmes. In this regard, it recognises that to be effective, road safety education should be provided on a systematic and continuous basis in pre-school establishments, primary and secondary schools, within out-of-school activities and places of further education. While there may be local variations in the provision of road safety education, depending on children's age, their capabilities, the local environment and their means of moving about, the fundamental aims and approaches are common. To maximise the educational and safety impact of road safety education, it must teach areas beyond simply the highway code, such as practical skills, knowledge of and positive attitudes towards safety via technical subjects, ethics, social science. In other words, it may be used in subjects across the curriculum. The recommendations include the need for up-to-date training of teachers and other experts in road safety education.

#### *Criteria for developing road safety education programmes for children*

Within road safety education (RSE), a number of approaches can be taken. These vary according to the local environment, socio-cultural and legislative conditions, the road accident patterns, exposure to risk and behavioural pattern, the age and capabilities of the child, and the resources available and the deliverers of RSE. Together, they determine the local approaches to education.

The local environment refers to the area in which the child is operating: at one level, it can refer to whether it is an urban or rural environment, at another level, to the number and types of roads and junctions in a given area, whether there are parked cars, etc. The socio-cultural and legislative conditions may include typical behaviour of adult road users, average levels and nature of accompaniment of children, drinking-and-driving and speeding laws.

There are clearly developmental changes in the abilities of children to be safe road users, and it is important to take these into account in developing and targeting effective education programmes. Related to the capabilities of the child to be safe are the general behaviour of children and their actual

exposure to road traffic. It must be said that there is still too little information on the basic patterns of children's exposure to risks in traffic, particularly as pedestrians and cyclists. While it is accepted that there are practical difficulties in gathering information on this group (travel diaries are not particularly suitable and observation may be unacceptable), it is important to know how children interact with traffic and their general behaviour in order to improve our understanding of the actual risks they face.

For RSE programmes and resources to be fully utilised, they must be attractive to the users and those delivering the programmes. The ultimate users are typically children and young people, but the deliverers may be many and varied. In the main, they are expected to be parents and teachers, but may also be police officers, local government staff, and increasingly other health professionals, such as public health officials, health visitors, community nurses, etc. It is important that all the agencies delivering RSE provide complementary and consistent messages. All potential deliverers need to be identified and used effectively. In the past, RSE has been seen as confined to schools, particularly primary schools. This should not be the case, and there are many groups of deliverers and opportunities within and outside schools for road safety education. One group in particular needs positive encouragement: parents/carers. It is necessary to encourage the full participation of parents in the process of developing safe road user skills and to ensure that road safety education is delivered in a progressive way for all ages. This can be achieved in a variety of ways, for example educating new parents about safety needs of their children, involving parents in pre-school activities, or in school-based practical training schemes, encouraging active accompaniment of children, and ensuring messages delivered from other sources are supported.

#### *Setting educational objectives for road safety education programmes*

Setting objectives remains a fundamental issue in road safety. Traditionally, road safety education programmes tended to have very broad objectives, such as "to reduce road accidents". Such aims, although worthy, are largely unworkable. What is required are much more explicit educational objectives, that are achievable and can be evaluated.

More detailed objectives are required at a practical level. "*Understanding the skills and strategies needed to interact with traffic would seem an obvious starting point for the development of educational objectives.*" (Thomson et al., 1996). In their comprehensive review of child development as related to RSE, Thomson et al. have summarised the main components of the pedestrian task as follows:

- detecting the presence in traffic;
- visual timing judgement;
- co-ordinating information from different directions;
- co-ordinating perception and action.

These skills are fundamental to the pedestrian task. It is also important to note that they need to be deployed strategically, and often simultaneously. The objectives therefore of any RSE programme must start by considering the development of these skills. Before setting specific objectives, it is also necessary to understand the capabilities of children in relation to the aforementioned skills.

*Children's capabilities and how they can be influenced*

From an educational point of view, it is necessary to know how skills develop in childhood and what level of skill children are capable of at different ages. Moreover, it is essential to know whether the skills can be influenced by education, and, if so, at what age intervention is likely to be effective. Over the past 20 years, progress has been made in the understanding of what children are capable of and how their skills develop. Perhaps as important, we now have empirical evidence that children's development of road safety skills can be influenced by education as early as four years of age (Thomson et al., 1996), provided it is undertaken in suitable conditions, i.e. in small groups at the road side or somewhere very similar.

In 1983, the OECD study of Traffic Safety of Children presented a summary of children's development, based on the accepted interpretation of Piaget's model of childhood development (OECD, 1983). This suggests that children develop through four different stages, each associated with particular age ranges: the sensorimotor stage (birth to two years); the pre-operational stage (from 2-7 years of age); the operational stage (from 7-11 years); and the formal operations stage (over 11 years). Earlier evidence (such as Sandels, 1975) also supported this view that children were biologically incapable of certain skills at very young ages, and therefore could not be taught them. These views lead directly to the traditional knowledge-based RSE programmes undertaken in the classroom.

The recent review of developmental theories (Thomson et al., 1996) suggests that the earlier interpretations of Piaget's theories were too rigid, and that the most important aspect is that children learn from a "bottom-up" process, i.e. learning progresses from context-bound actions, beginning in infancy with reflexes, to more general concepts. Traditional knowledge-based road safety programmes teach knowledge at a general level in the belief that this will then transfer to the many specific situations to be faced at the road side. Other developmental theories (e.g. Gibson and Vygotsky) support the view that road safety skills can be taught and that learning the skills needed to be a safer road user requires practical training beginning at the road side and progressing from the real road context to more complex situations and concepts. The authors conclude, "*developmental theory, then, almost with one voice, argues for the natural progression of understanding from action to concept*".

*Future approaches to road safety education*

The theoretical basis for the development of road safety skills clearly suggests starting with a practical approach to education and influencing of behaviour. Indeed, the developmental theories suggest that there is no substitute for practical training. Previous road safety education programmes have been directed towards imparting knowledge or instilling positive attitudes to road safety. While there is still room for such approaches, it is essential that road safety education programmes are practically based. Practical skills training is already widely accepted and well evaluated for cycling and driving, but is equally important for young child pedestrians.

Practical road safety skills programmes are relatively resource intensive, but directly target improving behaviour. The links between behaviour, and knowledge- and attitude-based educational programmes are not so clear, and there is little evidence that traditional knowledge based programmes improve behaviour. Practical skills, once developed, can be built upon and consolidated by classroom based and other activities. Imparting knowledge, and improving attitudes to safety, form part of the progression "*from action to concept*". In order for such knowledge-based and attitudinal programmes to be effective, the messages must be clear and well targeted. For example, the traditional Green Cross Code in Great Britain is now considered to be inappropriate for children under the age of seven, since it requires

a high level of verbal skills and basic understanding of complex concepts such as “*a safe place*”. However, this and other kerb drills could be used among older children (7-9 years old) once basic skills have been established via practical methods.

Generally, RSE amongst teenagers in schools is limited and is typically taught in isolation as part of personal/social development/citizenship type courses. Increasingly, there is pressure within the schools timetable, and less time is spent on such subjects. In addition, road safety competes with other health and safety education issues, in particular sex and drug education, for this limited time. One way to approach this problem has been to identify road safety with other public health issues, and to present road safety as part of a wider health and safety education programme. In addition, RSE can easily and effectively be incorporated into mainstream curriculum subjects. The benefits of this are to raise the awareness and consolidate road safety skills, knowledge and attitudes, but also, and perhaps more importantly for subject teachers, it provides a real and relevant context for learning that is shared by teachers and pupils. There are many examples of the application of road safety education to mainstream subjects, ranging from illustrating the use of seat-belts and brakes in cars in science lessons to role-playing issues around drinking and driving and speeding in drama lessons. Such lessons can be used to complement such schemes as “*Safe routes to School*”. This illustrates how education can complement engineering and enforcement measures.

As already noted, safety education is not confined to schools or even the school years. It can be complemented by parental training from an early age, resources already pre-exist before school and can continue after school. Through the school years, clubs outside school can provide further opportunities to participate in road safety education. For older children, road safety education and training should carry on beyond school at colleges and places of work through vocational training.

#### *Providers and deliverers of road safety education*

An essential part of planned and progressive programmes of road safety education is the integration of providers and deliverers. Key to this are road safety professionals, typically attached to the Police or local authorities. As already noted, the road safety professionals do not necessarily deliver programmes directly to children. More and more, they are responsible for planning and supporting road safety programmes and educating the educators. In schools, teachers have been identified as best placed to deliver RSE. However, they require the support of road safety professionals. Traditionally, police and local authority road safety officers gave one-off lectures to large groups of children, with a view to imparting knowledge and/or instilling positive attitudes to road safety. Such lectures are only useful if they are planned as part of a progressive programme and are followed up by related activities.

Training is required for teachers at the initial teacher training stage and while they are in-service. Training needs to be systematic across all subjects, so that objectives of road safety are well understood, clear, and easily incorporated into a wide range of educational activities. It is clearly important that:

- teachers and other experts (e.g. police officers) giving road safety instruction in schools should have up-to-date training equivalent to that required for other subjects on the school curriculum, backed by practical experience;
- governments and other bodies, including non-governmental organisations, involved in road safety work (e.g. local authorities) should ensure an adequate supply of teachers with suitable up-to-date training in traffic education;

- up-to-date manuals, workbooks and other teaching aids need to be available for use by lecturers and children.

Teachers are not the only deliverers of RSE and consideration needs to be given to the training needs of others such as parents. It is essential to encourage parents to take personal responsibility for instructing their children, starting before they start school and continuing throughout their development. Parents should be given the means necessary for them to participate in their children's road safety development, i.e. material, message, information.

Other health professionals are becoming increasingly interested in road safety. Examples include child minders, kindergarten teachers, community nurses, and health visitors. All of these groups need to be aware of the objectives of road safety education programmes and where they contribute to other educational goals and safety issues.

In addition, road safety professionals need to keep up to date with developments in research and in the field of education and related areas, and also in external issues that have implications for road safety education. For example, increased mass media attention on the abduction of children has heightened awareness of "*stranger danger*", and has resulted in more children being accompanied. Road safety education programmes must address issues such as personal safety in conjunction with appropriate organisations.

#### *Conditions for future action*

In order to be effective, i.e. to improve behaviour, road safety education programmes need to be rooted in practical training. Moreover, they need to be planned and progressive, starting with a child's first trip, continuing through primary and secondary school, and extending to vocational education. There is a need to create a demand for RSE programmes from users, communities and schools, while also co-ordinating national and local activities to raise the status of road safety education. In creating that demand, it is also essential to encourage groups to actively participate and to take responsibility for RSE programmes.

Governments and other providers need to work with deliverers to ensure that road safety education programmes are appropriate to local needs, are based on the most up-to-date educational theories and approaches, and that there are sufficient resources to support them. There are resource implications in the provision of educational and information materials and in the training of deliverers and children. This sets a challenge for governments and road safety professionals to consider innovative methods of incorporating road safety education into the development of children, for disseminating materials, and for ensuring deliverers understand and actively support RSE programmes.

Perhaps the most fundamental requirement, particularly where young children are concerned, is that road safety education should move away from simply imparting knowledge and rules, to developing practical training programmes closely tuned to the skills which are needed at a particular stage of the child's development.

#### *Other areas of education and training*

Contrary to the many educational programmes available for young children, very few intervention programmes for elderly pedestrians and cyclists have actually been implemented, far less

evaluated. The few items of evaluation available showed participants in such programmes to be enthusiastic about it; the practical approach was particularly appreciated.

Better knowledge of design, implementation and effects on safety of education programmes for the elderly is strongly needed. What little there is suggests at least that such programmes are welcomed by the target population. It is recommended that more effort should be put into developing and evaluating programmes based on a practical approach and specifically aimed at elderly pedestrians and cyclists. Such programmes should be locally based and their implementation necessarily involve local authorities. Programme development should call upon active participation of the recipients.

### ***VI.2.2. Measures to enhance visibility and conspicuity***

From the experiments reviewed in this chapter on measures to enhance visibility and conspicuity of vulnerable road users, it appears that retro-reflective markers accentuating the form of the bicycle or of a pedestrian and highlighting their movements are the most capable of enabling other road users to recognise them as pedestrians and cyclists.

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 would if the observer did not have these advantages. Conspicuity aids alone are not sufficient to secure recognition of vulnerable road users. Other measures, in general infrastructural ones, should indicate to the drivers of motor-vehicles that vulnerable road users should be expected on some roads or in some situations (e.g. the presence of bicycle lanes or pedestrian paths can set such expectations).

The most difficult 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 proportion of cyclists use their lights; conspicuity aids for pedestrians appear to be used even less.

### ***VI.2.3. Motor-vehicle characteristics***

The review of evaluated measures has shown that a number of changes in vehicle design, especially of car fronts, could lead to a substantial improvement of pedestrian safety. Such changes remain to be carried out on a full scale basis, through appropriate constraints or incentives.

Other promising measures are near-proximity and wide-angle mirrors on lorries, which 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. Since 1988, it has been compulsory for Danish lorries over 6 tons to carry these mirrors; a before-and-after study carried out over two four-year periods with a control group did not demonstrate the expected safety effect on the relevant accident type; however, over half of the 2 000 lorries investigated had poorly adjusted mirrors, which might have contributed to the lack of effect (Behrendorff & Hansen, 1994). The measure obviously requires further investigation.

### ***VI.2.4. Speed limiters***

Speed limiters on board vehicles have been designed for the purpose of ensuring that all cars in traffic keep within the speed limit; as such, they are very promising for road safety. The technique

currently under test involves fixed speed limits, but can later be made more flexible by placing transmitters on the road at locations where lower speeds are required, for example on links outside schools, when passing some junctions, at pedestrian or cycle crossings, etc.

From 1987 to 1993, the Department of Traffic Planning and Engineering, Lund, Sweden, carried out a series of research projects on safety potential and practical testing of a speed limiter installed in a private car. Literature surveys combined with round table discussions with experts completed the theoretical phase. From this work a long sequence of hypotheses were formulated which were to be tested in practice.

- The device examined (TempoMaster) ensured that the speed limit, defined either automatically or by the driver, could not be exceeded. When the driver started the car, the speed limit was automatically set to 50 km/h. Up to this speed, the car worked as normal, but close to the speed threshold, the driver felt a pressure on his foot from the accelerator pedal, and a continued acceleration was not possible. In the experimental car, two different fixed speed levels (30 and 50 km/h) could be chosen with push buttons. In the future, it should be, of course, possible to choose other suitable speed levels. Technically the equipment can be installed in any standard motor vehicle.
- Seventy-five persons from the public, asked at a public parking in the city of Lund, were invited to take part in the experiment. The test population was divided into three equivalent groups, and each group drove the 18 km long test route in real traffic three times on different occasions. The control group did not use the speed limiter at all, one group used the speed limiter during one ride and the last group used it during two rides. The first ride was always a reference ride to find out the drivers "normal" behaviour. The test route covered different urban traffic conditions. On the major part of the route, the legal speed limit was 50 km/h, but occasional parts had a limit of 30 or 70 km/h. Changing the speed limiter according to prescribed speed limits was done by the accompanying observer. The driver continued his driving as if the changing was automatic: the fundamental idea was to simulate a compulsory and automatic system for the project design. Evaluation methods consisted of automatic speed logging, standardised and qualitative observation of driver behaviour, TCT (Traffic Conflict Technique) observation, and interviews after every test ride.

The analyses of the collected data from 225 test rides, with and without the Speed Limiter (SL) showed:

- increased speed adaptation in critical situations with the SL; as a consequence a substantial reduction of serious conflicts was observed when the drivers used it;
- an increase of time consumption of 30 seconds during a 30 minutes trip with SL;
- acceptance or neutral attitude of 65 per cent of drivers to the SL-function, but increased acceptance with repeated test-rides;
- only marginal effects on fuel-consumption and air-pollution, based on modelling from the speed logging;
- lower and smoother speed during the SL-rides compared with the non-equipped rides (speeding was common in the reference rides).

Continuation and extension of this research project was planned for 1996-97, including development of the technical function and longer test periods for test drivers.

### VI.2.5. Telematics

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 have so far been developed for motorised traffic, and safety evaluations are not available yet. Recently, Levelt (1994) made an inventory of telematics projects for the benefit of vulnerable road users. Information on a number of systems at different stages of development was collected from literature and international correspondence. Some systems were being developed specially for vulnerable road users, others were targeted to a somewhat broader group, but were useful for vulnerable road users. Intelligent pedestrian crossings and electronic mobility aids for visually impaired people are two examples. Multifunctional transponders were thought to be helpful for cyclists. Access to public transport can be improved by the use of telematics in route choice, trip planning, and booking.

### VI.3. Literature

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## CHAPTER VII -- INFRASTRUCTURAL SAFETY MEASURES

This chapter about physical measures addressing the road environment has been divided into: infrastructural measures that have been evaluated in a safety perspective; and prospective infrastructural measures for which we have only a few examples of implementation, but which show promising results.

### VII.1. Evaluated infrastructural measures

#### VII.1.1. Speed reducing measures

As pointed out earlier when discussing accident factors, speed has a strong influence on accidents, both on the actual risk of an accident happening (primary safety) and on the severity of accidents that do occur (secondary safety). It is therefore essential to reduce speed in situations where vulnerable road users are to interact with motorised traffic.

##### *Roundabouts*

Roundabouts are often introduced to reduce speeds at intersections. The literature inventory shows that speeds do decrease at roundabouts but that the safety effects are not always those anticipated. Here, the similarities as well as the differences between a few studies and their results are brought forward.

In Sweden a comprehensive trial has just been completed in the city of Växjö, 70 000 inhabitants, a medium-size city fairly representative of Swedish built-up areas (Hydén, Odelid & Várhelyi, 1995). The research project started in 1986 with the aim of developing and testing a total traffic safety program for the city. It later focused on the evaluation of a general speed reduction in the urban area since lower speed is a precondition for the success of most other safety measures. The primary traffic safety goals were to obtain a sustained reduction in the number of casualties and to make vulnerable road users, in particular children and the elderly, the main beneficiaries of the measures. To ensure speed reduction on arterial roads, with special attention to junctions, 21 of these were changed into small roundabouts. The roundabouts were designed with small circular islands, a single lane circling it, and single lanes both on access and exit roads. The island itself was an “*upside-down plate*” of asphalt, over which long vehicles could pass when turning left. Diameters of the central islands ranged from four to 18 metres; only two of them exceeded ten metres in diameter.

To evaluate the safety effects, before-and-after studies were conducted. In order to analyse short term and long term changes, there were three periods of study: (i) before the implementation; (ii) directly after the implementation; and (iii) four months after the implementation. Several forms of analysis were performed in the before and after periods. Among these, traffic conflict and behavioural studies were the most interesting with respect to assessing safety effects. Results obtained from traffic conflict studies

were converted into estimated numbers of police reported injury accidents. Behavioural studies consisted in observing interactions from video-films and speed measurements.

At junctions, the average speed on arterial roads decreased by 11-18 km/h. Almost all speeding was eliminated. Speed decreased on the links between roundabouts, all the more when the roundabouts were closer together. When the distance exceeded 300 m, there was no speed reduction at all. The conversion into expected number of accidents of the conflicts collected on 11 out of the 21 roundabouts showed that the number of injury accidents and the total number of accidents were reduced at roundabouts. Compared to regular junctions: injury accidents decreased by 53 per cent, car occupant victims by 1 per cent, cyclist victims by 66 per cent, and pedestrian victims by 89 per cent. The primary goal was fulfilled. The reduction was significantly higher for vulnerable road users than for others. On road links between the roundabouts, the number of injury accidents as well as the total number of accidents were reduced by approximately 40 per cent. In non-experimental parts of the city, the number of injury accidents as well as the total number of accidents remained unchanged.

A study of zebra crossings at junctions showed that, in the before situation without roundabouts, 27 per cent of the drivers stopped to let pedestrians cross. In the after situation, after the introduction of roundabouts, this was increased to 50 per cent. The proportion of car drivers on the arterial road entering the junction that gave way to cyclists already in the junction increased from 13 per cent to 73 per cent. The proportion of car drivers on the side road entering the junction that gave way to cyclists increased from 77 per cent to 92 per cent. It can be concluded that the "main-road syndrom" decreased and that the side roads became more equal to the arterial roads. Thus, interaction between road users improved, which implied increased safety. The introduction of roundabouts did not seem to create any compensatory behaviour in terms of higher speeds outside the experimental area. Driving against red was also studied as an indicator of compensatory behaviour. The proportion of drivers red-running did not increase, rather the contrary. No rerouting of vehicle traffic due to the roundabouts was noted.

The study concluded that safety was considerably improved, particularly for the vulnerable road users, both through lower speeds and better interaction in traffic. It showed a very close relationship between speed reduction, improved interaction, and increased safety for vulnerable road users, the reason being that speed reduction makes it possible for motorised vehicles to detect the vulnerable road users in time. Also, lower speeds enable vulnerable road users to participate in traffic on more equal term, so that they dare to use their right of way more often. Based on these findings, it was estimated that, if a full-scale speed reducing system was built in Växjö in which 111 junctions would be changed into roundabouts, the number of police reported personal injury accidents would be reduced by 47 per cent at the roundabouts, while for the whole city, the reduction would be 27 per cent. CO and NO<sub>x</sub> and fuel consumption would be reduced by 1-2 per cent. At junctions, there would also be a slight general decrease in noise. Total time spent in traffic would be reduced. The cost of building 111 roundabouts was estimated to be 33-55 million SEK and the accident savings to 22.5 million SEK/year.

A study was carried out in Denmark with the aim of finding out how roundabouts ought to be designed in order to provide cyclists with highest possible safety (Danish Road Administration, 1994a). Seven urban roundabouts with different design were analysed through video recordings. Entry and exit flows, errors in the use of the roundabouts by cyclists, and interaction with other road users were recorded. At all roundabouts, the cyclists were in some way separated from motorised traffic, either by a solid white line forming an outer circle or by small islands. The conclusion was that cyclists do not obtain the same safety effect as motorists at roundabouts. Information available on the design of the evaluated roundabouts was rather poor, but all seven of them seemed to be rather large. Better traffic safety for cyclists could perhaps be obtained if the diameter was smaller, as shown by results from the Swedish town

Växjö. In mini-roundabouts, all road users have to share the circling area, which promotes interaction and safety.

In another Danish study (Danish Road Administration, 1994b), traffic safety was analysed at 82 roundabouts, of which 49 were in urban areas. The geometry differed between the roundabouts. The circular island had a diameter of 26 metres in the largest urban roundabout, and of three metres in the smallest, with an average of 14 metres. The number of injuries among car-occupants was reduced by 90 per cent, but the cyclist injuries were unchanged. The injury severity was overall reduced. The effects on cyclist injuries were unfortunately not analysed with regard to different roundabout designs.

A study was conducted in 1993 in the Netherlands to analyse the safety effects of “modern” roundabouts, defined as circular plazas with a central island which cannot be travelled over (Van Minnen, 1993). In general, the plazas were small with single lane traffic circling the centre, and single lanes both on access and exit roads. Depending on the geometrical design, speeds were affected to different degrees. Approaching traffic had to give way to traffic in the roundabout. Evaluation was based on accident analysis of some 300 “modern” roundabouts. After introduction of the roundabouts, the number of accidents was reduced by 47 per cent and the number of casualties by 71 per cent. The greatest reduction was among car occupant victims: 95 per cent. Pedestrian casualties decreased by 89 per cent, but cyclist ones “only” by 30 per cent. There were indications that different types of design for cycle use of the roundabouts were preferable at different traffic intensity and that this could be an explanation of this relatively “poor” result.

Finally, it is worth mentioning a survey of some 24 studies of roundabouts (Elvik, 1995) for a Norwegian Traffic Safety Manual. The studies were from different countries and included different kinds of roundabouts. From this survey, Elvik concluded that roundabouts reduced the number of personal injury accidents by 30-40 per cent. A few of these studies also investigated the safety effects of building roundabouts for different types of road users. They showed that pedestrian accidents were reduced to the same extent as other accidents; for cycle accidents, the reduction was somewhat smaller, “only” 10-20 per cent. The number of damage-only accidents increased at roundabouts.

In short, the few studies compared here produced encouraging results. In Växjö, Sweden, the effects of roundabouts were particularly promising for vulnerable road users. In Denmark, the results were better for the safety of motorised traffic than of vulnerable road users. In the Netherlands, the conclusions were similar to the Danish, showing better effects for traffic safety in general than for cyclist safety in particular, but a strong improvement for pedestrian safety.

#### *Other speed reduction measures and area-wide schemes*

In July 1991, a study by the Department of Transport in Great-Britain investigated measures for constraining the speed of vehicles passing through villages. Twenty four different village schemes were monitored:

- in 11 of the schemes, measures were only introduced on approaches;
- in four of the schemes, measures were mainly introduced within the village;
- the remaining nine schemes had measures introduced both on the approaches and within the village.

The aim of these schemes was primarily to reduce the highest speeds. Changes in the 85 percentile is a good indicator of the effectiveness of such a measure. For the 11 schemes without any measures within the village, the 85 percentile speed reductions within the village were very moderate. Depending on the effort put into the gateway treatments, the 85 percentile speeds at the gateways were reduced by 3 to 10 mph. For the 4 schemes relying only on measures within the village, the 85 percentile speed reductions were less than 3 mph. For the nine schemes introducing measures both within the village and at the most important gateways, the 85 percentile speeds were generally reduced by up to 9 mph at the gateways and by up to 10 mph within the village. The fact that these reductions appear to be small should not be misleading as the established relationship between speed, accident numbers and severities, indicates that even smaller reductions in speed are of great value. The general conclusion was that more significant physical measures are more effective in reducing speeds.

Another study where a whole collection of measures were introduced to improve safety was carried out by the Finnish National Road Administration (FINNRA, 1995). Here, the layout of the main road through Rantasalmi was revised. Pavements and cycle tracks were built on both sides of the main road in the central area of the town. The carriageway of the main road was narrowed to 6.5 m throughout and to 5.5 m at pedestrian and cycle crossings. The speed limit was lowered to 40 km/h in the central area. Pedestrian refuges were introduced at the pedestrian crossings. The carriageway was raised at the market place and the shopping area to promote safer crossing conditions for pedestrians. New lighting was also installed. Overall, the main road through Rantasalmi was given a more urban look. In an opinion survey, pedestrians and cyclists expressed their satisfaction with the improvements. They said that they felt that their safety had improved. The volume of traffic on the main road was reduced but the flow was unchanged into the centre, i.e. through traffic was reduced. Improved access did not result in longer waiting times at the junctions. A speed reduction was observed in the central area, particularly amongst heavy vehicles. Traffic noise was lower. Winter maintenance did however cause some problems, which were solved in part by snow ploughing with extra care.

In the Netherlands, the principle of a sustainable safe infrastructure is that every road is allocated a specific function, and is designed so as to meet optimally its functional requirements, and, most important of all, to guarantee optimal safety. In residential areas, the specific function of the street network is accessibility of destinations inside the area, while streets should also be safe as a meeting place ("habitat function"). 20-40 per cent of the accidents occur in streets with a residential function (SWOV, 1994). These accidents are scattered over entire residential areas, so that area-wide solutions to road safety problems are needed. During the 70s, the "*woonerf concept*" was widely applied, introducing mixed traffic on residential roads, with redesigned road space including wall-to-wall paving and speed reducing measures (obstacles to divert vehicle trajectories, chicanes, etc.). The first experiments showed that some care had to be taken in order to make sure that the various types of obstacles used did not create mutual visibility problems between drivers and children. The "*woonerf concept*" received legal status in 1976, in the new law. The predominant role of car traffic was reduced, and drivers were allowed walking speed only. Results of accident investigations carried out in 1984 indicated that application of the concept led to a reduction of the number of accidents of approximately 50 per cent.

Following the *woonerf* approach, other area-wide solutions to reduce speed and through traffic in residential areas were sought. In a 1993 study, data from 151 of these "*30 km/h zones*" in the Netherlands were compiled. The results showed a 22 per cent reduction of personal injury accidents. The magnitude of the reductions depended on the magnitude of the safety problems beforehand, and the design quality of the measures taken. *Woonerfs* and 30 km/h zones were both found to be efficient in reducing numbers of accidents, but due to the higher costs involved in the implementation of *woonerfs*, 30 km/h zones are particularly recommended.

Over the years, a large number of municipalities in several European countries have decided to introduce “*traffic calming schemes*” in residential areas, based on a legal speed limit of 30 km/h, and diverse simple speed reducing measures. In an English study (Mackie, 1994), different traffic calming developments in the United Kingdom were evaluated on the basis of speed and accident analyses. It was found that vertical measures were generally more effective in reducing speed than horizontal ones, and that measures needed to be repeated at frequent intervals to maintain low speeds. The different traffic calming measures compared were 20 mph (30 km/h) zones, road humps, raised junctions, rumble areas, and jiggle bars which are small raised areas across the carriageway designed to alert drivers and encourage them to slow down. In the 30 km/h zones, the most common traffic calming measure used was the round-top hump, followed by flat-top humps and raised junctions. The average speed at the humps was 13.2 mph (21 km/h) and the average speed between the humps was 17.4 mph (28 km/h), indicating that the calming measures were effective in physically enforcing the 30 km/h speed limit. Accident reductions ranged from 70 per cent for child pedestrian accidents to 29 per cent for bicycle accidents, with an overall accident reduction of 61 per cent.

Different kinds of speed-humps, including raised junctions, need different spacing in order to achieve the required mean speed of 30 km/h. On an average, speed-reducing devices need to be less than 100 metres apart. Accident data for 25 sites where humps were installed showed a 70 per cent reduction on the roads treated. Pedestrian accidents were also substantially reduced. Pedestrians were the group of road users that benefited most from the Traffic Calming schemes. Rumble devices were found to produce generally only small speed reductions.

Several Swedish studies confirm the benefit of using humps as speed reducing measures. In a study by Hydén (1981), humps were introduced at a four-way non-signallized intersection in the city of Malmö. The rule of giving way to traffic from the right applied. One hump was placed right in front of each pedestrian crossing, which made it eight humps altogether. Safety evaluation methods used conflict studies, speed measurements, behavioural observations, interaction studies and attitude studies. Safety was analysed before and after the introduction of humps. Conflict studies showed a big reduction in the number of serious conflicts after implementation of the measures. The reduction was largest for the conflicts involving vulnerable road users. The safety effect of humps was further strengthened by the fact that vehicle speeds were reduced by 20-30 per cent; the 85 percentile speed was reduced from 38 km/h to 24 km/h. Almost nobody drove faster than 30 km/h in the after situation, even though the speed limit had not changed from the previous 50 km/h. A majority of the car drivers, pedestrians, cyclists and residents of the area interviewed were in favour of keeping the humps and also of building more humps at “many more similar intersections”. However, ambulance drivers and fire engine drivers did express problems with the humps and were therefore very negative towards the measure.

Similar results had been found in an earlier study carried out in Great-Britain, but restricted to speed humps on residential streets (Baguley, 1982). The one-year evaluation study concluded that humps were effective in reducing speeds at all sites to an average journey speed of less than 27 km/h on the streets equipped with the facilities, and that traffic flows were reduced by varying amounts, depending on the proportion of through traffic and availability of alternative routes. Overall traffic flow reduction was 31 per cent. As a result of both effects, introduction of humps produced a reduction in the number of accident casualties of 64 per cent. The residents’ opinions proved favourable to speed humps on most sites, in spite of localised problems of vibrations caused by heavy vehicles. A side-effect was that the risk of accidents increased on some of the alternative routes, which brought up the need for more area-wide schemes; moreover, as in the Swedish experiment, fire and ambulance services disliked the humps as they added to the time necessary to respond to an emergency.

The Danish Road Directorate has also published their experience of reconstructing roads through smaller towns by means of “environment-priority” measures. This was very valuable since the possible alternatives were either by-passes or reconstructing the through-road to give top priority to through traffic. The term “environment-priority measures” stands for a collection of measures making drivers in through traffic aware of passing an area where lower speed is necessary, due to presence of vulnerable road users. Individual measures included information at the entrance of town, differences in paving on the through road, planting of trees and bushes along the road, refuges, differences in road width, vertical speed reducing measures. The results of this experience were very positive. The environment around the through road became more pleasant. An increased number of people within the town walked and cycled. Speeds and accidents were reduced. There was also a reduction of noise and of the barrier effect caused by the through road (Herrstedt, 1990).

Similar experiments were carried out in France in the 80s, in a demonstration project called “Better Towns with less Traffic”. Over 50 municipalities took part in the project, which consisted in re-designing a through traffic route and the adjoining area in order to reduce accidents, reduce the “severance effect” of the arterial roads, facilitate access traffic, local activities, and movements of vulnerable road users, and improve the living environment. The areas for which experimental schemes were designed included small towns and villages located on trunk roads, and parts of suburbs at the edges of cities where drivers were going through a transition between rural and urban conditions. Traffic on the main arterials could be up to 10 000 vehicles a day. A wide variety of measures and combinations of them were implemented, with the aims both of reducing speeds and of making drivers aware of the presence of other road users and of activities other than through traffic. They included roundabouts, speed humps, mixed traffic zones with wall-to-wall paving, broken-line kerbs, chicanes, as well as street side devices (plants, vertical poles or archways to indicate entry in a different type of area, special lighting, etc.), and avoided the more traditional vehicle-oriented traffic devices such as traffic lights (CETUR, 1990, OECD, 1990). Detailed evaluations could not be carried out due to the diversity of experiments and of actors involved, but a general evaluation of the demonstration project showed that speed reductions had been obtained in most experimental schemes, and accident reduction in almost all of them. There were some design problems in the villages. Exchange of experiences between the municipalities involved was intense during the project, and a growing number of French cities have subsequently adopted the same type of traffic calming schemes.

#### ***VII.1.2. Letting cyclists merge before a junction***

By making the road users approaching a junction more visible to each other and visible earlier, the risk of unexpected appearance is reduced and safety improved. One way to accomplish this is to let cyclists merge with motorised traffic on the approach to the junction.

A study carried out in Sweden (Linderholm, 1992) showed that red running cyclists were exposed to a 2.3 times higher accident risk than cyclists travelling on green. Cyclists going straight ahead on a cycle track displayed particularly high red-running frequencies, 3-6 times higher than cyclists riding on the carriageway. While accident risk for a cyclist in mixed traffic did not seem to increase to any great extent with growing flows of conflicting motor-vehicles, the same condition increased the risk for cyclists on cycle tracks. In mixed traffic, the risk per cyclist seemed to decrease with an increased number of cyclists; on a cycle track, the risk seemed independent of the bicycle volume. However, for left-turning cyclists, the picture was totally different; cyclists on the carriageway face a 4 times higher accident risk than cyclists on separate cycle tracks. Linderholm finally suggested that cyclists should be moved onto the carriageway some 30 metres before the intersection, but that if left-turning cyclists exceeded 20 per cent of cyclists going straight ahead, it was preferable to build a cycle track across the intersection.

The Danish Road Administration conducted a study to analyse the interaction between cyclists going straight ahead and right turning vehicles (Danish Road Administration, 1993). The study covered a new design where the kerb between the carriageway and the cycle track was faded 20-30 metres before the junction. The motorists and cyclists were separated by a 30 cm solid line instead. Behavioural studies were carried out before and after the modifications. Video recordings provided a basis for behavioural observations at seven signalized junctions. The general conclusion was that, at most locations, there was a positive change in behaviour defined as more early interactions and less late interactions. This was expected to have a positive safety effect concerning right turning cars and cyclists going straight ahead.

Another study by the Danish Road Administration analysed cycle tracks at non-signalized T-junctions (Danish Road Administration, 1994c). Five non signalized T-junctions were studied before and after modification of the design. Modifications included bringing the cyclists and motorised traffic closer together as they approached the intersection and the possible conflicting area. Cycle traffic was protected from motorised traffic by a solid line on the carriageway. At the intersection, the cyclists and the motorised traffic were separated again, to enable the cyclist to leave the conflicting area before the vehicle entered it or to give the cyclist enough time to perform a slight evasive action if the vehicle proceeded. The conflicting area was also highlighted with the help of either different surfacing or painting. Behavioural studies and conflict studies were conducted by means of video recordings. The results showed that cyclists had more early reactions in the after period. At three of the five junctions, behaviour of motorists was improved: they drove with more care. At the fourth junction, behaviour was unchanged and at the fifth one, data were too limited. At all junctions, the time interval between a vehicle leaving the conflicting area and a cyclist reaching it was prolonged in the after period. The time interval was however reduced in the situation where a vehicle passed behind a cyclist. This was not critical as long as the vehicle driver kept the obligation to give way to the cyclist. At all junctions, the number of serious conflicts was reduced from the before to the after period. Behavioural studies showed that the modified junctions had changed the interaction between cyclists and motorists in a way that appeared to promote traffic safety.

### ***VII.1.3. Advanced stop line for bicycles***

By introducing ASL (Advanced Stop Line) for cyclists, the conspicuity of these road users is improved. Vehicle drivers have the cyclists in front of them, in their direct field of vision, which decreases the risk for cyclists to unexpectedly appear “from nowhere”, a well identified accident factor.

In the Swedish study mentioned earlier (Linderholm, 1992), Linderholm used a collection of safety evaluation methods: the traffic conflict technique, to estimate expected accident frequencies; traffic flow measurements, to calculate accident risk; behavioural studies of speed, undesired behaviour and interactions; and interviews. Linderholm analysed the effect of a pulled-back stop line for motor vehicles at signalized junctions. A measure that other authors prefer to refer to as advanced stop line (for cyclists). The underlying hypothesis was that a recessed stop line for motor vehicles should promote bicycle safety since:

- the cyclists are in front of the vehicles and are therefore more visible;
- cyclists get a few metres bonus when the signal changes to green.

The advanced stop line was combined with a cycle lane in the carriageway. The cycle track became a cycle lane at some 20-30 metres before the junction. Analysis of the before-after situation showed that a recessed stop line for motor vehicles reduced the accident risk for cyclists crossing by about

35 per cent. The effect was partly due to modified behaviour when approaching the junction and partly to modification of the left turning behaviour. The risk was unchanged for cyclists going straight ahead. Car drivers seemed to respect the new stop line. It was found, however, that the cycle lane on the approach should not be too narrow in order to prevent the motorists from blocking it. The percentage of cyclists running against red increased somewhat, although risk did not increase since red running took place within the safety period.

In Denmark, the Danish Road Administration (1994d) carried out a study at four signalized junctions, where the stop line for motorists was recessed by five metres. Twenty to 30 metres before the junction, the cycle track became a cycle lane of reduced width, separated from motorised traffic by a white rumble strip. Behavioural studies and conflict studies were carried out before and after the modifications. They focussed on situations in which a free motor vehicle, with the intention of turning right, approaches the junction at the same time as a free cyclist is riding ahead. The situations were selected and analysed from video recordings. The studies concluded that there was an earlier reaction to stop for a red signal in the after period. At three of the junctions, behaviour of drivers of motor-vehicles was improved. After the implementation, the time interval between the cyclist leaving the potential conflict point and a vehicle reaching the same point, increased at three of the locations and remained unchanged in the fourth. In the before period, between 12 and 24 per cent of the drivers turned right straight in front of a cyclist. In the after period, only 3 to 6 per cent did. On the basis of these results, safety of cyclists could be expected to improve.

TRL in England (Wheeler, 1992) studied advanced stop lines (ASL) for cyclists at signalized junctions. The stop line was set five metres ahead of the motorists' stop line, providing a reservoir for the cyclists in front of the motor-vehicles. Analysis of video recordings concluded that the ASL made it easier for the cyclists to get into a good position before turning right (corresponding to turning left in most other countries). In Oxford, for example, the number of cyclists having a good position before turning right went from 57 per cent to 97 per cent. At Newark and Bristol, about 95 per cent of the cyclists were correctly positioned after the introduction of ASL.

#### ***VII.1.4. Other studies of cycle tracks and lanes***

Ekman and Kronborg (1995) produced a report based on an international literature review, and interviews with experts from Denmark, Finland, the Netherlands, Norway, and Sweden. The conclusion was that one bi-directional cycle track was cheaper to build than two one-way tracks, one on each side of the road, but that bi-directional tracks were, however, less safe for cyclists, since it made merging with car traffic before the stop line at a junction impossible.

Two reports worth mentioning here are studies by the Danish Road Administration regarding merging or separation at junctions vs links (1994e & 1996a). They concluded that cycle lanes and cycle tracks were safer than no cycle facilities between junctions. There were however problems with parked cars on cycle lanes. It was recommended that separate cycle tracks should be built on road links when the volume of motorised traffic was high and when speeds were also high. There were some remaining problems at smaller junctions regulated by obligation to give way: at these locations, the number of personal injuries increased when cycle tracks were built.

A report by SWOV (1994) produced conclusions similar to those of the Danish reports. When considering both intersections and the connecting links, there was no difference in safety for cyclists on separate cycle tracks compared to cyclists having to use the carriageway. When considering intersections

and links separately, it was found that separate cycle tracks at the intersections are less safe than cyclists mixing in traffic on the carriageway.

#### ***VII.1.5. Making junction design simple and improving accessibility for vulnerable road users***

A report by Ekman and Kronborg (1995), earlier referred to in VII.1.4, looked into traffic safety for pedestrians and cyclists at signalized junctions. The report was based on international literature review and interviews with experts from five different countries. The primary conclusion and recommendation by Ekman and Kronborg was that pedestrian- and cyclist-friendly control strategies and simple intersectional design were important for safety. Long waiting times created dangerous red-walking situations. Efforts should be made to design control strategies which minimized the waiting time for green or gave automatic green. Whenever possible, automatic detection should be introduced rather than a push-button device.

Pedestrians tend to make mistakes at complicated intersections. If pedestrians walk against red it does not necessarily create a very dangerous situation. Red-walking is a matter of fact and must to some extent be taken into consideration. Lower vehicle speeds do, for instance, relieve the consequences of red-walking. Giving pedestrians the green light for only part of their crossing is considered as a major safety problem by many experts. This problem is especially serious when bus or tram stops are built on refuges in the middle of the street. Typical pedestrian behaviour is to start crossing some seconds before receiving green, assuming that the signal will turn green very soon and that all conflicting traffic has red. Pedestrians assume they are safe and become, for that reason, even more vulnerable. Advanced control strategies for vehicles (public transport priority, protected left turners, early cut off etc.) are therefore often very dangerous since the signal setting is impossible to predict for the ordinary pedestrian.

Linderholm also looked into the problem of different signal control strategies and junction design at signalized junctions (Linderholm, 1987). The study focused on pedestrian safety, with the aim to examine pedestrian risk and change of behaviour when: (i) a signal was introduced at an intersection; (ii) different signal control strategies and geometrical design were introduced. The evaluation methods used were: the study of delays to motor vehicles and pedestrians; interviews with pedestrians whose behaviour had been registered; behavioural observations such as speed registration, red-driving and red-walking; traffic conflict studies. The introduction of traffic signals increased travel time for all traffic categories: motor vehicles' travel time by 30-120 per cent and pedestrians' by 50-150 per cent. The accident risk for pedestrians was estimated to have been reduced by 60-70 per cent at four-armed intersections, provided no red-driving or red-walking took place. Most red-walking took place during the safety period, the seconds before the light turned green for pedestrians. The accident risk while crossing on red was on average 4.5 times higher than while crossing on green. These findings and others from the same study led Linderholm to make the following recommendations:

- the signal function should be simple and easy to understand;
- the pedestrian crossing should be as short as possible, especially when crossing the exiting lanes of a junction;
- the zebra-crossing should be placed close to the junction.

## **VII.2. Prospective infrastructural safety measures**

Some physical measures have not yet been evaluated since they have only been implemented on an experimental level and not on a large scale. Examples of such measures are the microwave detection of pedestrians at signalised crossings and the speed limiter inside the vehicle. Despite the lack of proper safety evaluation, these measures do show very promising results. Other measures, addressing the road infrastructure, are still in need of further evaluation or must be better designed before producing their full expected effects. More research is needed on all the examples described in this section.

### ***VII.2.1. Local measures affecting road design and traffic management***

#### *Microwave detection of vulnerable road users*

The main objective of the project carried out at the European level on this issue was to find ways to reduce pedestrian risks in urban traffic by improving accessibility for pedestrians. An earlier project within the Drive I framework had shown that it was possible to make traffic signals more responsive to pedestrian needs. The aim was here to find out if this might have positive safety and mobility implications for the pedestrians. Different techniques for detecting pedestrians were examined and it was found that microwave detection would be the most appropriate method. A microwave detector could easily be attached to traffic signal poles and indications from the detector could be transmitted to the signal controller and integrated in an intelligent way.

The VRU-TOO microwave detection system detected a pedestrian approaching the signalized intersection and, when possible, changed the pedestrian signal to green as the pedestrian reached the crossing. The system was tested at three locations in Europe (Greece, Portugal and Great Britain). For all three sites, the flow of crossing pedestrians was important and there was a conflict between the time required by pedestrians to cross and the need to maintain the vehicular flow. The trials aimed at improving safety and mobility for the pedestrians without making the situation significantly worse for the vehicular traffic. The system could be manipulated in several ways. Here are examples of manipulations that were carried out at least at one of the trials:

- 1) triggering of the pedestrian demand to cross, before the pedestrian actually reached the crossing point;*
- 2) extending the length of the pedestrian green time if pedestrians were still approaching the crossing point;*
- 3) extending the length of the crossing time if the occupancy of the crossing was above a specified level;*
- 4) extending the length of the crossing time if any pedestrians were still on the crossing;*
- 5) bringing the pedestrian green time forward when pedestrian demand was above a certain level;*
- 6) reducing the pedestrian green time if no crossing pedestrians were detected.*

In all three locations, there was an overall reduction in the number of serious conflicts between pedestrians and vehicles. There were considerable variations between sites and between carriageways at the same site. No increase of the number of vehicles driving against red was observed. The average waiting time for pedestrians was reduced. The number of pedestrians arriving at a green light increased. No significant increase of vehicle queue length was observed, but there was a slight increase in overall journey time in Leeds (GB). The equipment was reliable throughout the trials with very little need of adjustment. Controls showed that all pedestrians were detected and there were no spurious detections that would cause false green time.

Other new pedestrian facilities include PUSSYCATS (Pedestrian Urban Safety SYstem and Comfort At Traffic Signals), reported by Levelt (1993). PUSSYCATS is a system adapted to pedestrian behaviour. The pedestrian light is moved to the nearside of the street, positioned so that pedestrians waiting at the kerb have to face oncoming traffic when looking at the signal. There is no light showing on the opposite side. The system consists of a pushbutton together with a mat detector, or a mat detector instead of the pushbutton, with infra-red sensors detecting the presence of pedestrians on the crossing. Pressure on the mat causes the mat to send a signal to the controller calling for green light. Moving off the mat stops the signal and the call is cancelled. The infra-red detectors are used to lengthen the clearance time up to a certain maximum, related to the speed of very slow pedestrians, or to large groups of pedestrians crossing.

The advantages of this system are threefold:

- the new location of the pedestrian signal “forces” pedestrians to face oncoming traffic while waiting for green, and makes the signal easier to see for people suffering from vision deficiencies, while a sound signal clearly indicates that the lights have switched to green for pedestrians;
- the mat detector increases the accessibility of the crossing for pedestrians;
- the infra-red detector ensures sufficient time to perform the whole length of the crossing under protection.

#### *Other measures to protect pedestrians when crossing*

Observations have shown that a significant proportion of drivers do not stop to give way to pedestrians on marked crossings. This partly results from old habits and attitudes. Drivers do not consider pedestrians as dangerous and estimate that it is easier for them to stop than for vehicles; pedestrians give up trying to impose their rights and wait for the car to pass, etc. Difficulties in interacting and misunderstanding may also play a part. Pedestrians do not like to cross the carriageway when a vehicle has stopped too near the crossing as they fear it may start again any time. Pedestrians do not well appreciate, and usually underestimate, the level of speed under which vehicles can safely stop at the crossing. On wide carriageways, pedestrians fear that a vehicle will overtake on the fast lane, etc. Pedestrians thus cannot take full opportunity of their rights to cross. One solution experimented in a number of European countries consists in painting a 50 to 60 cm wide stop line a few metres before the pedestrian crossing. It seems that such a measure leads to drivers better respecting pedestrian right-of-way at non-signalised crossings, and provides pedestrians with higher feelings of security at signalised ones. The best location for the stop line, according to Danish studies, seems to be 5 metres before the marked crossing, a distance equivalent to that adopted for recessed stop lines for vehicles used to protect cyclists at junctions.

Interaction between pedestrians and left-turning vehicles (or right-turning in the United Kingdom for example) is often poor. This may force pedestrians to stop and wait in the middle of the carriageway. The solution experimented on large junctions with heavy traffic has been to add a repeater traffic light at the exits of the junction. The few observations carried out so far have shown that these additional lights were well respected by drivers, provided that they are not located immediately after the corner of the junction, and that the driver's attention is attracted by a central refuge [on the off-side after the turn].

To help blind pedestrians move around, and particularly cross traffic, special auditory indicators of green light have been experimented in a large number of countries. However, there is no homogeneity in the design of these devices, and this may cause a problem for the blind users. There is a need to design a uniform auditory system to assist pedestrians with vision impairment. Similarly, a number of tactile indicators have been experimented to give warning to pedestrians of possible obstacles or unexpected features on their route, such as a central refuge, a contra-flow bus lane, etc., but all of them are still tentative.

#### *Measures to protect both pedestrians and cyclists*

At locations where a cycle track or a cycle lane passes a bus stop, conflicts occur between pedestrians getting out of the bus on the carriageway and cyclists on the track. Some experiments suggest that marking the pedestrian crossing across the cycle track may be an effective way to slow down cyclists. In any case, it seems that keeping the continuity of the cycle track or lane is highly preferable to getting the bus to draw up alongside the kerb if that means cutting in front of cyclists.

#### *Other measures to protect cyclists*

In heavy traffic, it is difficult for cyclists to position themselves at junctions to perform a turn to the off side of the road. In some countries, the traffic laws or regulations state that cyclists should cross a junction one arm at a time, like pedestrians. Even when this applies, cyclists often tend to take a direct turn as drivers do.

In order to help them get to the off-side lane before junctions without conflicting with motorised traffic, the solution experimented with has been to create a "reservoir" space after the traffic lights, where motor vehicles are not allowed during the red phase, but where cyclists can cross the carriageway to position themselves to the off-side, ready to turn. Designing such a reservoir is not easy, as some misunderstanding may arise as to its use during the green phase. So far, it has been generally recommended to restrict the implementation of such devices to streets with light-to-medium traffic, and a maximum of two lanes in each direction. In addition, pedestrian crossings should be equipped with a central refuge.

Probably because more care has to be given to the design of such measures, they are still considered dangerous in a number of countries.

## VII.2.2. Networks for pedestrians and cyclists

### *Cycle networks*

In urban areas, cycle networks have been planned in several countries, such as Denmark, with a view to promoting cycling as a means of transport. Wherever possible, links of the network are segregated from the general traffic streets. Cycle networks are designed to offer cyclists improved safety conditions, as well as more comfortable and pleasant conditions for travelling. In particular, they are less subjected to pollution and noise from motorised traffic. The Danish Road Standards include planning principles (Herrstedt, 1996), according to which cycle networks should:

- *be an integral part of global transport and traffic planning:* Design of cycle networks should be performed at an early stage of the planning process, as provisions for transport and smooth traffic operations are bound to be different if there are more cyclists, and they are less frequently mixed with motorised traffic.
- *ensure acceptable safety levels:* This is best achieved by constructing, wherever possible, segregated paths, designed in such a way as to encourage their use by cyclists.
- *provide accessibility:* Cycle paths should directly lead to and be in close contact with the most important destinations for cyclists, such as schools and other locations used by children; shopping areas; work areas; transport terminals; local administrative offices or services; sports facilities and recreation areas.
- *enable cyclists to use the easiest and most direct routes:* Cyclists are very sensitive to detours as well as to additional efforts caused by gradients; efficient use of cycle paths cannot be achieved unless they provide the shortest distance to cyclists' destinations, and stairs, steep ramps and any other feature increasing effort are to be avoided as much as possible.
- *provide continuity:* All individual parts of a cycle network must be properly connected in order to avoid detours and the sudden change of traffic conditions involved for the users that would have to mix into motorised traffic on part of their routes.
- *ensure clearness of lay-out:* Cycle networks should be designed so that users can easily find their bearings; the lay-out should adapt to the structure of the town or city, provide a clear view of the main landmarks so that cyclists know where they are and where they are heading, and direction signing should be available.
- *be adequately maintained:* Acceptable quality of surface on the whole width of a cycle path is extremely important for both cyclists's safety and ease of travel; it is a condition for obtaining full usage of cycle networks; maintenance includes keeping the surface in good condition as well as cleaning it from leaves, snow, or other agents generating skidding risks.
- *include parking facilities:* Cyclists usually like to park as near as possible to their destination; fear of theft of bicycles is a common problem; parking facilities equipped with security systems should be provided at the main destinations on the network, especially

those where bicycles are parked for long period of times (for example at transport terminals).

### *Pedestrian networks*

Some cities, such as in France, have similarly started to introduce pedestrian networks. A concept long ignored as only relatively short trips are performed by walking -- but the whole street network of a city is never entirely used for one trip by an individual driver. The main planning requirements for a pedestrian network are similar to those of a cycle network: ensure acceptable safety levels; provide accessibility to the most important destinations within the city; offer direct routes to destination (or otherwise strong incentives to compensate for a detour); provide continuity, adequate surface conditions, and proper maintenance. In addition, pedestrian networks need to include rest areas at well-chosen locations, in order to make longer walking trips possible, and to provide for social contacts.

Design of pedestrian networks is usually based on existing pedestrian routes (pavements along streets, pedestrianised areas, etc.). It consists primarily in ensuring safety, continuity, and comfort of walking by:

- creating new links to avoid heavy traffic areas;
- widening existing routes where needed in relation to pedestrian flows and ease of movement;
- clearing the way of all obstacles;
- improving crossing conditions at the contact points with arterials;
- ensuring good quality surfacing;
- providing direction signing; etc.

As implementing adequate pedestrian networks involves careful planning and often large scale changes in the urban infrastructure that are bound to influence or impose restraints on motorised traffic as well, care should be taken to ensure that the networks are effectively used by the largest possible number of people. This implies in particular that they should be adapted to walking conditions of elderly or disabled pedestrians, both in terms of physical lay-out (avoiding steep gradients, stairs, high kerbs, etc.) and of the facilities provided (special facilities for wheelchairs, aids for blind pedestrians, etc.).

### *Non-motorised networks*

Experiments have been carried out in several countries to design “non-motorised networks” to be used both by pedestrians and cyclists. So long as they have been well planned, such networks do not seem to generate safety problems between the two groups of vulnerable road users. However, the mixed use of the physical space must be clearly set. One promising application of such a concept of network is “the route to school”.

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## CHAPTER VIII -- IMPLEMENTATION REQUIREMENTS

### VIII.1. Complexity of road safety policies for vulnerable road users

There are two possible approaches in improving the situation of vulnerable road users in traffic. One is to consider, as in the past, that motorised vehicles have a right to a priority treatment on the roads and that pedestrians and bicyclists movements -- restricted as they must be in such a case -- are to be protected through local facilities and regulations that do not introduce unacceptable disturbance to motorised traffic. The other is to consider that walking and cycling are two useful transport modes with at least as much right to exist on the roads as the others, and that their needs and practical requirements have to be taken into account in the design of infrastructure and the organisation of the traffic and transport system, just as the needs and requirements of car, bus or lorry traffic have always been taken care of. More elements to protect vulnerable road users can thus be directly built in the system.

The first approach, which was basically the only one until the mid-1970s, still applies to specific traffic situations (rural roads outside villages, urban through-traffic routes, etc.). The second approach has at first been implemented in specific parts of urban areas (city centres, residential neighbourhoods). It is now becoming more widely acceptable in towns and cities, in view of the environmental and health problems related to motorised traffic as well as because it offers greater scope for progress in safety. The two approaches obviously generate large differences in the treatment of the road environment and the organisation of traffic, as well as in the legal environment. However the second approach, if generalised, will also induce changes in education and training, as it results from a significant evolution of attitudes in the public, and as the renovated traffic and transport system should function on the basis of new behavioural patterns.

Improvement of the safety of vulnerable road users according to the first approach is usually limited to very local measures which require the intervention of a relatively small number of actors, and possibly to technological innovations in car-manufacturing and in car-road interactions. Implementation of the first approach is relatively simple, implementation of the second one will far outreach the problem of vulnerable road users.

Focusing on the second approach, we find that designing policies for vulnerable road users involves very complex processes. To summarise a number of points which have already been made:

1. At the macro level, physical and legal measures to meet the needs and improve the safety of vulnerable road users cannot be designed without some intentions, and anyway impact, on travel conditions and mobility, both for themselves and other road users. Vulnerable road users compete against motorised traffic in terms of road space allocation and legal rights. In addition, satisfying their needs somewhat restricts the freedom of drivers (for example, as concerns speed). In view of the issues at stake, it is clear that policies oriented at protecting vulnerable road users cannot be implemented without consultations with all the actors involved in managing the transport system or representing the road users' interests.

2. There are different categories of vulnerable road users: pedestrians, cyclists (and possibly moped riders). The corresponding transport modes are non-pollutant, non-energy consuming (with the exception of human energy which is renewable), and they are, in most countries, accessible to the greater part of society. It is quite logical to consider vulnerable road users as one group when designing new (urban) transport policies. It is therefore also logical to treat their safety problems as a whole. However, at the micro-level, vulnerable road users are also competing against each other: space taken off car traffic has to be shared between pedestrians and cyclists and conflicts between them have to be controlled. As a consequence, the design of physical and legal measures to protect vulnerable road users requires trade-offs, not only between their interests and those of motorists, but also between the interests of the different parties in the group.
3. The extra-vulnerable road users, i.e. the disabled people, the elderly persons, and the children, need special attention. In some instances, their existence may justify some measures involving substantial changes in the environment or the expected behaviour of road users, that perhaps would not have otherwise been considered. In all instances, changes brought to the environment have to be checked as to their consequences for those with more limited mobility or abilities to cope with traffic. Taking into account these issues introduces an additional factor of complexity in the decision-making process, but one which cannot be eliminated while it becomes more and more widely acknowledged that adequate mobility should be provided for all.
4. Integrated policies to protect vulnerable road users (and possibly to enhance the use of non-motorised modes of transport) may include measures based on physical changes in the road environment, changes in the organisation of traffic and transport, new regulations, as well as a new content and adequate procedures for traffic education, driver training, or police enforcement. Such measures have to be co-ordinated, both in design and implementation, which requires an inter-sectoral structure of management (OECD, 1994).

It can be seen that any progress in this field requires thorough understanding of the trade-offs at stake in the choices of strategies at the macro-level, as well as sufficient knowledge of behavioural patterns to solve conflicts at the micro-level. Clearly, sound decision-making requires the support of research and the development of scientifically based tools to assess alternatives. Decision-making also involves taking into account political issues and making political choices, which implies, in democratic systems, wide consultation or participation of the parties concerned. Finally, the implementation of inter-sectoral policies makes it necessary to set up a co-ordinating structure that should enable decision-makers and professionals in different sectors of activity to take an active part and assume collective responsibility in the action planned.

## **VIII.2. Organisational requirements**

Organisational requirements to implement measures in favour of vulnerable road users are not, in nature, different from the requirements to implement road safety policies in general. However, they are particularly important in approaches that tend to put more emphasis on non-motorised transport, as the reversal of priorities implied is likely to meet with some opposition (in particular from car users or manufacturers lobbies). Any decision taken will therefore have to be well-supported, both by factual data and by a large social consensus. Implementation conditions should also be particularly well controlled in order to prevent negative reactions to stop action before it has had time to prove itself.

### *VIII.2.1. At the local level*

In most OECD Member countries, municipal authorities have a large part of responsibility (often full responsibility) in road safety and local traffic and transport matters. Even when subjected to national orientations or policies, they usually have the initiative in planning and implementing new schemes. Relationships between local policies and national policies may be quite loose, or they may be strengthened through various means: incentive programmes, pilot demonstration projects, allocation of targeted funds from the national government, provision of scientific and technical support from the national level, etc.

In any case, local authorities must develop the capabilities to diagnose their problems, define their own objectives based on the local problems and/or on national orientations, plan, design, choose the final measures and policies, decide, programme, and implement (OECD, 1990). The tasks involved can be classified broadly in three categories:

- scientifically based studies, including diagnosis, proposal of objectives for action, proposal of possible measures or courses of action to be included in the final policies;
- decision-making, taking into account scientific information as well as local political issues. It includes discussing the diagnosis and the proposals, formulating the objectives, selecting the preferred strategy, organise the funding of the scheme, setting up a timetable for use of funds and implementation;
- implementation activities, including detailed design of measures, planning for implementation, co-ordinating the implementation of associated measures, supervising implementation.

The scientific studies should be objective and performed by skilled road safety professionals or researchers. They provide the necessary background information and should remain unbiased by political considerations. The scientific team may be organised in different ways, according to local availability and to budgetary constraints, and may include qualified members of municipal services, professionals from local universities or research institutes, outside consultants, or professionals and researchers from the national administration or national institutes. The team needs to be multi-disciplinary, well aware of recent methods developed for road safety work, and should be engaged for a sufficient period of time to see the scheme through.

Decision-making is a long process, that requires well-established communication with the scientific team on the one hand, and with the professionals in charge of implementation on the other. In most cases, the decision-making structure will need to be formally set, as local actors concerned with the scheme may originate from very different backgrounds: locally elected representatives that have final responsibility of choices; representatives of the local (and possibly the national or regional) administration in charge of the road network; municipal services responsible for urban and transport planning; teachers and educators; enforcement agencies; representatives of the local society (road users, residents, employers, elderly and disabled people, local politicians, trade unions, etc.). For any complex and innovative policies to be accepted and properly implemented, it is essential that a solidarity should develop between all the actors, and the best way to reach this is to involve them at all stages of the decision-making procedure, and ensure that the trade-offs that have to be made reflect the best possible consensus (Muhlrad & Faure, 1989). Efficient co-ordination is indispensable to disseminate the background information, organise contacts and meetings, and enhance communication and good

understanding. All participants in the decision-making process should have sufficient authority in their structure of origin (or be properly mandated) to be able to take decisions on its behalf.

Implementation must be prepared and carried out by specialists belonging to the agencies concerned (normally all represented in the decision-making structure) and well aware of the objectives pursued and of the associations of measures whose design and implementation have to be co-ordinated. External consultants may also be needed to provide the skills not yet available at the local level (for example, when innovative measures are planned), or to supplement manpower. The different groups of professionals involved need to keep close contacts with the scientific team on the one hand, and with the decision-making structure on the other. They also need to be able to communicate with each other, to ensure inner consistency of the final scheme as well as conformity with the objectives and the strategic choices made by the decision-makers. Co-ordination of the measures which are part of the policies implemented is obtained through communication efforts of both the professionals and the co-ordinators at the decision-making level.

### *VIII.2.2. At the national level*

Improving the safety of vulnerable road users is usually one of the targets of a broader national road safety programme. Some measures -- such as introducing a specific content in driver training programmes or traffic education programmes; designing new laws providing the different categories of road users with different sets of rights and duties; reorganising police enforcement, etc. -- need to be homogeneous over the whole territory and are typically to be decided upon and implemented at the national level. Physical measures such as implementation of safety facilities for pedestrians or cyclists on the national road network are also centralised activities. All these courses of action need, of course, to be integrated and made consistent with other aspects of road safety policies. They also need to be given appropriate priority. At the national level, such trade-offs between road safety targets may be unavoidable (Mohan et al., 1994).

Most OECD Member countries have an intersectoral co-ordinating and decision-making agency responsible for defining objectives and priorities, and initiating national road safety programmes. The road safety authority may include a Parliamentary Committee (as, for example, in Denmark) with decisional or consultative powers, or an Inter-Ministerial Committee, also decisional (as in France) or consultative (as in Finland or in Spain), and legally instituted. In all these cases, there is a need for an executive body to assume daily decisions and promote practical action along the lines set by the higher authority. The executive group can be a permanent secretariat (as in Finland), or sometimes within a government department (as in France). The road safety authority may also be directly allocated to a government department (as in Sweden or Great Britain); in such a case, it will assume both policy decisions and promotion of action.

Most of these forms of organisation are still tentative and likely to undergo changes, but have succeeded to a large extent in improving road safety conditions in their respective countries. Safety programmes have evolved towards better integration of measures (Finland, the Netherlands, etc.), towards more ambitious targets of accident reduction (Sweden, Finland, France, Great Britain, Norway, etc.), and towards wider policies on sustainable transport, associating objectives related to environmental issues, safety, and energy saving (the Netherlands).

However, with responsibilities in road safety shared between national governments and local authorities, intersectoral co-ordination at the highest level is not sufficient. Some co-ordination and links must also exist between the national and the local decision-making structures. On the one hand, national

policies need to be relayed at the local level in order to become effective. On the other, effects of local policies need to be assessed and taken into account when formulating new policies at the national level. Some countries have thus organised networks linking the national road safety authorities with some level of decentralised ones (the Region in the Netherlands, the “Département” or county in France, etc.) in order to promote co-ordinated planning and disseminate the necessary information. Such networks usually imply some specific funding, at least for communication purposes.

Co-ordination with urban road safety policies is usually a difficult task, at least in countries where municipal authorities have a high level of budgetary and decision-making autonomy. Incentive programmes for local authorities, which may be either full scale programmes over the country or demonstration programmes involving a limited number of towns or cities, are one current way of getting local authorities to adhere to national policies. Incentives include of course at least partial funding of the operations, but may also consist in theoretical or technical help, organisation of exchanges of information or experience, stimulation of communication between the various territorial authorities involved, etc. Multi-disciplinary teams are usually formed to co-ordinate, give orientations for, and monitor, incentive programmes.

It appears much more difficult to gather and assess the effects of local safety policies at the national level. Evaluation is usually considered a lengthy and costly exercise, sometimes providing unwelcome results. The main problem, however, seems to be that there is generally no structure in charge of monitoring local road safety policies in a systematic way, on the grounds that local authorities are fully responsible for their actions and their budget, and the national government is therefore not entitled to more than an overview of their activities. Hence assessment of local practice has usually been performed only in the framework of incentive programmes, where at least some funding from the national level justifies monitoring.

There are therefore some elements of information missing when designing national road safety policies, especially having regard to vulnerable road users since much of the protective action in their favour is carried out at the local level. There is a case for suggesting that scientific agencies -- such as research institutes or universities, that can be considered “neutral” from an administrative and political viewpoint -- should design and supervise observatories of local safety policies, thus providing findings to the decision-makers, both at the national and local levels. Again, the funding for such activities can only be found at the national level, which requires some political will to build the tools necessary for real future progress in road safety.

More generally, it needs to be stressed that there cannot be good decision-making and policy planning in road safety without an adequate potential of research and studies. The more innovative and complex the course of action undertaken, the less its final outcome can be predicted both in quantitative and qualitative terms. A pool of experienced researchers is necessary for immediate advice as well as research planning to prepare future decisions and action design. The predictable characteristics of future transport and safety policies imply that the pool of researchers should be multi-disciplinary, with diversified experience, including accident and behavioural research, transport economics, transport planning and modelling, pollution and noise studies, legal aspects of transport management, etc. (Muhlrad, 1994).

### ***VIII.2.3. At the international level***

Countries function less and less as independent units and are becoming more strongly related to their neighbours or other countries in the world. This trend which is found in commercial and political

activities, is also relevant in the road safety field, if only because of the international circulation of people, vehicle and goods. It is becoming important to harmonise the travelling conditions in order to facilitate the adaptation of road users who move from one country to another. It is also considered important to homogenise vehicle fleets so that no country will inherit the left-overs of others with stricter regulations.

Existing international organisations, such as the United Nations or, more recently, the European Union, have long undertaken to harmonise the parts of road policies involving laws and regulations. International recommendations exist with regard to the highway code and road signs, organisation of goods transport, working conditions for professional drivers, etc. There is still scope for such activities as some discrepancies remain between countries, as can be seen from Chapter II. In general, the larger part of discussions at the international level seems to have focused on vehicles and drivers. Vulnerable road users have been mostly left aside, if only because their international movements did not seem, at first, to be so important. Very little has been studied as to the relative safety of pedestrians or cyclists finding themselves in alien environmental and regulatory conditions, when on holidays or on working trips.

Another aspect of international organisation for road safety is evaluation and research. Pooling efforts makes it possible both to get better funding for research studies, and to be able to undertake comparative research that is particularly relevant to a complex course of road safety actions or programmes at the national level, of which there cannot be too many at a time in a given country. Research institutes have long tried to co-operate, particularly on pedestrian and bicycle safety, often with the help of international organisations such as the OECD or the WHO for co-ordination and dissemination of findings. However, problems in co-ordinating funding from national sources have resulted in a near-impossibility to undertake co-ordinated experimental or follow-up studies.

European research programmes have gone one step further towards promoting international research activities by distributing a global budget. However, the process of selecting relevant research topics and generating international research teams is still tentative and is, for the research institutions wishing to get involved, extremely time and manpower consuming. Also, past research programmes have focused, once again, on vehicle and road technology, and vulnerable road users are only now being taken into account on a larger scale. New programmes aimed at promoting international research networks on topics which are not necessarily part of the pre-planned European programmes are under way. More progress will, no doubt, still be made.

### **VIII.3. Information and training networks**

Any innovative policies require that the professionals in charge of implementation should be adequately informed of their principles and trained to implement them. A fair amount of safety measures or programmes -- even when decided at the national level -- need the intervention of a decentralised network of professionals to be implemented. Information and training systems have therefore to be designed in order to convey the necessary knowledge. Conversely, the experience gained by professionals at different levels may be useful for other professionals and participate in improving the global information system. Research and evaluation studies should provide sound bases for all programmes. In what follows, examples of networks particularly relevant to safety of vulnerable road users are given.

#### ***VIII.3.1. Road safety education***

As seen in Chapter VI, road safety education will more and more involve not only teachers, but also traffic safety professionals, health professionals, and families. Road safety education takes place at

the local level, even if the contents of education programmes are designed at the national or State level. Several information and training networks are therefore necessary:

- one addressing the safety professionals who will participate in the monitoring or the delivery of traffic education, aimed at providing them with a consistent road safety “culture” and at updating their knowledge of safety-related problems according to progress made in research and practice;
- one addressing teachers, aimed at motivating them for traffic education, and at providing them with adequate knowledge of safety problems, as well as with useful pedagogical materials and the best means to integrate traffic education and other subjects;
- one addressing health professionals, and pursuing similar goals as mentioned above;
- one addressing families, aimed at making parents aware of the part they should play in educating their children to behave in traffic, and providing them with the necessary knowledge of what and how to teach, in relation to the children’s age.

The contents of the information conveyed through the four networks should, of course, be consistent, and should be an integral part of the design of education programmes. However, the frameworks for delivering information may be quite different for the four groups of potential educators, if they are to rely on existing structures. Teachers as health professionals may be reached at the initial stages of training in professional colleges or universities, but will also be in need of regular recycling courses within their professional set-ups. Road safety professionals may come from different backgrounds and be found in different sectors of activities (road engineering, police enforcement, etc.), and regular specific courses have to be offered. Finally, specific information structures to get in touch with families have to be set up. Of course, the four groups of actors concerned may interact already at the training stage, with, for example, experienced safety professionals taking part in training teachers, or teachers taking part in programmes for parents.

### ***VIII.3.2. Driver training improvement***

If, in the future, traffic and transport organisation requires changes in attitudes and behaviour towards vulnerable road users, such changes will need to be induced by new elements of information or new rules introduced in driver training programmes. Driver training is usually delivered through a network of driving schools at the local level. Materials defining the changes and helping to teach them will need to be delivered to all driving schools. Moreover, driving instructors have to be made aware of the changes and of their usefulness and given incentive to adapt their teaching. New driving instructors can be trained adequately, but those already in function need to undergo some recycling.

### ***VIII.3.3. Facilities for pedestrians and cyclists on the national road network***

Improvement of the national road network is usually in the hands of a governmental administration, but implementation is, of course, decentralised and performed by teams at the local level. Items of national road safety policies such as, for example, protection of vulnerable road users in villages or small urban areas located on trunk roads, need to be taken up by road professionals at the regional or county level. When specific courses of action have been found useful and are recommended at the national level, local teams have to be reached through a relevant information network in order to:

- understand the level of priority allocated to safety of vulnerable road users in national safety policies, and to calibrate their efforts at the local level in accordance;
- fully understand the goals and principles of action of the measures recommended, and to gain the necessary knowledge to design them or adapt them to the local context, in such a way that the measures implemented work as intended and do not induce unwanted side-effects;
- get increased awareness of the need to involve local partners in the design and implementation of the measures, and increased abilities to organise and manage meetings and working groups;
- understand the need for monitoring projects.

Guidelines may be provided, but seminars or courses are usually particularly useful to get the message across and ensure that basic principles are well assimilated, while some flexibility in the design of road improvements remains.

#### ***VIII.3.4. Traffic calming and area improvement schemes***

Traffic calming schemes and other area improvement plans are usually in the hands of local city authorities, and therefore not subjected to central government. However, they may be part of national policies, and the object of strong recommendations, or of incentive or demonstration programmes. In any case, there is a need to organise information and training networks involving both central and local actors, and aiming at:

- providing local authorities with all necessary information on traffic calming schemes (goals, principles, diagnostic approach, design of measures, physical elements that may be combined in the design, etc.), and making them aware of the various local actors that should be involved as partners (CETUR, 1990);
- helping local authorities of different towns or cities to co-operate on the design of traffic calming schemes, and to exchange information, ideas, and experience;
- making local authorities aware of the need to monitor and evaluate the schemes, especially those involving innovations, and to make results available to other local authorities and the road safety professionals;
- gathering evaluation results from local sources in order to assess the effects of traffic calming schemes at the national level and to improve know-how for further implementation.

In addition to information, the networks may also provide research and expertise, as local authorities, especially in small towns, do not always have enough trained safety professionals to manage operations that require sound adaptation to the local traffic and social conditions.

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## CHAPTER IX -- CONCLUSIONS, POLICY RECOMMENDATIONS AND RESEARCH NEEDS

### IX.1. Conclusions

#### IX.1.1. *Vulnerable road users and their environment*

In most OECD Member countries, there is a growing trend towards transport strategies that give greater importance to non-motorised traffic -- which is less energy-consuming and polluting than motor-vehicles, and more accessible -- and to improved mobility for the most vulnerable road users, the elderly and the disabled. In order to understand safety and mobility problems of vulnerable road users and to be able to plan accordingly, it is essential to understand the environments in which they live and move.

The *regulatory environment* of vulnerable road users is not homogeneous in the OECD Member countries, although there are common frameworks and common features (see Section II.3). Traffic rules and regulations vary in forms (i.e. laws, decrees or regulations) between countries. General rules were formulated in the Vienna Convention and have been accepted by OECD and other countries; they are usually complemented by rules or laws enacted at the national level. Most of the traffic rules have as a primary aim the orderly movement of motorised traffic. Analysis of the content of laws and regulations shows that:

- *Pedestrians* are mainly considered to be external elements, needing protection, but at the same time disturbing traffic and having to be restrained in their movements; and that
- *Cyclists* are treated as a hybrid between pedestrians and drivers; they must follow general driving rules, but in some instances are expected to behave as pedestrians, for instance when turning to the off-side at junctions.
- Every national legislation exhibits significant concerns about the special vulnerability of *children, elderly and disabled* people. However when rules are established, they seldom refer to these very vulnerable road user groups and almost exclusively mention the extreme care to be observed by drivers.

The legal environment tends to evolve with changes in population attitudes. Giving greater priority for non-motorised modes of transport in the organisation of traffic could have beneficial effects as pedestrians and cyclists may comply better to rules that are tailored to their needs and less restrictive of their mobility.

In a number of OECD Member countries -- where the trend is to gradually improve the status of vulnerable road users in traffic -- attitudes are already changing and a number of rules reducing the rights and freedom of movement of pedestrians or cyclists are gradually becoming obsolete. For instance, crossing outside a marked pedestrian crossing is no longer considered by judges as the determining factor in an accident and some responsibility is always attributed to the driver.

In the same vein, rules which used to be common to all countries are in the process of being modified. For example, in the Netherlands it is no longer compulsory for the pedestrian to cross the carriageway only at pedestrian crossings, even if one of these facilities is nearby.

In OECD Member countries, the *road environment* of vulnerable road users has evolved over the years and bears the mark of successive attitudes and priorities of society, embodied in the designs of planners and engineers (see Section II.4). However, changes occur at a different pace in different countries or different cities. As a result, the physical environment of vulnerable road users is heterogeneous:

- On most *inter-urban roads*, priority has remained with the car. Roadsides are often not equipped to suit the needs of pedestrians or cyclists. Better facilities may be provided for walking through villages or small built-up areas. However crossing facilities still demand greater attention from pedestrians than from drivers. They are implemented so as not to further impair motorised traffic, already considered to be penalised by a severely restrictive speed limit (50 km/h in a majority of countries).
- *Transition zones* between built-up and rural areas, and the neighbourhood of radial arterials in the larger cities seem to be critical locations. Infrastructure details are still often unclear as to which aspect to emphasise, through-traffic or local activities, although new schemes aimed at stressing the urban character of the road infrastructure and at reducing speeds of through traffic have been experimented in a number of countries.
- In many *old and dense city centres*, traffic has been reduced, and public transport has partly taken over, so that pedestrians and, in some northern European cities, cyclists are getting a more and more comfortable environment to move in.
- Many *residential areas* have also been either built or altered to avoid through traffic, or redesigned as traffic calming areas (or 30 km/h zones). However, comprehensive networks -- with appropriate continuity and safety -- for pedestrians and cyclists across cities are only starting to be introduced as part of the transport planning process. This is a first step towards considering pedestrians and cyclists as fully-fledged road users, whose movements need not be confined to a limited area, whether a city centre or a residential neighbourhood.

Only few countries can boast of a physical environment taking good care of the most vulnerable road users. Although a number of design features have been meant primarily for the safety of children -- particularly in residential areas -- children are still very much at risk in other parts of towns.

As to elderly people, they often have to cope with traffic lights or crossing conditions meant for more alert pedestrians or cyclists, and with pavements or footpaths left with obstacles or littered, or, in winter conditions, slippery with uncleared leaves or snow. The attempts made in the past at building overpasses or tunnels for pedestrians, have been particularly penalising for elderly people or anybody with reduced mobility.

Few cities have designed specific facilities to promote mobility of the disabled. Some experiments of tactile or auditory guidance for blind pedestrians along routes or at crossings have been made, but these devices are not of general use in any country and are not homogeneous. However the experience of Japan having widely introduced tactile surface indicators is worth noting. Some cities have endeavoured to organise pedestrian networks usable by all, including wheel-chair users, but such examples are still rare.

In summary, the road infrastructure is supposed to be designed as a support for transport activities, and thus to be adapted to the needs of the various road user groups. In fact, care has mostly been taken in the past to adapt road networks to the needs of car, lorry, or bus traffic, at the expense of vulnerable road users whose needs and requirements were introduced only after most details of infrastructure had already been fixed. Trends in OECD Member countries are now slowly reversing towards a more balanced situation between motorised and non motorised traffic.

The *social climate* for vulnerable road users is influenced in many ways (see Section II.5). In spite of differences between the various countries, the perception of pedestrian behaviour in most OECD Member countries is very similar: pedestrians are not considered to be very well behaved. Pedestrians are unwilling to go out of their way to cross the road at crossing facilities. Cyclists, especially in the younger age groups, also tend to take risks. Research has found that pedestrians are unwilling to accept that their intentions may be difficult to predict by the driver, and that they bear some responsibility for their own safety. However, the rules protecting vulnerable road users, in particular priority of pedestrians on a zebra crossing, are not well observed by drivers, especially when the enforcement level is low.

As pedestrians cannot feel protected by facilities implemented according to rules with which drivers do not comply, it is not surprising that they should be reluctant to make efforts and accept a restriction to their movements without the compensation of improved safety. In addition, the physical environment of towns and cities creates a social environment: the extent to which pedestrians and cyclists are subjugated to the needs of motorised traffic influences the priority accorded to them by drivers, i.e. their social standing, and can affect their willingness to move about. As the physical environment has been modelled in part to reflect the laws and regulations enacted to organise motorised traffic, its effects on drivers' attitudes towards vulnerable road users may be in contradiction with the effects that driver training and information policies seek to obtain, and with the need for all road users to act responsibly as conveyed through training, education and publicity.

However, although pedestrians and cyclists must take some responsibility for their safety, their ability to protect themselves is limited. In particular, children -- even if well taught in the principles of safe road crossing -- cannot be relied upon always to follow the rules, and often act unpredictably. This is increasingly being recognised, and in Germany and Great Britain for example, the approach is to place more of the onus for child safety on the driver not the child, in residential areas where children may be expected to be on the roads. In recent years, there is a trend to "deregulate" road users' behaviour, calling upon the road user to determine the safest and most correct behaviour to be adopted.

This changing emphasis also needs to be followed through in road safety publicity. Publicity programmes aimed directly at children, pedestrians, and cyclists may be of limited effectiveness, although more effective as part of a programme of road safety education. This approach, however, runs the danger of reinforcing drivers' preconceptions that they have little responsibility for the safety of others. Recent publicity programmes have addressed this problem through directly targeting speeding behaviour in residential areas. Such campaigns focus in particular on the consequences and social unacceptability of driving too fast. The ultimate aim is a change in the social climate of speeding as normal acceptable behaviour, and increased awareness of the needs of vulnerable road users.

### ***IX.1.2. Vulnerable road users in traffic: mobility and safety***

In order to adequately plan for vulnerable road users, it is very important to identify precisely their mobility patterns. In other words, it is important to know both their actual travel activities and their wishes for travel in the future (see Chapter III). People's transport needs are not always equal to their

actual travel activities. It is therefore important to know of any factors that may prevent people from fulfilling their transport wishes, e.g. their possible fear of getting involved in an accident or their feelings of insecurity. For example in some countries, there are indications that children are less and less often left to make trips on their own. Elderly people seem particularly prone to trade off between mobility and safety or security (at night, for instance). Lack of “friendliness” of the road infrastructure towards pedestrians and cyclists is a deterrent, as it makes walking or cycling both difficult, even strenuous, and dangerous. Too little research has yet been devoted to these issues.

Some countries have conducted national travel surveys which among other things, show people’s travel by different modes and also by purpose. In order to know people’s actual transport patterns, surveys should be conducted in all countries on an on-going basis. In this way, the evolution of travel activities over the years will be known. The proportion of elderly people is increasing; similarly, the number of disabled persons is also growing, and the mobility needs of these vulnerable road users are now taken into consideration to a larger extent by decision-makers and planners. Changes in mobility patterns are likely to occur in OECD Member countries with changes in population age structure. Economic changes will also influence both mobility demand and supply.

Nowadays, methods to collect data differ from one country to another and it is therefore difficult to compare results. Moreover, trips are usually classified according to the main mode used, which hides the fact that almost all trips include a part of walking (or cycling). Most surveys also exclude short trips, which leads to underestimation of walking and cycling. Also, assessing and comparing public transport data without a comprehensive picture of the offer of transport in different countries or cities remains a difficult task.

In summary, available data show that, in OECD Member countries, most trips are still performed using a private car, but that a significant proportion (20 to 40 per cent) are however performed by means of walking or cycling. Cars are still frequently used even for trips under 5 km. Frequency and length of walking or cycling trips vary according to the age-group. One of the main determinants of the modal split seems to be the level of car ownership.

Any action taken to alter environment or traffic conditions has an effect on mobility in terms of number of trips and modal split, as well as on safety, in terms of accidents, injuries and feelings of insecurity. Policies aimed at promoting non-motorised transport would therefore need to integrate safety in transport planning and road design or improvement. Any attempt at reducing the number of accidents involving vulnerable road users through a decrease of exposure rather than a decrease in risk is therefore bound to have negative side-effects on mobility and hence on social integration.

To assess the safety of vulnerable road users, the IRTAD database is very useful as it provides harmonised definitions at international level for accident data (see Chapter IV). However, these data are limited in that they only allow comparison of fatal accidents. To better identify the safety problems of the various groups of vulnerable road users, more detailed accident statistics available at national or even local levels were analysed for the purpose of this study. There are large discrepancies in the way such data are collected and processed, due to varying definitions of travel modes, road categories, road user groups, level of accident severity. This makes it difficult to compare accident figures and accident circumstances at the international level. Although it is not possible to provide a complete and accurate picture of all the problems faced by vulnerable road users in OECD Member countries, some general features clearly appear from analysis of accident statistics. They can be summarised as follows:

- Car occupants account for the larger part of road fatalities in OECD Member countries, but
- Pedestrians are the second group almost everywhere, with 15 to 30 per cent of fatalities, except in the Netherlands where cyclists account for more fatal accidents than pedestrians.
- The elderly account for the larger share of pedestrian and cyclist fatalities in European countries and in Japan.
- Accidents involving vulnerable road users are more frequent in urban areas than on rural roads, but are, as a rule, more serious on rural roads.
- Children tend to get involved in accidents more often on minor roads, which is consistent with their exposure patterns.
- Most serious and fatal reported accidents to cyclists have been found to occur at junctions, either road junctions, or crossings between a street and a cycle track, but there are indications that falls may occur more frequently on road links.
- A significant proportion of accidents seem to occur at locations with facilities for pedestrians or cyclists (pavement, marked crossing, cycle track); and finally
- Too little is known of the number and circumstances of accidents involving disabled people. Statistical data do not mention them as separate groups and specific studies are therefore needed to assess the size and characteristics of the problem.

Accident statistics are well suited to overall nation-wide safety assessments, although risk assessment is made impossible by the lack of exposure data relevant to vulnerable road users. But there are some major drawbacks when it comes to using accident data analysis for preparing local traffic safety work and evaluating local safety measures. Statistically speaking, accidents are rare events. Moreover, accidents involving vulnerable road users have been shown by studies carried out in different countries to be heavily under-reported by the police (see Section IV.3). The more detailed police investigation reports provide the reader with little information about processes leading to pedestrian or bicycle accidents, especially about the role played by the road and traffic environment. Without this knowledge, it is very hard to propose effective safety measures. Road safety work cannot therefore rely only on police based accident data, but generally requires the complement of specific accident investigations and complementary or surrogate data based on observation studies.

### ***IX.1.3. Vulnerable road users and accident factors***

To design efficient measures, an assessment of the magnitude of safety problems and the identification of priority targets for action are not sufficient: it is also essential to understand what processes contribute to generating future accidents, and what factors are likely to play a key role in them (see Section V.1). Both epidemiological and clinical approaches based on one form or other of accident data have been used to this purpose. For local traffic safety work, it is also necessary to use intermediate methods to provide complements or surrogates for accident analysis, based on direct traffic observation of events resulting from processes similar to those of accidents, or on the observation of particular characteristics of traffic behaviour and analysis of their determinants. Traffic Conflict Techniques have proven to be a valid, reliable and very effective tool for safety evaluation and diagnosis. As changes in speeds are at the root of a large number of measures to improve safety of vulnerable road users,

measurements of speed as an intermediate variable have also been widely used. Studies and research based on all types of approaches, or combinations of them, have been reviewed to describe accident characteristics and factors.

There is a close relationship between *speed* and safety, at two levels:

- the probability of an accident occurring increases with the traffic speeds involved; and
- the injury severity of an accident depends on the collision speed (see Section V.2).

For example, the probability for a pedestrian of being killed is eight times higher if the collision speed is 50 km/h compared to 30 km/h. When speed can be identified as a contributory factor in accidents involving vulnerable road users, it usually means that the approach speed of the colliding vehicle was too high relative to the reaction time needed to respond to incidents likely to occur in the surrounding traffic situation. A number of studies have also shown that obtaining better respect of the 50 km/h speed limit by drivers in urban areas would, in itself, significantly reduce the number of accidents to vulnerable road users.

*Lack of communication* between road users is another factor affecting the safety of pedestrians and cyclists. In urban areas, interaction between road users is the basis of traffic operations. Safe interaction implies that road users both correctly understand their respective status in traffic, and have enough time to adapt their movements and behaviour in relation to each other's position and action. Lower speeds obviously promote safer interaction. The same applies to clear and simple infrastructure design and good mutual visibility. Parked vehicles and roadside obstacles have often been identified as active factors in accidents involving vulnerable road users, particularly children.

*Differences in expectations* between the various types of road users is a contributing factor to accidents involving pedestrians and cyclists. This occurs particularly in situations where one group feels protected and adapts accordingly while another group is unaware of such safety feelings and therefore expects more careful behaviour. This is the case, for example, on zebra crossings where priority to pedestrians is not systematically accepted by drivers. All forms of risk-taking by either drivers or vulnerable road users are likely to create differences of expectations, as well as non-compliance with the right-of-way. Infrastructure design, when it does not show clearly where priority or right-of-way is, or where vulnerable road users are supposed to come from, obviously contributes to wrong expectations. Intersections between carriageways and cycle tracks are particular locations where infrastructure design often creates problems. Lack of conspicuity of vulnerable road users is bound to make such situations worse.

*Other prominent factors* include: lack of data gathering and insufficient information handling by the vulnerable road users, which particularly occurs when pedestrians or cyclists travel on a familiar route; and some perceptual problems experienced by children and by the elderly -- particularly with regard to assessment of speed of approaching vehicles, time gaps, and distances -- that may be worse at night-time. Children have been found to have insufficient knowledge of traffic rules, both as pedestrians and cyclists. Very young children are often found on roads whose traffic conditions they have not the abilities to cope with; this may be with or without approval of their parents, which calls for specific measures addressing families. Finally, excessive alcohol consumption has been observed in a significant proportion of accidents involving pedestrians or cyclists, either on the part of drivers, or on the part of the vulnerable road users themselves. Alcohol involvement is one aspect of a larger society problem, which cannot be solved only through traffic safety approaches (see Section V.2).

#### ***IX.1.4. Vulnerable road users and safety measures***

Many types of “*non-infrastructure*” measures to increase the safety of vulnerable road users can be distinguished. Given the limited time frame available to complete the study, it was not possible to fully document all evaluated measures. Only selected areas -- including education and training, measures to enhance visibility and conspicuity, and protective devices for cyclists (bicycle helmets) -- where promising advances are still anticipated, are discussed in the report (see Section VI.1).

When dealing with the issue of vulnerable road user 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, infrastructure facilities, 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, i.e. in terms of accident involvement. Examples show that the effects of Traffic Clubs for children are still inconclusive. Contrary to the many educational programmes available for children, very few intervention programmes for elderly pedestrians and cyclists have actually been implemented. Although the evaluation of an education programme aimed at elderly pedestrians in Japan does not demonstrate an effect on accident involvement, a questionnaire study showed that participants in the programme were enthusiastic about it. Especially the practical approach was valued by the participants.

From the review on measures to enhance the *visibility* and *conspicuity* of pedestrians and cyclists, it appears that retro-reflective devices accentuating the form of the bicycle or person (pedestrian), and highlighting their movements, are the most capable of having these road users recognised as such. However, 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, expectation is a very important factor in visibility: on average, when an observer knows what is ahead and where he should approximately encounter the “obstacle”, it will be detected at twice the distance than when the observer does not have this information. Conspicuity aids alone are not sufficient to secure recognition of vulnerable road users. Other physical measures should indicate to motor vehicle drivers that vulnerable road users could be expected on certain roads. The most important problem is probably not the effectiveness of visibility aids but rather encouraging more widespread use of even the most basic aids in darkness. Only a small proportion of cyclists use their lights and conspicuity aids. For pedestrians, these devices appear to be used even less.

Research has shown that the use of *bicycle helmets* can markedly reduce head injuries among cyclists. However, in most countries only a minority of children and adults wear helmets. In several States in the USA and in Australia, compulsory usage of bicycle helmets has led 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 OECD Member countries, it appears that such legislation is not yet feasible; both governments and cycling organisations are not willing to make helmet use mandatory or await high usage levels before planning to launch legislation. Therefore, bicycle helmet use must be promoted on a voluntary basis. This is not an easy task, because negative attitudes to the usage of helmets generally exist among both adult and child 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 with helmets offered at reduced prices, availability of attractive, colourful and sporty cycle helmet designs, as well as clear safety standards, are important factors.

*Prospective non-infrastructure safety measures* for vulnerable road users are (see Section VI.2): “*life-long*” *traffic education* to be integrated with the more traditional areas of education, and involving not only teachers, but safety professionals, health professionals, as well as associations and the families; *training processes and networking* to be set up in order to provide adequate safety culture to the deliverers of education and keep their knowledge of accident factors and pedagogical approaches updated; guidelines to traffic education have already been produced; *education programmes for elderly* road users may be quite promising, provided they are based on a practical approach and rely on the active participation of the elderly in designing such programmes; greater use of *conspicuity aids* for pedestrians and cyclists, and promoting *acceptance* and use of bicycle *helmets* are still prospective measures in most countries, and should prove most useful. Improvement of *motor vehicle equipment* such as *speed limiters* and the use of new technologies such as *telematics* are also promising.

The *evaluated “infrastructure” measures* reviewed include essentially speed reducing measures for use in urban areas, various infrastructure facilities for cyclists, and specific elements of junction design (see Section VII.1).

The most efficient *speed reducing measures* are those that make driving above a designated speed physically impossible. A good example of this kind is the introduction of roundabouts. The safety benefits of roundabouts depend very much on the local conditions. Pedestrians and especially cyclists experience safety problems at the larger roundabouts. Integration of cyclist and car traffic at small roundabouts -- where they have to share the entrance, the circling area and the exit -- works well at low traffic volumes; at higher traffic volumes, a separate bicycle lane is recommended. Evaluations of series of roundabouts at successive junctions showed large reductions of the overall number of injury accidents and high cost-effectiveness, although the benefits were less for cyclists than for other road users.

Besides roundabouts, other good speed reducing measures are those that use differences in levels in order to slow down traffic, e.g. humps, elevated pedestrian and cycle crossings or elevation of the whole intersection. Well-designed humps have proven to be successful in ensuring traffic speeds under 30 km/h. Measures like narrowing the carriageway and installation of central pedestrian refuges do not actually, in a physical sense, force the vehicles to slow down, but they generate a speed reduction since the feeling of driving too fast is high, even at rather low speeds, when the environment gets close enough.

All forms of speed reducing measures have been implemented area-wide in many towns and cities, in traffic-calming schemes, 30 km/h zones in residential areas, or speed-reducing schemes on through traffic arterials in sensitive urban neighbourhoods. In addition, various forms of features aimed at emphasising local activities and the presence of pedestrians and cyclists, such as roadside planting or pieces of street furniture, special lighting or surfacing, etc. have also been used. Although evaluation of the effects of such schemes on accidents is not easy due to the heterogeneity of situations and of the combination of measures applied, as well as to the difficulty of defining control areas, follow-up of demonstration projects have shown good overall safety results, as well as other benefits in terms of local accessibility, mobility of the most vulnerable road users, environmental amenities, reduced noise and pollution. When planning traffic calming measures, care has to be taken however to avoid generating visibility problems.

The most common conflicting areas between motorised traffic and vulnerable road users are at *junctions*. To improve safety for cyclists at these locations, different means of making them visible have proven to be successful. Introducing an Advanced Stop Line for cyclists allows these road users to position themselves in front of drivers, which decreases the chances of the cyclists appearing “from nowhere”. While cycle tracks have been found efficient in decreasing bicycle accidents on links, particularly on arterials, they create safety problems at junctions. Interrupting cycle tracks to let cyclists

merge with motorised traffic before the junction makes road users more aware of each other before they reach the conflicting area. It has been found an efficient approach to reduce the risk of unexpected appearance and thereby improve safety. Based on the results of several studies, bi-directional cycle tracks should not be built even if they are cheaper than one-way cycle tracks on each side of the road. The main reason that bi-directional cycle tracks create problems is again because of expectation: drivers expect cyclists to appear from the “right” and not the “wrong” (in most countries left) direction.

At signalised junctions, pedestrian- and cyclist-*friendly control strategies and simple intersectional design* are important for safety. Red-walking is a major safety problem; it is quite common behaviour among pedestrians often caused by long waiting times. The accident risk for pedestrians crossing against red is on average 4.5 times higher than when crossing on green. Effort should be taken to design control strategies which minimise the waiting time for pedestrians or gives automatic green when they appear at the kerb. Giving pedestrians a split phase, or a green light for only half of their crossing, creates major safety problems: the risk of misunderstanding such a strategy is extremely high. It is especially dangerous when only the second part of the crossing shows green since cars to the near-side may approach at high speed. It is also recommended to make the pedestrian crossing as short as possible. Visibility and safety are improved if the pedestrian/cycle crossing is placed as close as possible to the junction.

As to *prospective “infrastructural” measures* (see Section VII.2), new technologies may be used to improve mobility and safety of pedestrians or cyclists at crossings, in particular mat and infra-red *detectors* applied to providing immediate green light to vulnerable road users approaching the kerb and lengthen the green light until all of them have safely completed their crossing; further experimentation is, however, needed. On a larger scale, implementation of *comprehensive* bicycle and/or pedestrian *networks* across towns or cities, with emphasis on continuity, comfort of use, and protection from motorised traffic, is a step towards a more balanced and equitable transport system and an essential component of any transport policy aiming at promoting non-motorised transport modes; design guidelines have already been produced.

Implementation of safety measures for vulnerable road users may be a complex process when changes in transport policies are involved or when solutions integrating physical and non-physical measures are chosen. A large number of partners are concerned and organisation of a budget for the road safety programme may involve several sources and management procedures. Good communication between partners is essential and co-ordination is needed and should be organised on the national as well as the local level. A large part of the actions -- such as traffic education, programmes for infrastructure improvements, etc. -- rely on the participation of *professionals’ networks*. As a consequence, it is also necessary to set up networks for the dissemination of a road safety culture, i.e. latest developments in the fields of accidents, measures, programmes, communication tools, etc.

## **IX.2. Recommendations for action**

Research and experience documented by the Group mainly focused on built-up areas and most of the Group work has concentrated on related safety issues. The recommendations that follow apply mostly to urban policies and the urban environment. National accident statistics have shown that accidents in rural areas, although less numerous, tend to be usually more severe. Future work on the situation of vulnerable road users on rural roads should be advocated.

### ***IX.2.1. General policy***

#### *Designing concrete policies and actions*

In all OECD Member countries, deep concern exists regarding road traffic accidents. To the loss of human lives, one must add the economic and social cost of accidents. The policies aimed at improving road safety vary from one country to another, although they retain some common characteristics. The differences may be due to the different habits, customs and ways of life of the residents in each country, and also to the size and structure of the budget allocated to road safety.

In spite of differences, it is clear that vulnerable road users -- including children, the elderly, and disabled people -- are special groups that require concrete policies and actions. Whatever the degree of wealth of a country, all citizens are pedestrians, and giving them a priority serves a purpose of equality. All citizens may, at some particular periods of their life, become disabled, either temporarily or permanently, so that planning for the disabled may be beneficial to all. Walking and cycling are cheap means of transport which do not cost as much in terms of infrastructure as other modes. Not aggressive in that they do not usually inflict damage to other road users in accidents, they are not polluting, and have definite advantages in terms of public health (regular physical exercise has been acknowledged to reduce risks such as, for instance, cardio-vascular diseases). Encouraging walking and cycling for appropriate purposes and distances, and planning towns so that a larger proportion of trips can be made by these modes, has obviously many advantages.

In the countries that have set goals for non-motorised transport in the future, mobility surveys must be carried out with the aim of developing tools for reaching these goals. Only a few countries have undertaken surveys on people's attitudes to cycling and walking. It should be noted that knowledge in this field is extremely relevant for planners to assure that the most effective measures will be initiated.

Encouraging walking and cycling cannot be aimed at and achieved without increased protection of vulnerable road users. Decision-makers cannot take the responsibility of shifting modal split for environmental or economic reasons without taking due care not to increase health problems related to accidents. Moreover, citizens will use non-motorised transport modes as little as possible as long as they feel too unsafe.

One condition of social integration is to promote safe mobility. One of the top priorities in most OECD Member countries' policies and strategies is to promote greater participation of disabled people -- including those gradually losing abilities through the ageing process -- in social activities. Disabled people are less able to cope with risky situations and are therefore particularly likely to avoid trips that make them feel insecure. It can be understood that improving mobility and safety for the disabled is not a marginal goal that benefits a small group of population, but, on the contrary, an essential move to increase the potential of a society and its quality in terms of equal rights and opportunities: a goal which no democratic country can ignore. As indicated earlier, in OECD Member countries, the proportion of elderly and disabled persons is increasing and this has to be taken into consideration when planning physical, legal and social environment. Their transport needs should be studied more carefully. Policies to integrate disabled people should in part be based on improved infrastructure. Construction and conditioning of the road or street network should be such as to make it suitable for use by persons with various levels and types of disabilities. The main principles are to remove all elements that may generate impassable barriers, check and remove all sources of possible surprises that may not be detected, improve continuity of walking routes and networks, provide guidance. Policies will also necessarily involve some

action on motorised traffic, aimed at eliminating conflictual situations that cannot be rendered safe for the disabled through purely infrastructural measures. This may include traffic restraints at specific locations, and in most cases speed reduction.

*Shifting modal split to obtain better conditions for vulnerable road users*

By minimising motorised traffic, and by shifting modes to walking and cycling as well as to public transport, safer, more pleasant and less environmentally damaging transport systems can be organised. Encouraging the use of non-motorised transport must therefore be obtained through a shift from the use of private cars or motorcycles. This may involve both restrictions on private vehicle traffic, at least in urban areas, and incentive methods to make walking and cycling more comfortable and more widely accepted by the public. Redesigning urban street space is one necessary component of such policies.

Some action to develop and to increase use of public transport is also necessary to promote non-motorised traffic as well as mobility of the less able. In particular, for the longer trips that cannot be entirely performed by cycling (or walking), a combination of bus or other public transport mode and of a non-motorised mode is essential to obtain a modal transfer from private vehicles. Introduction of elderly-friendly buses, accessibility of public transport for wheel-chair users, devices to help blind people use public transport easily, provision of facilities to transport bicycles on buses and trains, provision of secure bicycle parking facilities at the main bus and train stations, etc. are a number of features that deserve greater attention in the future.

*Treating all road users equally*

Equality is the basis for good interaction in traffic. Inequality only leads to conflict and trauma on the roads. Safe behaviour is seriously compromised when some categories of road users are convinced that they have some sort of priority or more rights than the others. This is particularly obvious in social situations where private motor-vehicles are considered a status symbol, and cyclists or pedestrians are consequently viewed as second-rate citizens. Even in OECD Member countries where this kind of attitude tends to disappear, the fact that infrastructure has historically been adapted to increasing usage of private vehicles conveys to the drivers the idea that they dominate.

For further progress to be made in road safety, and particularly in safety of vulnerable road users, all road users must to a great extent take part in traffic on fairly equal terms. At the micro-level, conditions for improved communication between road users should be developed, so that behaviour should move from competitive to negotiated. At the macro level, this implies a complete change in the legal, physical and social environment of vulnerable road users, including renewal of transport policies towards better balance of transport modes, but also more equitable allocation of road space to all groups of road users, and psychological action to prepare road users to adapt to the new situation. Such changes cannot be attained at once, as attitudes have to evolve, but through an iterative process.

*Listening to vulnerable road users before taking decisions*

Road users are the direct recipients of transport policies and of safety measures; but they are not passive recipients and do participate in the implementation of policies, if only through an adaptation of their attitudes and behaviour. Policies will get a better chance of succeeding if they are discussed, even

negotiated, with the potential participants. It is therefore necessary to hear the opinions of vulnerable road users, including the disabled, at the early stages of policy making and infrastructure design. They can bring information or ideas that may not have been initially familiar to professionals or decision-makers. Conversely, designers can explain and clarify the ideas and design behind the measures or plans proposed. Safety measures and devices should be developed to incorporate their views wherever possible, and thorough education should follow to promote participation and implementation.

#### *Organising demonstration projects*

All the recommendations above can be integrated in sustainable transport policies. The iterative process of changing the environment of vulnerable road users and providing more equality in traffic, needs to be initiated. For this purpose, large scale demonstration projects should be organised on test cities and followed up to provide international experience. Such projects should be funded internationally.

#### *Providing homogeneous design principles for the road and transport environment*

Road users, including those using non-motorised modes, are more and more often international travellers. There is a need to homogenise attitudes and policies at least with regard to equality of road users and integration of the most vulnerable ones, in order to avoid unexpected situations which should be not only extremely uncomfortable, but also conducive to accidents. As a follow-up to present international activities on road safety and traffic regulations and to the findings of the demonstration projects recommended above, international groups or organisations should endeavour to disseminate details of the new policies and promote them at least in neighbouring countries. Obviously, implementation details will differ between countries, but the basic principles should become easily recognisable for the citizens.

### **IX.2.2. Infrastructure and the traffic environment**

#### *Giving priority to vulnerable road users in planning the environment in built-up areas*

When planning the physical environment, pedestrians and cyclists should be prioritised, so that their needs are met without unnecessary restrictions on their mobility, and safer behaviour is promoted.

Because the physical environment creates a social environment, moves to “return the streets to the people” through traffic calming in residential areas, pedestrianisation, and traffic management schemes which take account of the needs of vulnerable road users, will have psychological effects. The more that drivers are persuaded that vulnerable road users have the right to use road space safely, and that responsibility for their safety rests with drivers, the greater the potential for increasing their safety.

#### *Reducing vehicle speeds and promoting traffic integration in built-up areas*

Research has shown conclusively that even fairly small reductions in vehicles’ average speed can result in major reductions in the number and severity of pedestrian accidents. It is essential to create the necessary conditions to lower vehicle speeds in built-up areas in order to make major improvements to the safety of vulnerable road users. Care should be taken to ensure that speeds are reduced at locations where interaction between the various groups of road users is likely to occur. Quality of interaction will

thus improve considerably and the accident risk and the injury risk will decrease. Movements of the less able road users would be facilitated.

Categorisation of roads into traffic routes, arterial roads with mixed functions, and residential (or local interest) streets is a preliminary step in improving the urban road network for increased safety of vulnerable road users.

Traffic calming measures, as well as integration of mixed traffic on the same road space, have been widely used on residential or local interest streets to reduce speeds to levels below the usual regulatory ones and promote communication between vulnerable road users and drivers. General application of traffic calming and traffic integration schemes in residential areas should be strongly encouraged.

Experiments have shown that such schemes were also feasible, with some adaptation in design, on urban roads with heavier traffic. It is therefore time to widen their scope to answer the more severe accident problems on arterials with mixed functions. On such arterials, where it is possible neither to divert through traffic, nor to design all crossings with grade separation operating in acceptable conditions, the only real alternative for safety is to integrate the vulnerable road users with motorised traffic and let the road users meet and interact, designing the road environment so as to oblige car drivers to interact safely. As a precondition to a traffic integration, speeds should be substantially lower than the usual speed limit in use in urban areas or on urban arterials. To make sure that low speeds are respected by all road users, physical constraints integrated in the road design are necessary.

It is sometimes impractical to lower speeds on major urban arterials with mixed functions. In such a case, they should be treated as traffic routes, with adequate separation between through traffic and the urban surroundings. Some additional facilities are then necessary to ensure that local access traffic can operate and that local activities on both sides of the road can be reached safely by walking and cycling.

#### *Making the road “legible” and the traffic environment “forgiving”*

The way the road and its environment are designed communicates a message to the road users. This message should be clear: there should be no uncertainty when it comes to identifying hazardous situations. The road must be made “legible” for all road users. In particular, it should convey consistent messages to drivers and non-motorised road users thus avoiding differences in expectations as mentioned earlier.

Conveying the right message is particularly important in “transition” zones where the characteristics of infrastructure or traffic are changing, as, for example, at the entry of built-up areas, or to warn road users they are approaching a critical location, such as, for instance, a school area. It is also particularly important to obtain the kind of behaviour required in relation to local regulations -- such as speed limits -- this should appear clearly in the way the road environment is designed. Road design should also provide all the necessary information to make decisions easy for all road users. Infrastructure and design of the road environment should promote driver awareness and set expectations of the possible presence, movements and behaviour of vulnerable road users.

It is human to make mistakes, and mistakes committed during an interaction between road users or in critical situations can lead to accidents. Collisions that may not have generated serious consequences given the speed or violence of the crash are often aggravated by secondary factors. Human “errors”, that

in no other circumstances would have been considered serious, end up in injuries, disabilities or even death. The road environment and traffic control must allow mistakes to take place without inevitably generating fatal or serious accidents. A “forgiving” environment for vulnerable road users requires the combination of several types of actions, including physical improvements of the infrastructure, better design of cars, lorries and buses to reduce aggressiveness, and, of course, lower speeds.

*Improving the design of space for pedestrians and cyclists*

The physical environment should be more friendly to vulnerable road users. Comprehensive networks for pedestrians and cyclists should be systematically created to enhance both mobility and safety.

When designing the space allocated to pedestrians and cyclists for their movements, the following criteria should be considered:

- make pedestrian and cycle networks an integral part of global transport and traffic planning;
- provide accessibility to the important destinations of pedestrians or cyclists;
- calibrate pedestrian and cyclist facilities so as to ensure smooth pedestrian and traffic flows;
- ensure clearness of layout, with adequate direction signing;
- ensure acceptable safety levels and encourage use by pedestrians or cyclists;
- provide continuity by properly connecting all links of the networks and avoiding detours and sudden changes in traffic conditions;
- avoid steep gradients, as well as stairs or high kerbs for pedestrians; if any such critical locations cannot be avoided, provide adequate facilities for disabled people (for example, elevators or escalators that can take wheelchairs, guiding systems for people with impaired vision);
- provide sufficient lighting, in order to make vulnerable road users feel safer and more secure in night trips; lighting should be particularly efficient at locations where pedestrian or cycle networks are not separated from motorised traffic, in order to enhance night conspicuity of vulnerable road users;
- provide proper maintenance;
- include parking facilities for bicycles as near as possible to their destinations.

The maximum level of safety is obtained when separating pedestrian and cycle facilities. When shared use is required, special care needs to be exercised in the design to avoid excessive speed of cyclists.

In some countries, it should be useful to consider people using roller skates, skate boards, and other “special categories” of road users. There is a question as to whether those road users should keep being allowed to use the same facilities as pedestrians, including pavements.

*Improving safety for vulnerable road users at road junctions and at crossings*

The following principles should be considered to further improve safety of vulnerable road users through physical design of the road junctions and of crossings between carriageways and pedestrian or cycle routes:

- enhance good visibility between drivers and vulnerable road users;
- make decision-taking easy: junction design should be simple and easily understandable; road users' expectations must be met to a large extent; road users' attention should be enhanced at the junction approach; on the junction itself, attention should be focused on the points where it is actually needed, for example turning or merging areas;
- do not give drivers an obvious feeling of right of way, which leads to higher speeds;
- facilitate the use of crossings by provision of refuges; this will be of particular benefit to elderly or disabled people;
- introduce light-control systems which are more responsive to pedestrians, including, for example, new technologies based on pedestrian detectors.

Finally, combined solutions should be found to increase the use of pedestrian crossings while also increasing the protection level they afford by making them better respected by drivers.

**IX.2.3. Road user behaviour and attitudes***Combining measures to influence behaviour*

Behaviour and attitudes can be influenced directly through a variety of measures addressing the road user, such as education, publicity campaigns, laws and enforcement. They can also be influenced through environment and the way road users interact with it. Changes in behaviour and attitudes may therefore be achieved through a combination of means, including environmental measures. "Non-infrastructure" measures should not be seen as a substitute for other measures such as infrastructure improvements. They should rather be seen as complement.

Vulnerable road users can protect themselves, make themselves more visible and acquire theoretical and practical knowledge and skills through education and training. However, they should not be solely responsible for their safety. A balance needs to be struck between vulnerable road users protecting themselves and measures to reduce the risk imposed by motorised traffic. 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.

While continuing to develop effective educational and training programmes to encourage safe road user behaviour, and other non-infrastructure 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.

Urban and traffic planning using engineering measures to reduce the volume of traffic and driving speed in urban areas improve road safety effectively. Such measures 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 devices to simplify the human task and constructed to protect vulnerable road users as effectively as possible, and road users who are adequately educated, informed and, where necessary, controlled.

*Supporting socially acceptable behaviour in traffic, increasing feelings of responsibility and enhancing equality*

The traffic system is our greatest social system and it must work according to certain acceptable social rules. One should not do things in traffic that one would not do in other life conditions. The present situation is not yet acceptable; one example is the attitude often adopted by drivers towards pedestrians or cyclists. The latter pose no threat, and therefore do not deserve attention; sometimes they are even submitted to intimidation or, at least, impoliteness. Adequate policies are needed to reverse this way of thinking and behaving. Another example is the ignorance of the difficulties or needs of the less able road users. Some form of education of people who are not disabled is necessary to make them understand behavioural characteristics of people with various degrees or kinds of impairment. This is fundamental in order to support the social participation of the disabled. Drivers also need to be aware of the physiological limits and specific behavioural characteristics of children, in order to assume their responsibilities.

Road users must be made to feel they are responsible for other road users' life and comfort. The responsibility has to be mutual. This kind of attitude cannot be obtained without equality of treatment of road users. Action to promote it therefore calls for a combination of education and information processes and of legal and physical measures. Drivers of motorised 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.

Such goals should be achieved through a variety of combined measures. Quality of the traffic environment obviously plays a part. Relevant and consistent policies should be promoted in all fields of communication with the road users, from traffic education in schools and driver training and testing programmes, to publicity campaigns and commercial advertising.

*Making road users more respectful of the rules favourable to the safety of the most vulnerable ones*

In the short term, it would be useful to get pedestrians and cyclists to comply with the traffic rules meant to protect them in difficult traffic situations (use pedestrian crossings, respect traffic lights, use lights on bicycles at night, etc.) and recommendations or regulations related to conspicuity (reflectors on bicycles, etc.). But the behaviour of vulnerable road users is not independent of that of drivers. For example, why should pedestrians make an effort to use a zebra crossing in traffic situations in which drivers pay no attention to zebra crossings and do not show any intention of stopping for pedestrian priority?

Traffic situations have to be considered as series of interactions in which all patterns of behaviour are related. More insight is needed into the way traffic rule works, in order to improve general compliance and safety.

#### *Teaching road safety to children, youths and adults as pedestrians and cyclists*

Special attention is needed on this point as the results achieved through a good education policy can be very beneficial in improving safety of these groups. The main principles to be considered are the following:

- use methodologies adapted to the road user group they address;
- for young children, road safety education should move away from simply imparting knowledge and rules, to developing practical training programmes closely tuned to the skills which are needed at a particular stage of the child's development;
- make adults aware of their own limitations, and also of their own responsibility; in particular, help the elderly to recognise their limits in terms of physical abilities, and to compensate for them;
- help adults, particularly the elderly, to understand the right use of facilities, and improve their knowledge of traffic rules.

Special safety education programmes for the elderly, based on their active participation, would be appreciated by the recipients and should be useful to help them cope with traffic as long as possible. Such programmes should be based on a practical approach, and should be developed, implemented and evaluated on a larger scale. Local governments are best placed to organise activities for the elderly and could take the initiative, with the support of central governments where necessary.

#### *Reducing alcohol abuse*

Reducing alcohol abuse is a promising area for reducing pedestrian and cyclist casualties. This concerns both drivers that may cause accidents to vulnerable road users while under the influence of alcohol, and pedestrians and cyclists who have been shown to be particularly at risk after consuming significant quantities of alcohol.

While drinking-and-driving is, to some extent, taken care of through laws limiting the blood alcohol content of drivers, solutions are not so easily found for pedestrians and cyclists. The general drinking patterns are at stake, which makes the problem a social one. Possible interventions include consultations with industry to develop and implement more effective Alcohol Beverage Control policies and practices, and community-based programmes aimed at targeting problem areas.

#### *Promoting the use of cycle helmets*

Head injuries are the major cause of death for cyclists. Introduction of bicycle helmet legislation has been shown to result in a major reduction in the number of cyclist fatalities. Wearing rates are the

major factor underpinning the success of this measure, and additional measures to maintain and improve high levels of compliance are vital to its ongoing success.

If there is some resistance from authorities or from some professional groups to the enactment of a helmet law, there are ways to overcome it, as shown from the experience of countries that have already adopted the law. Appropriate action needs to be organised on a voluntary basis.

However, there is some concern that wearing a bicycle helmet may encourage cyclists to take more risks, under the misconception that they are now much better protected. This issue should be investigated scientifically, and where problems exist they should be addressed through education.

#### *Promoting conspicuity aids for cyclists and pedestrians*

It has been shown that a number of conspicuity devices were efficient and useful, but that their safety effect was limited by low usage. The benefit of these measures should be increased by promoting more widespread use through campaigns, education, and voluntary work.

### **IX.2.4. Vehicle design**

#### *Primary safety*

Better vehicle design should ensure better lateral visibility in order to improve bicycle and pedestrian safety. This goal is particularly important for lorries, in which lateral visibility is usually very poor.

A number of research and industrial projects aim at developing the use of telematics and drivers' aids in vehicles. Some particular attention should be given to components that could possibly be useful to increase safety of vulnerable road users such as on-board detectors of pedestrians or cyclists, on-board dynamic speed limiters activated by roadside beacons, etc.

#### *Secondary safety*

It has been shown that some particular designs of the front part of vehicles were more likely than others to inflict severe injuries to vulnerable road users in the case of a collision. More research is needed in developing "friendly" vehicle fronts, particularly for cars and buses. In any case, more care should be given to eliminate elements sticking out on the front of vehicle and to obtain systematic removal of damaged parts through better maintenance.

### **IX.3. Research needs**

#### ***IX.3.1. Data collection and analyses***

##### *Improving data on exposure and risk*

The risk of being killed depends upon the mobility of the various groups of road users. More knowledge is needed on mobility and exposure of road users in relation to the various transport modes, particularly of the very vulnerable road users (the elderly, the disabled, children). This is particularly important to determine more accurately the real risk faced by the different groups, to make international comparisons, and thus to provide a solid background for decision-making when policies including the promotion of non-motorised modes of transport are considered.

##### *Reducing and compensating for accident under-reporting*

A number of studies carried out in some OECD Member countries have shown a rather large rate of under-reporting of road accidents, particularly for pedestrian and cyclist casualties. Assessment of under-reporting should be more systematically conducted, in order to increase completeness and reliability of statistical accident data, and to take care of the existing information biases when identifying priorities for action. In research and studies aimed at preparing road safety policy decisions, more attention should be paid to surveys of hospital data, especially with regard to injured pedestrians and cyclists.

#### ***IX.3.2. Knowledge of accident characteristics and of mobility patterns***

##### *Understanding processes leading to accidents involving vulnerable road users*

Most clinical accident analyses have tended to bypass cases involving vulnerable road users, or have provided little information on the processes generating them because, on the one hand, in-depth accident investigations have been mostly sponsored by agencies interested in improving vehicles, and on the other, police reports usually provide biased information on pedestrian and bicycle accidents as the point of view of these victims, often seriously injured, is seldom collected during the investigation. As a result, we have only general knowledge on the factors taking part in the accident process.

More research into accident causation should provide the necessary knowledge to make preventive action progress, especially in situations where motorised traffic remains dominant. All research methods available should be used for the purpose. In particular, greater use should be made of observational data collected through traffic conflict techniques or other forms of in-depth behavioural studies.

##### *Identifying the characteristics of accidents involving elderly or disabled persons*

Very few studies have assessed the extent of the safety problem and analysed in-depth actual accidents and interactions involving the elderly or the disabled. Better understanding of the causation

patterns would help design measures more closely related to risk factors. Adaptation of behaviour to compensate for growing disabilities is also an issue requiring deeper investigations.

As standard accident data do not allow for any studies focusing on these particular groups of vulnerable road users, specific data have to be collected and ad hoc investigations are needed.

#### *Learning more about factors influencing mobility and choice of transport mode*

More knowledge is needed on factors determining modal split or promoting modal shifts in order to plan sustainable transport policies; encourage the use of non-motorised modes; and enhance mobility of the most vulnerable road users. Patterns of travel behaviour need to be investigated to understand the various trade-offs that are made between mobility and safety.

It is to be noted that, within the EU Fourth Framework Programme on Transport, Research and Development a number of task projects are directed towards suggestions for measures aimed at facilitating cyclists' and pedestrians' travel and at encouraging these modes.

#### *Increasing knowledge of accidents involving vulnerable road users on rural roads*

Too little information and research is available on accidents to vulnerable road users outside built-up areas and on the processes generating them. Although less numerous than in urban areas, these accidents are nevertheless the most serious ones and involve a high proportion of fatalities. They therefore deserve special attention and the design of appropriate safety measures should become a priority.

### ***IX.3.3. Development and evaluation of safety measures***

#### *Increasing knowledge of environmental design for vulnerable road users*

Knowledge obtained through research on safety problems of vulnerable road users and the environmental solutions that are likely to reduce these problems is still full of gaps. For example:

- problems with cycle tracks and their integration in the road network should be further examined, in particular, problems at signalised junctions and how to ensure mutual attention of drivers and cyclists;
- the study of pedestrians safety problems is too often limited to pedestrians crossing the roads or the streets; more knowledge is needed about behaviour, safety, and perception of safety of pedestrians along a whole route in relation to road environment and traffic;
- the potential for new technological developments to increase safety of pedestrians and cyclists should be explored.

#### *Increasing knowledge of other types of measures*

As noted earlier secondary safety characteristics of cars and trucks can influence the number and severity of injuries of vulnerable road users.

Rules and regulations might affect the safety of vulnerable road users, as well as judicial practice giving rise to a legal doctrine which becomes an essential reference when interpreting the rules. Police enforcement as well as telematics aids can provide useful tools in reducing accidents involving vulnerable road users. More research in these areas is recommended, because at present not enough is known about the effects of these types of measures on the safety of vulnerable road users.

*Increasing efforts to evaluate safety measures for vulnerable road users and disseminating results*

Better evaluation of measures to improve the safety of vulnerable road users is needed, both in terms of quantity and quality. In particular, there are serious gaps in knowledge on the effects of education and publicity programmes. Appropriate methods still need to be designed for this purpose.

Development of adequate evaluation methods is also needed to assess the potential effects on safety, mobility, and the environment, of various alternatives of transport planning involving different mixes of modes or different forms of road space allocation.

More research on measures currently in use or being experimented in different countries, and better dissemination of results are also needed, particularly on issues such as education for the elderly or specific environmental measures for the blind. This calls for some form of continuing organised co-ordination at the international level.

**IX.4. Recommendations for follow up of the group's work**

*IX.4.1. Promoting the results obtained in OECD Member countries*

A number of international organisations as well as European institutions are, to various degrees, interested in providing guidance or promoting research to improve safety of vulnerable road users. Some organisations, such as WHO, are also interested in developing pilot projects for healthier cities, involving greater use of non-motorised modes of transport. At the national level, some countries, for example in Northern Europe, are relatively advanced in promoting "sustainable transport systems", including "sustainable safety", and in protecting vulnerable road users, while other countries show signs of initiating similar kinds of policies. At the local level, more and more cities are seen to have the willpower and means to improve urban transport and safety for their citizens, at the same time as providing them with a less polluted, less noisy, and more pleasant environment.

Wide exchanges of experience are obviously needed on the issues discussed in this report. The amount of work necessary to evaluate the state-of-the-art of research and practice is enormous. Because of a limited time frame, the information collected and assessed in this study does not provide a complete picture of the knowledge available in OECD Member countries. However, the information provided is extensive and it is to be recommended that the work carried out should not be duplicated by other agencies or groups of experts.

The Group therefore recommends that particular efforts be made at disseminating the present report, promoting its recommendations and monitoring future developments in the field. Different means can be envisaged to reach these aims. It is suggested that, among other actions, the organisation of an international Symposium on safety of vulnerable road users should be initiated, addressing other

international organisations, national policy-makers from OECD Member countries, local policy-makers and safety professionals, as well as road safety researchers.

It is also suggested that the symposium be opened to non-OECD member countries, in relation to the goals stated below.

#### ***IX.4.2. Using the experience to provide knowledge and assistance to non-OECD member countries***

The terms of reference given to the Expert Group in 1994 included a second phase of work, to be devoted to problems of less motorised countries. It is clear that safety problems to pedestrians are currently much more acute in Eastern European countries than in the OECD ones. These problems will rapidly increase as motorised traffic there is sharply growing, unless some appropriate action is taken in the short term. Similarly, pedestrian accidents are extremely frequent and lethal in most cities of the developing world. In addition, bicycle accidents are a major problem in most Asian countries, a framework for action could be gathered from the state-of-the-art drawn up by the Second International Conference on Asian Road Safety (Beijing, October 1996).

The Expert Group feels that:

- safety problems in the less motorised countries are alarming and all means should be used to promote fast preventive action;
- vulnerable road users are the primary victims; the approaches used by the Group to investigate pedestrian and cyclist safety problems are relevant to other countries and other conditions;
- some of the fundamental knowledge summarised may be applicable or at least useful to researchers and policy-makers in less motorised countries;
- experience at implementing safety measures provides some valuable information, especially on what does not work or on unexpected side-effects, even if the measures applied are not quite the same as those needed in other countries and conditions; finally,
- analysis of the problems experienced by countries or cities with very different traffic and infrastructure conditions may cast a new light on our own interpretation of safety problems in OECD Member countries.

The Expert Group suggests therefore that Group members particularly interested in co-operation with less motorised countries or particularly assigned to such co-operation by their professional duties, set up the basis for a network of researchers, policy-makers, and safety professionals in OECD and less motorised countries, with a view to widening the scope of the work already accomplished, producing an expanded state-of-the-art report, and promoting future international co-operation on research and on pilot-projects. As an intermediary aim, provisions should be made in the organisation of the symposium suggested above to include the active participation of representatives of the less motorised countries, at the regional, the national, and the local level.

## ANNEX A -- GLOSSARY OF TERMS

### ACCIDENT

Unexpected adverse event. May be a fall, a crash, a collision, an explosion.

#### **Road accident (or traffic accident)**

Definition used for statistics in most countries: Collision occurring on a public road and involving at least one moving vehicle. Road accidents include damage-only accidents and injury-producing accidents. *N.B.: According to the general definition, a fall of a pedestrian or a cyclist should also be considered as a road accident.*

#### **Damage-only accident**

Road accident resulting only in material damage to vehicles or the road environment.

#### **Injury-producing accident (or injury accident)**

Road accident in which one or more people are killed or injured.

#### **Fatal accident**

Road accident in which at least one person involved died as a result of the collision within a defined period of time. The period of time is usually of 30 days, according to WHO recommendations, but some countries use shorter periods (for example, six days in France, 24 hours in Spain).

#### **Urban accident**

Road accident occurring in a built-up area indicated by traffic signs (generally, one sign at entry of the built-up area and one sign at exit).

#### **Rural accident**

Accident occurring outside built-up areas.

### ACCIDENT CAUSATION

Set of events involving different elements of the road traffic and transport system (the road environment, the vehicles, the road users) and leading to collisions.

Set of related or non-related accident factors (see **factors**).

#### **Accident process**

A series of events involving different elements of the road traffic and transport system (the road environment, the vehicles, the road users) that have led to a road accident.

### ACCIDENT DATA

Formalised set of information on injury-road accidents.

**Statistical accident data**

A standardised set of well-defined items describing a road accident and its consequences, which are collected on all injury accidents occurring on a given territory for a given period of time. National accident statistics are thus files collected on all accidents occurring in a country over one calendar year.

**Detailed accident data**

A set of records extensively describing a road accident, and usually including objective data as well as written accounts of the collision provided by the road users involved or by witnesses. Such records may be drawn for all injury accidents (for instance, police reports in most European countries, or law courts files in other countries); usually, analyses are performed only on samples of them, representative of a period, of an area, or of a given safety problem.

**In-depth accident data**

A set of records extensively describing a sample of road accidents, and obtained through in-depth on-the-spot investigations, carried out by specifically trained multi-disciplinary teams of investigators.

**Surrogate accident data**

A set of data that can be used to measure or describe safety changes, when accident data is not available or not sufficient to do so. Surrogate data must be collected through standardised procedures and validated.

**BEHAVIOUR**

Reactions of the human being which are objectively observable.

**Behavioural analysis**

Study of some particular behavioural items, based on the analysis of information collected through behavioural observations, and performed in reference to psychological models of behaviour.

**Behavioural observation**

Set of procedures defined to observe or measure in traffic situations a number of variables describing specific behavioural items relevant to road safety. A grid of observation is usually designed to ensure consistency and reliability of the data collected.

**CARRIAGEWAY**

Road space to which motorised traffic is normally confined.

**CASUALTY (or VICTIM)**

A person killed or injured as a result of a road accident.

**Fatality**

Person involved in an accident who was killed outright or who died within a definite period of time as a result of the collision. The period of time is normally of 30 days after the accident (a WHO recommendation), although some countries use shorter periods (for example, six days in France).

**Injury**

Person involved in an accident, who was not killed but sustained, as a result of the collision, injuries requiring treatment in the hospital or at home. In some countries, statistics do not record injuries for which no treatment has been prescribed after first aid, for instance scratches or bruises.

**Serious injury**

The definition of a serious injury varies from country to country. A serious injury may be related to the time spent in hospital (for example, six days and more, in France, 24 hours or more in Spain) or to the severity of the lesions sustained, assessed by medical personnel. Some countries do not classify injuries at all in statistics (for example, Finland).

**Slight injury**

An injury which is not classified as a serious one, in countries where such a definition exists.

**COLLISION**

Crash occurring between two elements of the road traffic and transport system (persons, vehicles, animals, obstacles).

**Main collision**

The first significant collision in a series (Finland); a first collision that generates secondary collisions.

**CONFLICT**

Meeting of two opposing elements; simultaneous action of incompatible motivations; argument between two powers demanding the same rights.

**Conflict of flows**

Meeting of two or more traffic flows from different directions on the same road space (a road junction, a pedestrian crossing, a railway crossing, etc.).

**Traffic conflict (or near-accident)**

A traffic situation in which two road users approach each other in such directions and with such speeds as to produce a collision unless one at least of them performs an emergency evasive manoeuvre. More rarely, a traffic conflict may involve one road user only, on a collision course with a fixed obstacle or an animal.

**Traffic conflict technique**

A set of standardised procedures to identify, record and count traffic conflicts through the observation of traffic, and to process and interpret the data.

**CONSPICUITY**

Ability to be seen, recognised and identified as a particular element of the traffic system. Conspicuity thus implies that a particular object must “compete” with other objects to attract attention. For example, a pedestrian is conspicuous at a given distance if there is a high probability that he is detected and recognised as a pedestrian by other road users against the traffic background.

## **CROSSING**

Area of the carriageway, which is marked or signed, and serves to pedestrians or to cyclists to cross flows of motorised traffic. Specific regulations usually define the proper use of crossings by the various categories of road users.

### **Pedestrian crossing**

Area marked or signed, on which pedestrians cross motorised traffic flows with a priority, sometimes absolute, sometimes restricted to particular conditions or periods of time. Use of pedestrian crossings may be recommended, or mandatory within a defined distance, according to national regulations or legislation.

### **Bicycle crossing**

Area marked or signed at the intersection of a carriageway and a cycle lane or track.

### **Pelican crossing**

Pedestrian light activated crossing: marked area equipped with traffic lights, where pedestrians push a button to obtain a phase of green light giving them absolute priority to cross. Pedestrians are not supposed to cross unless they have been given the green light.

### **Zebra crossing**

Marked area on which pedestrians either have absolute priority (as in Great Britain), or have a priority to cross provided they have taken precautions to avoid creating a major hazard (as in France).

## **CYCLE LANE**

Marked area on a carriageway which is allocated to bicycle traffic. In some countries, mopeds are also allowed to use cycle lanes.

### **Cycle path**

Infrastructure designed and built for bicycle traffic and separate from the motorised traffic network.

### **Cycle track**

Part of the road, located along a carriageway but separated from it, designed for bicycle traffic. A cycle track may be one-way or bi-directional. In some countries, mopeds are also allowed to use cycle tracks.

## **DANGER (or HAZARD)**

Anything that threatens the integrity or the existence of a person. The resulting situation.

### **Danger indicator**

Variable that can be used to detect or measure changes in danger. When in significant number, injury-accidents are usually the variable chosen as danger indicator in traffic situations. Validated surrogate data may also be used.

### **Dangerous behaviour (or hazardous behaviour)**

Item of behaviour that exposes its author or another road user to a danger. By extension: item of behaviour frequently found to play a part in accident processes.

**Dangerous location (or hazardous location)**

Particular location, or type of location, where road users are frequently exposed to danger.  
By extension: location, or type of location, where accidents accumulate or where accident risk is very high.

**DETECTION**

The fact of noticing a particular traffic object or traffic event. For example, detection of a road user or of an obstacle against the traffic environment; detection of a traffic conflict.

**DIAGNOSIS**

Identification of a disease through a study of its symptoms. By extension: Identification of malfunctions of the traffic and transport system through an analysis of accidents that have occurred, in order to be able to design measures to eliminate these malfunctions and, therefore, prevent future accidents and casualties. (In a complex system, malfunctions are problems of interactions between different elements of the system, that generate undesired effects).

**EFFICIENCY**

Quality of a measure that creates the effects expected, that meets the objectives. Efficiency of a road safety measure : quality of a remedial measure that succeeds in significantly reducing the expected number of future accidents or casualties.

**EVALUATION**

Type of study aimed at qualitatively and/or quantitatively assessing the effects of a remedial measure (or of safety policies) in order to determine if the goals set for the measure have been achieved.

**Controlled evaluation**

Form of evaluation based on an experimental scheme, in which two comparable samples of populations or locations are selected, and safety measures are applied to one sample only; safety changes between two equivalent periods, before and after implementation of the measures, are estimated on the basis of appropriate danger indicators (accidents, risk, surrogate data) for the two samples; the sample not subjected to safety measures serves as “controls” to account for the influence of current trends or external events.

**Product evaluation**

Evaluation study aimed at estimating the effects, in terms of reduction of expected accidents or casualties (or surrogate indicators of danger), of a particular safety measure or programme, or of a particular type of measure.

**Process evaluation**

Evaluation study aimed at observing the changes generated by a safety measure or programme in the traffic and transport system, and at checking that these changes meet with the original expectations. Process evaluation is generally based on “intermediate” variables, defined to describe the changes in behaviour or in traffic patterns which are expected to lead to the final reduction of expected accidents or casualties.

**EXPOSURE**

Variable measuring the presence in traffic of different categories or groups of road users.

**Risk exposure**

Variable measuring the involvement of different categories or groups of road users in dangerous situations. In practice, presence in traffic (for example for cars, vehicle x km driven) is often taken as exposure to danger (indicated by expected accidents).

**FACTOR**

Element of a product.

**Accident factor (or contributory factor)**

Any element of the traffic and transport system (i.e. related to the road and its environment, vehicles, traffic or transport organisation, road users, or to interactions between these) that has been identified as taking part in an accident process in such a way that the accident would not have occurred if this element had been different or missing.

**Epidemiological factor**

Variable that contributes to explain the variations of another variable (for example, number of accidents or of casualties) which is the object of the epidemiological study.

**FOOTPATH**

Infrastructure designed for pedestrians and separate from the road network.

**INFRASTRUCTURE**

Complex system used as a support for an activity.

**Educational infrastructure**

The system set up in a country to provide education to a target population.

**Road (or traffic) infrastructure**

The physical system supporting traffic and road transport activities.

**INTEGRATION**

Incorporation of elements into a system. Organisation of interactions between different elements of a system.

**Integrated safety policies**

Implementation of safety programmes, based on an extensive diagnosis taking into consideration all types of accident factors, and composed of safety measures of different nature (engineering, planning, education, etc.), organised so as to complement each other and strengthen each other's effects.

**Integrated safety management**

Implementation of integrated safety policies through inter-sectoral organisation and decision-making procedures.

**INTERACTION**

Situation in which two elements of a system influence each other.

**Traffic interaction**

Traffic situation involving at least two road users, in such a way that each road user has to adapt his behaviour in relation to the other's presence and actions.

**Interactive behaviour**

Pattern of behaviour of two road users responding to each other in traffic.

**KILOMETRE**

A thousand meter distance in the metric system. A km is worth 5/8 of a mile.

**MOBILITY**

Ability of a population to move through various modes of transport. The number and characteristics of the trips performed by a given population over a period of time and for various purposes.

**Mobility needs (or mobility demand)**

The amount and characteristics of trips necessary to ensure adequate development and functioning of a society.

**Mobility offer**

The amount and characteristics of trips made possible by the different modes of transport available to a given population.

**MODE**

Particular form under which an action is accomplished.

**Mode of transport**

Any means through which trips are performed or goods are moved. For example: car, bus, bicycle, walking.

**Modal split**

Distribution of trips or distance travelled in a geographical area between the different modes of transport.

**Modal transfer (or change in the modal split)**

Change observed in the modal split over a period of time, in which the part played by some modes of transport is substantially increased at the expense of others; such a change can occur spontaneously or can be induced through various types of measures, either forcibly restraining the use of a given mode, or introducing opportunities or incentives to the use of another.

**PAVEMENT**

Part of the road space located along the carriageway and separated from it by a kerb. Use of pavements is usually restricted to pedestrians. N.B.: In the USA, the word is used to designate the carriageway; it is not used this way in the present report.

**RISK**

Expected danger. Probability of an event that does not result exclusively from the will of the parties involved and that may cause damage or loss of life.

**Accident risk**

Probability of accident occurrence in a given location or area and during a definite period of time. Accident risk is estimated through statistical procedures, based on data of observed accidents and exposure.

**Risk indicator**

Variable used to measure variations in risk.

**Risk taking**

Behaviour consisting of exposing oneself to danger in view of obtaining some advantage out of it.

**ROAD**

Physical area specified for the movements of people or vehicles.

**Road network**

System of roads sufficient to ensure all the necessary movements of population and goods in a given area.

**Public road**

Road open to the public and usually built and maintained by national, regional, or local administrations.

**Road junction**

Area where two or more roads join. A junction can be at-grade or grade-separated. At-grade junctions include T-junctions, Y-junctions, three-armed junctions, intersections, roundabouts, or multiple intersections. A grade-separated junction is a road junction built on several levels and designed to separate motorised traffic flows, so that crossings are eliminated and only merging takes place.

**Road link**

Length of road including no junction.

**Road section**

Length of road selected for a particular study or operation.

**ROAD SAFETY (or TRAFFIC SAFETY)**

The quality of the traffic and transport system that generates a sufficiently low number of accidents or casualties to be considered as acceptable.

In practice, road safety is a relative concept, of which only changes can be measured. Changes are defined in a “negative” way, as what is measured is really the increase or decrease of “unsafety” or danger. The number of observed injury accidents or of casualties is a typical indicator of “unsafety”, although it is an imperfect predicting tool and may have to be complemented with indicators based on surrogate data, in particular for research purposes.

**Road safety action**

Any measure or policies aimed at preventing future accidents or at reducing their severity in terms of casualties.

**Road safety measure**

Any change brought to elements of the road and its environment, of vehicles, of traffic and transport organisation, or to road user behaviour, that aims at preventing future road accidents or at reducing their severity.

A road safety measure can be remedial or structural. A **remedial measure** is a road safety measure that aims at eliminating a well-identified accident problem, i.e. that aims at preventing groups of accidents observed in the past to occur again in the future by influencing or eliminating some of the factors contributing to the processes that generate these accidents. A **structural measure** (or **design-integrated measure**) is a disposition taken when developing or structuring the urban environment, the transport or traffic system, the road network, etc. to ensure through better design that future accidents will be limited to the minimum amount, in view of the current knowledge of accident causation.

### **Road safety policies**

Decision-making procedures leading to the design and implementation of road safety programmes.

### **Road safety programme**

A set of road safety measures bearing on the road and its environment, traffic or transport organisation, vehicles, and/or behaviour, that are co-ordinated in design and implementation.

## **ROAD USER**

Any person moving on a public road.

### **Cyclist (or pedal cyclist)**

**Road user** travelling on a bicycle, defined as a non-motorised vehicle with at least two wheels and pedals or hand-crank, designed to carry one or several persons and possibly also goods. Wheelchairs are not considered as bicycles. In some countries (Sweden, for example), toy-bicycles are not considered as vehicles.

### **Disabled road user**

Any person with a physical, sensory or mental impairment affecting mobility. **Ambulant disabled people** are able to walk, but depend on artificial limbs, sticks, crutches, or other walking aids. **Wheelchair users** depend on a wheelchair for mobility, whether independent or assisted.

### **Driver**

Road user driving a motor-powered vehicle or a non-motorised vehicle. In some countries, persons who lead animal-drawn vehicles or herd animals on the roads are considered drivers (in Spain, for example), while in others, they are counted as pedestrians (in France, for example).

### **Elderly road user**

There is no standard definition of an elderly road user. For statistical purposes, most countries classify in this category all road users past retirement age (65 in most of Europe).

### **Moped-rider**

Driver or passenger of a moped or light motorised two-wheeler (usually defined by an engine capacity under 50 cc, and generally not requiring a driving license for its use).

### **Motorcyclist**

Driver or passenger of a motorised two-wheeler whose usage normally requires a driving licence.

**Passenger**

Road user travelling in or on a vehicle without being the driver.

**Pedestrian**

Road user who walks on public roads or spaces subjected to traffic legislation (not including drivers in countries where persons herding cattle or leading animal-drawn carts are classified as such).

Disabled persons using a motorised or non-motorised wheelchair, roller-skates, skis, roller-skis, etc. are usually considered pedestrians, as well as road users walking and steering a pedal cycle or a moped or pushing a pram. Persons busy on the road, although not walking (for instance, repairing a motor-vehicle, changing tyres, involved in road-works, etc.) are also counted as pedestrians.

**Vehicle occupant**

Driver or passenger.

**Vulnerable road user**

Road user belonging to a category most at risk in traffic and generating little risk to other road users. By extension: road user unprotected by an outside shield, i.e. pedestrians and two-wheelers.

Among two-wheelers, cyclists are the most vulnerable. Moped riders and motorcyclists may be excluded from the group of vulnerable road users as they are more likely to inflict damage to other road users (pedestrians, cyclists, other motorised two-wheelers, even cars where motorcycles are concerned).

**STREET**

Urban road, usually serving multiple functions: traffic, trade, social activities, etc.

**Mixed traffic street (or space-sharing street)**

Street designed to accommodate a mix of motorised and non-motorised traffic on the same space.

**Pedestrian street**

Street reserved to exclusive use by pedestrians. Exceptionally, residents may be allowed to access their homes by car, or delivery vans may be allowed to operate at given times.

**TRAFFIC**

Movements of road users on the road network. Quantity of such movements.

**Traffic calming**

Area-wide programme of self-enforcing measures aimed at reducing speeds of motorised vehicles, and at enhancing the quality of interaction between road users.

**Traffic flow**

System of road users using the same road and going in the same direction (motorised vehicle flow, pedestrian flow, bicycle flow). Volume of such traffic flows (number of pedestrians or of vehicles using a particular road in one direction over a given period of time).

**Mixed traffic**

Traffic organised in such a way that movements of all categories of road users, motorised and non-motorised, are performed on the same road space.

**Through traffic**

Traffic flow through a given area, that has no origin and no destination in that area.

**TRIP (or JOURNEY)**

Movement performed to go from one place to another. One trip may include several stages, performed by one or different transport modes. A **return-trip** is the combination of two successive trips, performed to go from one place to another and to come back.

**URBAN AREA**

Built-up area whose limits are marked on the roads leading to or from them by specific signs. Speeds are usually limited in urban areas (to 50 km/h in most European countries).



## ANNEX B -- NATIONAL TRAVEL SURVEYS

Member countries have been asked to give information on travel surveys which have been conducted or which are ongoing. In total, information has been gathered from ten countries, and in eight of these countries the surveys are nation-wide.

The travel surveys include, for example, information on how far the respondents travel, how many daily journeys and their purpose. The background of the various travel surveys, as illustrated in Table B.1, is described in the text below.

Table B.1 **Travel surveys in Member countries**

Country	Survey	Year	No. of persons incl. in survey	Age
Finland	National	1992	7 125	18-70 years
Sweden	National-ongoing	1994	5 235	6-84 years
Denmark	National-ongoing	1992	6 243	6 years and older
Great Britain	National-ongoing	1991-93	25 173	all
The Netherlands	National-ongoing	1992	25 000	12 years and older
France	Grenoble	1992		6 years and older
	Lyon	1985		6 years and older
Switzerland	National	1994	43 006	10 years and older
Australia	National	1985-86	45 000	all
New Zealand	National	1990	8 719	5 years and older
Japan	Tokyo-Urban area	1988	820 000 (300 000 families)	5 years and older

In the following text all travel surveys are described, based on information from the Member countries.

**Finland:** Nation-wide passenger transport survey 1992, Finnish National Road Administration.

A national travel survey was carried out in 1992, including interviews with 7 125 people between the age of 18-70. The information covers the journeys undertaken during a randomly selected day. The survey consists of both a travel day (24 hours) and a travel period of one week for long journeys (journeys of 50 kilometres or more). The 1992 survey is an updated version of similar surveys of journeys and travel conducted at approximately six year intervals beginning in 1974. The survey provides data on the relative use of various modes of travel and information on the characteristics of those travelling and the characteristics of the journeys taken such as; journey purpose, length, time, time of departure and number of occupants in the vehicle. The survey was based on interviews sent by mail and the data were collected over a twelve month period to insure that seasonal variations in travel were represented. The sample was a random sample consisting of 17 500 people and the response rate was 41 per cent.

**Sweden:** Databases from NTS, SCB Statistics Sweden.

The survey is national, continuously ongoing, at least for five years. The survey started on 1 April 1994. The interviews are conducted per telephone. The age of the respondents ranges between 6 and 84 years. People aged 6-14 are only indirectly interviewed. The Swedish national travel survey is ordered by DPU -- the Delegation for Prognosis and development Activities within the Transport Sector. It is an authority under the Department of Communication. The National Survey includes both travel during a specific day and long-distance travel two months earlier. The telephone interviews take place on the day after the specific travel day. The selected travel days cover all days of the year. Data in chapter III are based on interviews from one half year in 1994, in total 5 235 persons interviewed.

**Denmark:** The inhabitants' travel habits 1992, Ministry of Transport.

In 1975, 1981, 1986 and every month since August 1992, national travel surveys have been carried out on the initiative of the Ministry of Transport. The purpose is to chart the Danes' travel habits, including how far they travel, how many daily trips they make, and the purpose of trips. The 1992 travel survey is based on telephone interviews with 6 243 people between the ages of 16 and 74. The respondents were asked about their journeys on the day before the interview took place. Children are not included in the national travel surveys, but in 1993 the Ministry of Transport carried out a separate survey of children's travel habits. This survey is based on interviews with 1 000 children between the ages of six and 15. In the same way, elderly people are not included in the national travel surveys, but in 1993 the Ministry of Transport carried out a separate survey of elderly peoples' travel habits. It is based on interviews with 500 senior citizens aged 75 and more.

**Great Britain:** NTS 1991/93, Department of Transport.

The National Travel Survey (NTS) is a continuous survey that began in its current form in 1988. In earlier years, ad hoc surveys were carried out. Data for three years are combined in a rolling programme for reporting purposes in order to achieve adequate sample sizes. Reports are available for 1989/91, 1991/93 and 1992/94. The 1992/94 report covers individuals in 10 296 households who provide personal information (age, sex, working status, driving licence holding) and details of travel made over a period of seven consecutive days. Details include journey purpose, mode of travel, time of day and length of journey.

**The Netherlands:** The mobility of the Dutch population. Yearly publication of the Dutch Central Bureau of Statistics CBS.

The Dutch National Travel Survey is conducted every year since 1979 (and since 1985 in its present form). About 25 000 persons from the age of 12 and older -- from about 10 000 households -- are questioned on their travel habits, including travel mode, how far they travel, the number of daily trips and purpose of their trips. Persons involved in the survey receive a questionnaire which has to be completed. In 1994 children under the age of 12 are included in the survey for the first time (their parents have to complete their questionnaires). Data in this chapter are based on the survey from 1992.

**France:**

Surveys have been carried out in Grenoble and Lyon.

**Switzerland:** Verkehrsverhalten in der Schweiz 1989, Generalsekretariat EVED.

Data on travel habits are collected every five years. The figures in chapter 3 are based on data from 1989. The data from 1989 are derived from 20 492 households, which represents 43 006 persons and 119 115 trips.

**Australia:** Survey of day-to-day travel in Australia 1985-86.

The survey is nation-wide. Data were collected during 1985-86 and they included 45 000 people of all ages.

**New Zealand:** 1991 New Zealand Household Travel Survey.

The survey is a nation-wide household travel survey, and it was carried out in 1990. Data are collected by interviews measuring all household travel over a two-day period. The sample design, with sampling over a 12 month period allows estimates to be made of national annual travel. Respondents covered people from the age of five and older. Trip distances are not estimated for pedestrians.

**Japan:** Personal journey survey in Tokyo 1988.

This survey is a personal travel survey in Tokyo urban areas conducted in 1988 by personal visits at homes. Tokyo Urban Areas includes Tokyo Metropolitan areas, Saitama, Kanagawa, Chiba, South of Ibaragi prefecture. 820 000 persons from 300 000 families took part in the survey. Effective number of respondents was estimated at 2.5 per cent. In the aggregate data of this survey, cycling is included in the two-wheeler mode of transport, which also includes mopeds and motorcycles. Cycling cannot be excluded from aggregated level of data.



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