**Deliverable D 5**

# Cost-benefit analysis of measures for vulnerable road users

**Public**

# P R O M I S I N G

**Promotion of Measures for Vulnerable Road Users**
**Contract No. RO-97-RS.2112**

## Workpackage 5

**Contribution of:**
TRL, Transport Research Laboratory, United Kingdom

**July 2001**

THIS PROJECT WAS FUNDED BY THE EUROPEAN COMMISSION DGVII UNDER THE TRANSPORT RTD PROGRAMME

**Deliverable D 5**

# Cost-benefit analysis of measures for vulnerable road users

**Public**

# P R O M I S I N G

**Promotion of Measures for Vulnerable Road Users**
**Contract No. RO-97-RS.2112**

**Project Co-ordinator:** SWOV Institute for Road Safety Research, the Netherlands

**Co-ordinator Workpackage 5:**
TRL - Transport Research Laboratory, United Kingdom

**Partners Workpackage 5:**
SWOV - Institute for Road Safety Research, the Netherlands
TØI - Institute of Transport Economics, Norway

**July 2001**

THIS PROJECT WAS FUNDED BY THE EUROPEAN COMMISSION DGVII UNDER THE TRANSPORT RTD PROGRAMME

## Notice to the reader

This volume is one of the six deliverables of the European research project PROMISING, on the promotion of mobility and safety of vulnerable road users. The research was carried out by a consortium of European partners, which was co-ordinated by the SWOV Institute for Road Safety Research.

The main report of the PROMISING project is written and edited by SWOV, based on the contributions of the various authors of the six deliverables. These deliverables were not re-edited, but are published in the form in which they were furnished by the authors. SWOV is not responsible for the contents of deliverables that were produced by authors outside SWOV.

Copies of the following PROMISING publication can be obtained by contacting the respective author, or by downloading them from the SWOV website www.swov.nl.

**Final report for publication**
Promotion of mobility and safety of vulnerable road users. Final report of the European research project PROMISING. SWOV Institute for Road Safety Research, Leidschendam, the Netherlands.

**Deliverable 1**
Measures for pedestrian safety and mobility problems. Final report of workpackage 1.
NTUA National Technical University of Athens, Greece.

**Deliverable 2**
Measures to promote cyclist safety and mobility. Final report of workpackage 2.
VTT Technical Research Centre of Finland, Espoo, Finland.

**Deliverable 3**
Integration of needs of moped and motorcycle riders into safety measures. Final report of work-package 3. SWOV Institute for Road Safety Research, Leidschendam, the Netherlands.

**Deliverable 4**
Safety of young car drivers in relation to their mobility. Final report of workpackage 4.
BASt Bundesanstalt für Straßenwesen, Bergisch-Gladbach, Germany.

**Deliverable 5**
Cost-benefit analysis of measures for vulnerable road users. Final report of workpackage 5.
TRL Transport Research Laboratory, Crowthorne, United Kingdom.

**Deliverable 6**
National and international forums to discuss the approach and the results of PROMISING. Final report of workpackage 7. SWOV Institute for Road Safety Research, Leidschendam, the Netherlands.

**Leaflet**
Integrated planning for mobility and safety is promising. Leaflet on the European research project PROMISING. SWOV Institute for Road Safety Research, Leidschendam, the Netherlands.

**CONTENTS**

## SUMMARY

The report examines the issues of measuring exposure and relating this to accidents. It concludes that monitoring of exposure is clearly important if valid conclusions are to be drawn from changes in casualty numbers. However the means to monitor exposure accurately, especially for pedestrians and cyclists, are not routinely available.

It appears from studies in a number of countries that accidents with fatal injuries are almost always recorded by the police and by the hospitals. The level of recording of injury to pedestrians and pedal cycles seems to vary somewhat between countries. This may well be due as much to recording protocols in the various countries as to true under-reporting to the police. What does seem to be prevalent in the literature is a problem with the level of reporting to the police of pedal cycle injuries in particular. Care needs to be taken when comparing studies and databases as definitions of what is a pedestrian or pedal cycle accident may differ in important ways between hospital based researchers and road safety researchers.

Cost-benefit analysis is a technique designed to help policy makers find the most efficient way of realising policy objectives. It is based on economic welfare theory and the definition of efficiency given in that theory. The requirement to assign monetary values will restrict the application of cost-benefit analysis to measures whose effects are well known and situations in which policy objectives are clearly articulated and widely supported. It cannot be used to settle constitutional issues or profound disagreements over policy objectives. The results of a cost-benefit analysis are determined by the assumptions that are made. The assumptions made should fit national or local conditions. The results of cost-benefit analyses will vary between countries, and it will in general not be correct to generalise the results of these analyses across countries. For some road safety measures, however, general statements can be made concerning factors that influence the size of costs and benefits.

Cost-benefit analyses have been made of the following measures designed to improve safety and mobility for vulnerable and inexperienced road users:

- Roundabouts,
- Road lighting,
- Integrated area wide urban speed reduction schemes,
- Environmentally adapted through-roads,
- Upgrading pedestrian crossings,
- Parking regulations,
- Front, side and rear underrun guard rails on trucks,
- Local bicycle policy to encourage mode switching from car driving,
- Bicycle lanes,
- Bicycle paths,
- Advanced stop lines for cycles at junctions,
- Mandatory wearing of bicycle helmets,
- Improving bicycle conspicuity,
- Daytime running lights on cars,
- Daytime running lights on mopeds and motorcycles,

- Mandatory wearing of helmets for moped and motorcycle riders,
- Design changes on motorcycles,
- Graduated licensing - lowered age limit for driver training,
- License on probation - lowered BAC-limit for novice drivers,
- Disco buses.

In general, measures that improve both safety and mobility, or are neutral with respect to mobility, tend to have good benefit-cost ratios. Measures that reduce mobility, particularly by substantially reducing speed, tend to have a less favourable ratio of benefits to costs.
There exist very few technical and non-restrictive measures that can improve safety for inexperienced drivers and for riders of mopeds and motorcycles.
Measures that improve visibility or conspicuity (lighting, reflective devices, daytime running lights) or reduce driving speed are generally very effective in improving safety for pedestrians and cyclists.
The analyses presented are in most cases based on data taken from one country. Only for daytime running lights on cars has a cost-benefit analysis encompassing all of Europe been performed.

The following recommendations are put forward with respect to research and development.

1 An international conference or research project should be held in order to establish consensus with respect to identification of the relevant effects of measures that affect safety and mobility for vulnerable and inexperienced road users. It is particularly important to discuss and agree on how these measures affect the environment and road user security (subjective safety).
2 In current cost-benefit analysis, measures that reduce speed in urban areas to levels below about 40 km/h are often rejected in cost-benefit analyses because increased costs of travel time defeat any gain in safety or environmental amenity obtained by the measures. These results are often regarded as problematic and a critical examination of possible biases in current cost-benefit analyses of speed reducing measures in urban areas is called for.
3 The methods used to estimate the cost of accidents, costs of travel time and other costs of non-marketed goods used in cost-benefit analyses should be standardised between countries to the highest possible extent. However, variations in cost rates that are attributable to differences in income and population preferences should be respected.

Recommendations are also put forward with respect to the use of measures to improve safety and mobility for vulnerable and inexperienced road users.

1 Measures that *improve conspicuity and visibility* will often improve safety for all road users, but particularly for pedestrians and cyclists. An increased use of daytime running lights on cars, reflective devices worn by pedestrians and cyclists, and road lighting is encouraged. These measures are in many cases likely to give benefits that widely exceed the costs.
2 Measures that *reduce driving speed*, especially in urban areas, will improve safety, and sometimes mobility, for pedestrians and cyclists. Measures that reduce speed may, however, impose additional travel time on motorists. Measures that reduce

speed for motorists in urban areas will not always pass a cost-benefit test. There are, however, alternatives to basing speed limits in urban areas on cost-benefit analysis. An alternative that deserves careful attention is to determine speed limits according to the principles of Vision Zero, as stated by the Swedish National Road Administration.

3 The *wearing of helmets* protects both cyclists and riders of mopeds and motorcycles from head injury. It is at the present state of knowledge not possible to perform an adequate cost-benefit analysis of mandatory helmet wearing for cyclists. For moped and motorcycle riders, on the other hand, helmet wearing should always be mandatory.

4 The possibility of improving safety for motorcyclists by *design changes on motorcycles* should be explored carefully. For the time being, however, most design changes that have been proposed remain experimental and both their costs and effects are highly uncertain.

5 There exist few technical and non-restrictive measures that can improve safety for inexperienced drivers. *Graduated licensing* and *driver's license on probation*, are promising measures for inexperienced drivers. The continued use of these measures is encouraged.

# 1 INTRODUCTION

The objective of this workpackage was to bring together the information provided from the detailed reviews of each group of road users in the other workpackages, in a consistent way, to show the benefits and costs that might arise as a result of safety measures directed at these road users and to define a framework for cost-benefit analysis of measures designed to improve the safety and mobility of vulnerable and inexperienced road users and to give some case illustrations of cost-benefit analyses of selected measures.

The workpackage was led by Pat Wells from the Transport Research Laboratory (UK).
The cost-benefit analyses were carried out by Rune Elvik from the Institute for Transport Economics, TØI, (Norway) under contract to The Institute for Road Safety Research, SWOV (Netherlands) with assistance from Frank Poppe from SWOV.

The main research problems that are discussed in the report include:

(1) What current knowledge exists on the accident levels and exposure to risk of vulnerable and inexperienced road users?
(2) What measures can improve the safety and mobility of these road users?
(3) What are the basic ingredients of a cost-benefit analysis? Which are the issues that can be resolved by means of such analyses and which are the issues that cannot be resolved by cost-benefit analyses?
(4) Which factors affect the results of cost-benefit analyses? To what extent can the results of such analyses be generalised from one country to another?
(5) Which are the most cost-effective measures that can improve the safety and mobility of vulnerable and inexperienced road users?

The following tasks were defined as part of this workpackage.

1. *Define analysis methodology*. This task consisted in defining in detail the elements that should be included in cost-benefit analyses, preparing a list of relevant safety measures, defining in detail the required data and illustrating the use of the methodology by some examples.

2. *Assessment of mobility data*. A complete cost-benefit analysis generally requires fairly detailed data at the micro level. By the micro level is meant for each road user (or an average road user for the group concerned), for each vehicle, for each crossing location, for each junction, etc. Data has been supplied by workpackages 1 to 4, and workpackage 5 has, to a large extent, been based on input from these workpackages.

3. *Synthesis of evidence on present injury risk*. Based on input from workpackages 1 to 4, a synthesis of evidence on exposure and accident levels for the target groups of road users has been prepared. Underreporting of injury accidents in official accident statistics, which is a particularly severe problem for cyclist accidents, has been examined. The quality of exposure data varies between countries, as do the

definitions of reportable injuries vary between countries. These issues have been examined in the report.

4. *Synthesis of evidence on costs and effects of safety measures*. The term safety measure denotes any measure having the reduction of accidents or injury severity as one of its objectives.

5. *Economic valuation of safety and mobility*. In order to perform a cost-benefit analysis of a measure, an economic valuation of all relevant effects of the measure is needed. The relevant effects in the present project can be divided into three main categories: (1) Safety effects, (2) Mobility effects (restrictiveness of measures), and (3) Costs of implementing a measure. All three categories of effects have to be valued in monetary terms in order to perform a cost-benefit analysis.

This report considers first the target groups in the project and the types of measures that affect their safety and mobility. It then examines the evidence available on accidents and exposure. The elements in the framework for cost-benefit analysis are considered and the possibilities of generalising the results of such analyses at an international level is discussed. The report then examines examples of cost-benefit analysis of selected safety measures, designed to improve the safety of vulnerable and inexperienced road users.

# 2 TYPOLOGY OF TARGET GROUPS OF ROAD USERS AND MEASURES

## 2.1 Vulnerable and inexperienced road users

There are four target groups of road users in this project:

(1) Pedestrians,
(2) Cyclists,
(3) Moped and motorcycle riders,
(4) Inexperienced drivers.

Common to these road user groups is the fact that their risk of injury is substantially higher than for other road user groups. A case illustration of this is given in Figure 1. Figure 1 shows injury rates per million person kilometres of travel in Norway for the four target groups of road users studied in this project, compared to the injury rate of the safest group of car drivers. For the purpose of this comparison, inexperienced drivers have been defined as car drivers who are 18 or 19 years old. The minimum age for driving a car in Norway is 18 years.

A similar pattern is found in all motorised countries, although the numerical values of the accident rates will of course vary. It is important to realise, however, that the accident rate for a certain group of road users seems to depend on the amount of travel performed by that group. Thus, for example, the fatality rate for cyclists in a number of European countries is known to vary in inverse proportion to the amount of cycling done per inhabitant (see section 9.1). In countries where people cycle a lot, cyclists have a lower fatality rate (fatalities per million cycle kilometres) than in countries where people cycle less. This observation has a bearing on how one should estimate the effects on accidents of measures that induce more travel. The point will be discusses more in detail in a later section of the paper.

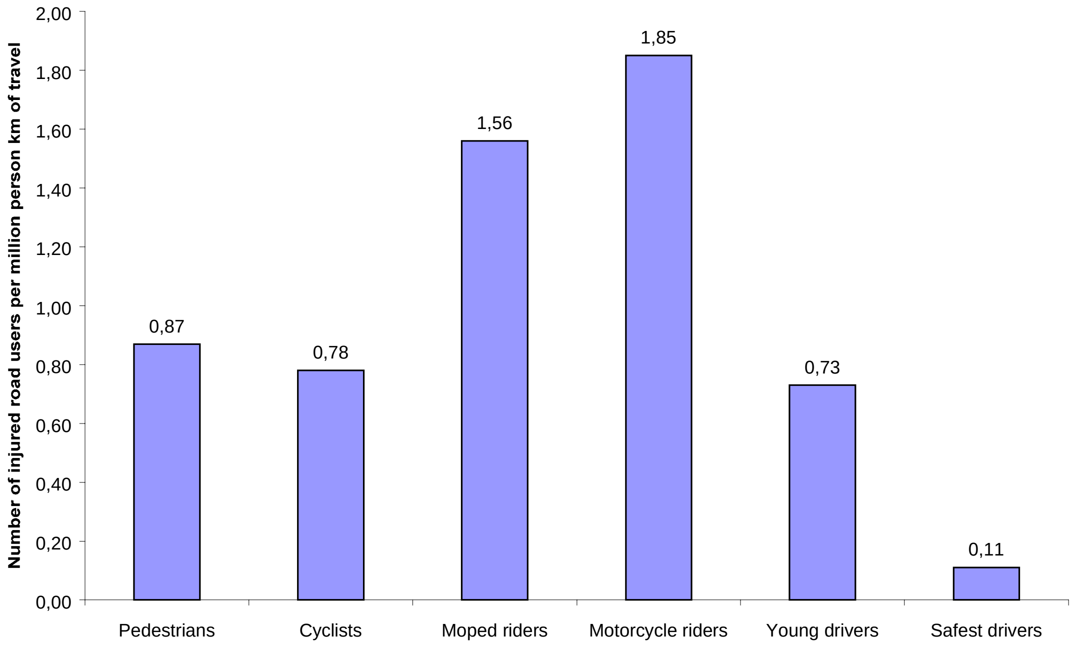


*Figure 1: Injury rate (injuries per million person kilometres of travel) for various groups of road users in Norway.*

## 2.2 Typology of measures designed to improve safety and mobility

A broad range of measures that may affect safety and mobility for the target groups of road users will be surveyed. A distinction is made between the following types of measures:

(1) Technical and non-restrictive measures,
(2) Technical and restrictive measures,
(3) Non-technical and non-restrictive measures,
(4) Non-technical and restrictive measures.

A technical measure is any measure that involves a modification of roads, traffic control devices or vehicles. Non-technical measures comprise all measures that are directed at road users directly, but do not change the traffic system as such.

The concept of a restrictive measure can be interpreted in many ways. As a first approximation, a measure will be regarded as restrictive if it:

(1) *Reduces the opportunities for travel*, for example by prohibiting driving at certain times (for example, night-time curfews for young and inexperienced drivers),
(2) *Restricts the choice of mode of travel*, for example by banning the use of a certain type of vehicle (for example, banning certain types of motorcycles),
(3) *Prolongs travel time*, for example by imposing additional waiting time at crossing facilities (for example, a vehicle actuated traffic signal may impose longer delays on pedestrians waiting to cross a road),

(4) *Requires pedestrians and cyclists to adapt to motorised traffic*, for example by imposing detours or restricting the use of traffic lanes (for example safety fences at pedestrian crossings or a prohibition against cycling in driving lanes when cycle lanes are provided),
(5) *Otherwise increases the cost of travel*, for example by requiring the use of protective devices (for example making the wearing of cycle helmets mandatory).

It is recognised that there are more dimensions to the concept than these. Restriction is primarily a psychological concept, related to the freedom of choice and to not being steered from outside. Perception of these qualities obviously varies between individuals and is rather difficult to capture objectively.

A preliminary list of relevant measures is given in Table 1. The table does not include a classification of measures in terms of their technical nature or whether the measures are restrictive or not.

*Table 1: Preliminary list of relevant measures.*

| Pedestrians | Cyclists | Moped or motorcycle riders | Inexperienced drivers |
|---|---|---|---|
| Walking tracks | Cycle tracks | Licensing age regulations | Licensing age regulations |
| Sidewalks | Cycle lanes | Basic rider training | Basic driver training |
| Road lighting | Road lighting | Advanced rider training | Advanced driver training |
| Simple marked crossings | Simple marked crossings | Graduated licensing | Graduated licensing |
| Signalised crossings | Signalised crossings | Treatment of problem drivers | Night-time curfews |
| Grade separated crossings | Grade separated crossings | Engine capacity restrictions | Treatment of problem drivers |
| Refuges in crossings | Refuges in crossings | Cycle design parameters | Special insurance systems |
| Raised crossings | Raised crossings | Use of crash helmets | |
| Safety fences at crossings | Advanced stop lines for cyclists | Protective clothing | |
| Pedestrian streets | Use of cycle helmets | | |
| Woonerfs etc | Cycle design parameters | | |
| One way streets | Lateral distance spacers | | |
| Street parking prohibitions | Reflectors and lights on cycles | | |
| Pedestrians | Cyclists | Moped or motorcycle riders | Inexperienced drivers |
| Speed reducing devices (humps) | Cycle brake systems | | |
| Reflective devices (clothing, etc) | Speed reducing devices (humps) | | |
| Daytime running lights on cars | Daytime running lights on cars | | |
| Soft bumpers etc on cars | Soft bumpers etc on cars | | |
| Training of children | Cycle training | | |

# 3 MOBILITY DATA AND EXPOSURE

## 3.1 Definition of exposure

The basic concept of exposure denotes the opportunity for road users to become involved in accidents, that is, when a person occupies the road that person becomes exposed to risk of road accident involvement. Being exposed to risk is not the same as being involved in an accident.

Exposure is a measure of how much of an activity there is. For example how much driving on motorways, or riding on cycleways. Risk relates this to the number of accidents which occur. For high risk behaviour there may be many casualties for relatively little activity, for low risk behaviours it may be possible to undertake a great deal of the activity with very few casualties.

A related concept is that of mobility. Mobility for road users is a measure of how they can move within the road environment. If mobility is reduced, exposure and hence casualties may also be reduced, but this reduced mobility may be unacceptable.

Exposure is usually assumed to relate to quantifiable measures; e.g. journey length, or time spent in travel. But less easily quantifiable measures such as the busyness of the roads or behavioural factors such as whether children or elderly road users are accompanied on their journeys also affect exposure. If risks are perceived to be high (regardless of the reality of the situation) this may lead to a reduction in mobility for many vulnerable groups.

Whilst vehicle flow multiplied by road length or trips by mode and trip length have long been used as proxies for motorised vehicle exposure, measures of exposure of other road users are much less well established. This is due to difficulties in defining trips, measuring trip occurrence, and measuring interaction with other modes which present risk to vulnerable road users.

Defining the basis of exposure measures is important to understanding. Definition of exposure in different ways can imply very different risks to road users. Table 2 shows the effect of considering exposure in terms of three different base measures; the distance travelled, the time spent in travel, and the number of trips undertaken.

Taking the KSI (Killed and Seriously Injured) figures and comparing walking with car travel in terms of distance, walking is about 12 times more dangerous than car travel. But in terms of time spent travelling the risks are more similar with walking being one and a half times more risky than being in a car, and in terms of trips there is about the same risk during a walking trip as during a car trip.

*Table 2: Number of casualties per units travelled by occupants and riders of several transport modes in the year 1988.*

| | | Casualty rate per 100 million | | |
|---|---|---|---|---|
| | Casualties | Occupant/ rider trips | Occupant/ rider km | Occupant/ rider hours |
| Killed | | | | |
| Pedal cycle | 227 | 12.5 | 4.6 | 64 |
| Walk | 1753 | 7.0 | 6.6 | 27 |
| Motorcycle | 670 | 122 | 11.4 | 342 |
| Car | 2142 | 5.2 | 0.4 | 12.4 |
| Bus and Coach | 17 | 0.4 | 0.06 | 1.4 |
| Killed and Seriously Injured (KSI) | | | | |
| Pedal cycle | 4879 | 268 | 98 | 1377 |
| Walk | 17880 | 72 | 68 | 279 |
| Motorcycle | 12654 | 2311 | 215 | 6461 |
| Car | 29346 | 71 | 5.7 | 170 |
| Bus and coach | 892 | 14 | 2 | 51 |

From: Transport Statistics Great Britain 1979-1989

Increasing mobility will result in increased exposure. However the increase in accidents will generally be less than would be expected because the relationship between traffic flows and accidents is non-linear. Summersgill et al (1996) have shown that for pedestrians crossing at junctions increasing pedestrian flows result in a reducing accident risk per crossing pedestrian. A similar reduction in risk per cyclist is found with increasing numbers of cyclists at junctions. These are specific examples of a more general result which shows that for two interacting flows at a junction (whether these are car flows, pedestrian or other vehicle flows) accidents and flows have a square root relationship

i.e.: $\text{Accidents}_{\text{car - ped}} = \text{Constant}. \sqrt{\text{Flow}_{\text{car}}} . \sqrt{\text{Flow}_{\text{ped}}}$

## 3.2 Vulnerable road users

Pedestrians, cyclists and motorcyclists are particularly vulnerable to being injured if they are involved in an accident. However this is an area where the difficulties of measurement are highest and existing sources of data least reliable.

Exposure for cyclists and pedestrians is very localised and site specific. They will be affected by "boundaries" which do not affect motor vehicles. For example a major road may act as a barrier to a cyclist or walker but is a gateway to freedom of movement for a motor vehicle. The potential for interaction with vehicles depends on whether they are on a footway or cycleway or on the road; whether they are in an area where motor vehicles are excluded or where there is speed restraint; whether they are moving along or across any traffic streams.

The relationship between walking and road accidents is complex. Walking may occur in the vicinity of a road but walking in pedestrian areas (either segregated pathways or pedestrianised shopping areas) may form a significant proportion of a journey for some walkers. Recreational and leisure walking is thought to be increasing but much of this is away from roads and probably should not feature in discussions of road casualty reduction. Since most walking data is likely to come from self reporting it will be necessary to ask people to identify the distances travelled on or beside public highways, as well as the traffic flows, speeds and constraints on free vehicle movement on each highway. This implies a very detailed questionnaire.

There are further complexities when the problems of age are considered. Elderly road users are known to adapt their behaviour to avoid some situations which they view as dangerous (e.g. reducing their driving or walking in the dark). Young pedestrians may be playing at the road side and not "travelling" anywhere, thus reducing their apparent exposure if the measure is distance travelled between a trip origin and a trip destination.

### 3.3 Policies which impact on exposure

Policies which are designed to affect travel behaviour may be applied at national or local level. These policies may affect different road users in different ways

Policies which are designed to encourage walking or the use of public transport may obtain their effect by discouraging the use of the private car. This may be done by making car parking less convenient or more expensive in urban areas or by introducing restrictions on access by cars to central areas of towns or to residential areas. Such measures, seen as negative or restrictive by car drivers, are usually implemented to encourage shifts to more environmentally friendly modes of travel. Policies which encourage particular modes of travel will often be supported by the provision of specific measures. For example countries which encourage cycling are more likely to provide cycle facilities than those where cycling is viewed as less important. The result of this is that where there are low levels of cycling the cyclists may be sharing the road space with other traffic and be at high risk of accidents. This means that the relationship between distance travelled by cyclists and accidents will not be a linear one. In countries where the amount of cycling is large the major part of cycle journeys may be travelled in safer conditions on cycleways and cycle lanes, hence keeping the accident levels down. The direction of cause and effect is not easy to see here. Where there is less cycling there is less demand for dedicated facilities but then the perceived risks of cycling may reduce the amount of cycling and hence the apparent need for facilities!

Another factor in this non-linearity will be that where cyclists form a significant part of the traffic flow the drivers of other vehicles are more likely to make allowance for their presence.
Within recent years the UK government has introduced several new transport policies aimed at encouraging the use of alternative methods of transport to the car.

In 1998 the UK government published its White Paper - *A New Deal for Transport: better for everyone* detailing its commitment to an Integrated Transport Policy. The paper states that planning guidance to local councils will be revised to reduce reliance on the car. Local services should be within walking distance and public transport links should be convenient. Guidance to local authorities will make it clear that higher priority should be given to walking, cycling and public transport, improving facilities for people to make connections and better information for passengers. Local transport plans will set local targets for increasing walking and cycling which will be achieved by such things as giving priority at junctions to reduce waiting times, maintaining cycle lanes and footpaths properly and relocating road space to cyclists and pedestrians where appropriate.

In 1996 the UK government launched the National Cycling Strategy with the aim that by 2002, cycle use in the UK will double and then double again by the year 2012. This target is to be achieved by cycle friendly planning, improved cyclist safety, more cycle parking and road space, reducing cycle theft and changing attitudes towards cycling. As well as a national target, local authorities and other transport providers and trip generators are to set local targets as part of the strategy which will contribute to the central targets to increase cycle use. Initiatives such as school travel plans, which establish safer routes for children to walk and cycle to school, are encouraged as part of the strategy. One such scheme, the Myton cycleway in Warwick UK linking major housing areas with schools has reduced traffic and emissions at school times and offers students and residents a healthier travel option (DETR 1998).

Several local targets for the increase in cycling are reported in Matthew(1995). Bradford’s ‘Cycling Action Plan’ in 1993 recommended a target of an increase in overall levels of cycling from 0.7% of all trips to 4% by 2001 but at the same time reducing the cycle accident rate by 30%. In 1994 the DOT gave an initial grant of £3million to the London Cycle Network which aimed to restore the level of cycle usage in London to 1981 levels by 1996 and to double these levels by 2001. The Oxford Local Plan Review of June 1993 set a target of increasing cycle use by 50% by 2000, and the city and county are continuing to engage in an energetic campaign of cycle promotion, which includes a steady extension of cycle parking facilities. One target within Bedford’s draft Structure Plan for 2011 is for 50% of all journeys to work within urban areas to be by public transport, walking or cycling with the help of its newly launched ‘Travelwise’ public awareness campaign.

A UK pedestrian strategy is also planned with its own targets for the increase of walking. One target is to halt the current decline in walking by the year 2003 and to increase the proportion of journeys where walking is the main mode to one third of all journeys by the year 2008. Also it is hoped to increase the average distance walked from 200 to 250 miles per person per year by 2008. The strategy will list actions to be taken at a national and local level to encourage walking, such as improving road safety, reallocation of road space, providing pavements fit to walk on, making crossing the road easier and increasing personal security. Local targets will also be set by local authorities. As a result of these new priorities in transport, existing funding will be reallocated towards pro-walking schemes.

Policies in other countries have developed the ‘sustainable traffic safety concept’ and the ‘Vision zero” approach’.

The starting point of the sustainable safety concept - as it is being developed mainly in the Netherlands (Wouters 1994) - is that in principle man is the reference standard. In the concept, we should try to drastically reduce the probability of accidents in advance, by means of the infrastructural design. And where accidents still occur, the process which determines the severity of these accidents should be influenced such that serious injury is virtually excluded. Hence, a sustainable, safe traffic system has

- a structure that is adapted to the limitations of human capacity through proper design, and in which streets and roads have a neatly appointed function, thus avoiding improper use;
- vehicles fitted with ways to simplify the tasks of man and constructed to protect the vulnerable human being as effectively as possible; and
- a road user who is adequately educated, informed and, where necessary, controlled.

The concept can be 'translated' in some, more practically oriented, safety principles:

- prevent unintended use, i.e. use that is inappropriate to the function of that road or street;
- prevent large discrepancies in speed, direction and mass at moderate and high speeds, i.e. reduce the possibility of serious conflicts in advance;
- prevent uncertainty amongst road users, i.e. enhance the predictability of the course of the road or street and people's behaviour on the road or street.

The 'Vision zero' of Swedish origin (Rumar 1996, Tingvall 1995) takes a different stand in designing the road transport system from the most common safety strategy, which is generally based on designing the system to minimise the number of events that cause injury. Starting point of its safety strategy is that the system has to be dimensioned in such a way that possible conflicts, or incidents which might cause injury, never result in exceeding a politically pre-defined level of an unacceptable loss of health. In achieving the 'zero vision' in reality, the intention is to create a situation in which exposure to violence is minimised. At the same time, the degree of violence has to be kept below the violence tolerance level of an optimally protected human being. So, in this approach too, man is in principle the reference standard. Some provisional elaborations of the concept partly resemble in practice, as we understand it, elements of the sustainable safety concept.

The 'Zero Vision' concept was recently adopted in Denmark.

## 3.4 Data available on exposure of vulnerable road users

The most widely used measure of exposure is the distance travelled in different transport modes. This requires detailed surveys on travel behaviour which are, in general, expensive. Only a few countries have routine collection of travel data which is detailed enough to allow the exposure of vulnerable road users to be estimated. The OECD report on Vulnerable road users (OECD 1998) collated exposure data from a number of countries (see Table 3).

The report describes the type of travel surveys undertaken in member countries. While the data varies between countries it is possible to use it to make estimates of the exposure for different groups within the population.

*Table 3: Travel surveys in member countries (from OECD 1998).*

| 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 |

### 3.4.1 Walking

Short Trips in European countries (WALCYNG 1996) presents data taken from national travel surveys , literature and statistical surveys in European countries. Table 4 shows data on the number of trips in 10 countries. The sources are as in the OECD report with extra information from Norway – National Travel Survey 1991/92, Germany – Kontinuierliche Erhebung zum Verkehrsverhalten 1989, and Austria – Verkehrhebung 1992.

Data is also given on the length of walking and cycling trips. In Norway, 68% of walking trips are shorter than or equal to 1km, and 83% are shorter or equal to 2km. For the other countries similar figures are 76% under 2km for Sweden, 82% for Denmark, 82% under 2.5 km (1 mile) in Great Britain, 90% under 2.5km for the Netherlands, 86% under or equal to 2km for Germany and 87% for Switzerland. Averages for Austria and France show a mean length of around 1km, but most walks are shorter than 1km, though some long walks give a rather high average. The Finnish data shows that only for trips shorter than 1km are the non-motorised transport modes prevailing. It seems that an acceptable distance for walking is between 1 and 2km. The average length of walking trips varies from just under 1 km in Great-Britain to 2.8km in Finland

*Table 4: Number of walking and cycling trips per person per day.*

| Country | Year | On foot | Bicycle |
|---|---|---|---|
| Norway | 1991/92 | 0.66 | 0.20 |
| Sweden | 1994/95 | 0.48 | 0.37 |
| Finland | 1992 | 0.39 | 0.22 |
| Denmark | 1992 | 0.30 | 0.50 |
| Great Britain | 1992/94 | 0.84 | 0.05 |
| The Netherlands | 1994 | 0.67 | 1.01 |
| Germany | 1989 | 0.79 | 0.34 |
| Austria (Ober) | 1992 | 0.55 | 0.18 |
| Switzerland | 1989 | 0.75 | 0.33 |
| France – Grenoble | 1992 | 0.98 | 0.16 |
| France – Lyon | 1985 | 1.15 | 0.06 |

The Finnish and Danish data includes all trips longer than 200m and 300m respectively. The data for all the other countries includes all trips.

Survey data from seven European countries (Denmark, Finland, France, Great Britain, the Netherlands, Sweden, Switzerland) is presented in WP1 (Pedestrians problem analysis; PROMISING, 2001a). The data show that 15-30% of all trips are made by walking, the highest figure being for Great Britain; the proportions decrease significantly when only considering trips between home and work. For short trips under 5km, the figures may rise to 40%, or more as in Great Britain; however, use of the car remains frequent with 30-60%, of trips using the car, but this is lower in the Netherlands due to extensive use of bicycles.. Generally, the number of daily walking trips is higher for women than for men, and it does not seem to vary much according to age, except for Denmark and Switzerland where elderly people tend to walk more.

The Federation of European Pedestrian Associations reviewed the position of the elderly pedestrians in Europe (1993) on behalf of the EC's European Year of Older People. The report gives exposure data collected from pedestrian associations throughout Europe concentrating especially on those over retirement age. The exposure while walking and cycling of those over retirement age and those under retirement age are compared in terms of the percentage of trips on foot and the time spent walking and cycling in a public space are shown in Tables 5 and 6.

*Table 5: Percentage of total trips that are on foot (FEPA 1993).*

| | | Under 65 | Over 65 |
|---|---|---|---|
| Belgium[1] | | 25% | 48% |
| W. Germany | | 22% | 48% |
| The Netherlands | Official statistics | 17% | 27% |
| | Pedestrian assoc. statistics | 45% | 55% |
| Spain | | 40% | |
| Switzerland | | 19% | 35% |
| UK | | 29% | 37% |

*Table 6: Time (min) spent per day as a pedestrian and cyclist in a public space (FEPA 1993).*

| | | Pedestrian | | Cyclist | |
|---|---|---|---|---|---|
| | | <65 | >65 | <65 | >65 |
| Belgium | | | 11 | | |
| The Netherlands | Official statistics | 10 | 16 | 18 | 23 |
| | Pedestrian assoc. statistics | 25 | 35 | | |
| Switzerland | | 14 | 24 | 7 | 3 |

Tight et al (1990) compared exposure and accident data between the three countries at national and local levels. The exposure data is in the form of number of trips per person per day and the distance travelled per person per day. The Swedish data is only for persons aged 15-84 and the Netherlands data excludes travel by persons aged less than 12.

*Table 7: Distance (km) per person per day by main mode of transport (Tight et al 1990).*

| | GB (1985-86) | Sweden (1984-85) | The Netherlands (1986) |
|---|---|---|---|
| Car driver | 10.60 | 19.30 | 15.44 |
| Car passenger | 6.99 | 8.20 | 8.40 |
| Public transport | 3.68 | 8.10 | 4.07 |
| Pedal cycle | 0.18 | 0.80 | 3.10 |
| Pedestrian | 1.06 | 0.80 | 0.86 |
| Other | 0.94 | 0.30 | 1.29 |
| All | 23.45 | 37.50 | 33.16 |

[1] The statistics for Belgium are for persons aged under and over 60 years of age

*Table 8: Trips per person per day by main mode of travel (Tight et al 1990).*

| | GB (1985-86) | Sweden (1984-85) | The Netherlands (1986) |
|---|---|---|---|
| Car driver | 0.87 | 1.14 | 1.13 |
| Car passenger | 0.54 | 0.42 | 0.48 |
| Public transport | 0.31 | 0.34 | 0.18 |
| Pedal cycle | 0.07 | 0.32 | 0.95 |
| Pedestrian | 0.95 | 0.66 | 0.60 |
| Other | 0.05 | 0.04 | 0.09 |
| All | 2.80 | 2.92 | 3.43 |

It is interesting that in total the Swedes travel 1.6 times as far as the British and about the same as the Dutch. However, walking and cycling make up 5 and 4 per cent of the total distance travelled in Britain and Sweden respectively and 12 per cent in the Netherlands. When not in their cars, the Swedes use public transport and the Dutch cycle. On average the British do not travel as far as the Swedes or the Dutch: when not travelling by car they are most likely to be on public transport or walking.

ADONIS (1998) presents data from a survey of attitudes to modal choice for short trips in three large European cities. A total of 354 people from Amsterdam, Barcelona and Copenhagen were interviewed.

Of total trips made by all modes, the proportion of walking journeys ranged from 9% in Copenhagen to 18% in Amsterdam and 31% in Barcelona. Of total trips made by all modes, the proportion made by bicycle was highest in Copenhagen (51%) followed by Amsterdam (34%). None of the interviewees bicycled in Barcelona. On average, people in Amsterdam and Barcelona made more trips on foot (2.5 and 2.7) compared with Copenhagen (1.7). More trips per day were made by bicycle in Amsterdam (3.5) than Copenhagen (2.2). The average trip by foot was shortest in Barcelona (0.77km) and longest in Copenhagen (2.27km): in Amsterdam the average distance was 1.06km. An average journey by bicycle was roughly the same length in Amsterdam (2.59km) and Copenhagen (2.60km).

In Amsterdam people travelled to work mainly by car (55%) or bicycle (42%) and very few walked. In Barcelona most people would drive to work (65%) but a substantial number would also walk (40%). In Copenhagen most journeys to work and school were by bicycle (65%). In Amsterdam and Copenhagen personal business was, to a large extent, carried out by bicycle (50% and 65% respectively) whereas in Barcelona people would walk(65%). Leisure journeys in Amsterdam (53%) and Copenhagen (59%) were mainly by car whereas in Barcelona they were on foot (63%). Multimodal trips were most common in Amsterdam and the least common in Copenhagen. 14% of all journeys by foot, 5% of all bike trips and 1% of all car trips were combined trips.
The differences in the amount of walking and cycling where investigated with regard to attitudes and behaviour in the three cities. In all three cities the most important reason for walking was distance, the acceptable length appearing to be around 1km. People in Barcelona where very negative about cycling believing that it was not a comfortable mode of transport and that they felt very vulnerable on a bike.

Jensen (1998) presents data from the Danish travel surveys of 1993-1995, May 1997 and from the national travel survey of children and the elderly 1993-94. Danish people walked 1.2 billion km per year during 1993-95. During May 1997 about 65% of trips less than 300m were on foot and 16.7% by bicycle. The report looked at the effect age has on exposure in terms of km walked per day and risk.

The study shows that people in large cities in Denmark walk further than those in less well populated cities. A person in municipalities with 0-25,000 inhabitants walked on average 0.4km per day compared to an average of 0.6km per person per day walked in a municipality with 50,000-99,999 inhabitants. People in Copenhagen and Frederksberg walked on average 0.9km per person per day but in the suburbs close to Copenhagen the average was 0.7km per person per day.

*Table 9: Total distance walked (km) per day by each age group.*

| Age | Distance walked per day (km) |
|---|---|
| 16-24 | 430,000 |
| 25-34 | 470,000 |
| 35-44 | 370,000 |
| 45-54 | 340,000 |
| 55-64 | 280,000 |
| 65-74 | 260,000 |
| 75+ | 380,000 |

The report also gives relative risk for walking in twilight and darkness in comparison with daylight, walking in rural compared with urban areas, and crossing roads compared with walking alongside roads. The risk of injury when walking was less overall on rural roads than urban roads but pedestrians on rural roads were more likely to be injured walking along the road and walking in twilight or darkness than urban pedestrians.

*Table 10: Pedestrian casualties per million km walked.*

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

Promising WP1 presents data from France's two surveys which collect travel data (Rennesson and Lourdaux, 1998; PROMISING, 2001a). A national survey 'INSEE transport & communication survey' covering the whole of France collecting daily short distance trips and long distance weekend trips. Also Household Surveys are carried out at town level, collecting data on individual travel practices, modal split as well as opinions and attitudes towards transport.

23.2% of weekday trips in France are walking trips (people aged over 5 years, continental France, 1993-94).

*Table 11: Modal split according to purpose.*

| | Walking | Two-wheelers |
|---|---|---|
| All purposes | 28% | 4% |
| Related to work | 11% | 6% |
| Related to school | 42% | 6% |
| Local shopping | 49% | 5% |
| Large shops | 15% | 2% |

As with the Danish report the amount of walking was greater in areas with larger populations than those with smaller populations. 30.5% of weekday trips in Paris were walking trips compared with only 17.6% of trips in districts with a population of less than 50,000, 21.6% of trips in districts with a population of 50,000 to 300,000, and 23.5% of trips in districts with a population of over 23.5%.

The report discussed the effect that jobs and age had on exposure. Farmers walked the least frequently with only 9.9% of their trips on foot. Those without a job walked 31.6% of their trips. Pensioners and children aged 6-14 walked 33.1% and 39.5% of their trips respectively.

Breithaupt (1994) selected four residential areas in the Netherlands selected and 600 questionnaires were distributed to parents through schools. A response rate of 73% was reported as 434 usable questionnaires were returned. Also 330 children and 100 parents, who had themselves grown up in the area, were interviewed. The study focused on four main areas: the age of independence, the frequency of play outside, whether play was supervised and the degree of independence in moving around.

*Table 12: Frequency of play outside.*

| | Amsterdam | Haarlem | Loon op Zand | Weststellingwerf |
|---|---|---|---|---|
| Almost never | 31.3% | 13.4% | 1.6% | 1.1% |
| Once a week | 12.6% | 5.9% | 3.8% | 0.5% |
| Twice a week | 30.8% | 22.7% | 21.9% | 15.8% |
| Three times a week + | 25.2% | 58.0% | 72.7% | 82.5% |

The study concludes that in places where basic traffic engineering measures have been taken, the children enjoy a greater freedom of movement but that even those children living on a ‘woonerf’ have their movements restricted by the nearest busy road.

Ward et al (1994) details a pedestrian exposure study in Britain funded by the AA Foundation for Road Safety Research in 1994. Northampton was chosen because it is a typical self contained British town. A sample of 400 private households were used. An interviewer called and left self-completion diaries for each member of the household aged over 5 years after they had agreed to take part. They were asked to record their activity on foot during a specified day. The interviewers called back and checked that enough information had been given to enable them to re-walk all the walks and for all other activities on foot to be located. While re-walking the interviewers recorded details such as road type, pavement condition, lighting and type of crossing facility used.

The study showed that people in Northampton made on average 2.4 walk trips a day and for those that walked, the distance travelled was about 1100m. These data are similar to the data reported by Tight et al. The average trip length was 0.48km and the average number of roads crossed by those who walked was 5.51, 15% of them at protected crossings.

The study looked at the effect on exposure of age, socio-economic group, car availability and health. 85% of 5-9 year olds walked on the survey day compared to only 59% of those aged 65 and over. Only 50% of those registered disabled walked on the survey day compared with 75% for the population as a whole. Among those with no car available, those who live in a household where the head is unemployed were less likely to walk than those with employed heads. Other than this differences in exposure between those with cars available and those without and between socio-economic groups showed no clear pattern.

In a study carried out by TRL (Lowe 1999) a random sample of 10,000 adults in England were sent a questionnaire with a travel diary and asked to detail all walking and cycling journeys on a single day. Included with each of these was a children's version of the questionnaire which was intended for any child between the ages of 5 and 16 living in the household of the adult respondent. Approximately 20% of the questionnaires were returned and a telephone survey of non-respondents demonstrated that the sample was representative of the population.

The questionnaire included questions on the number of roads crossed and the business of those roads as well as estimates of the time spent walking or cycling. (the respondents' memory of time spent walking was shown to be an accurate measure of actual time spent).

The respondents made an average of 1.85 walking trips a day and spent 33 minutes walking. The respondents who walked crossed an average of 5.07 roads a day with 26% of them at protected crossings. An average of 0.18 cycling trips a day were made by the respondents. Those who cycled spent an average of 58 minutes cycling a day. 21% of the child respondents played on or by the road for, on average, 111 minutes a day.

Variations in exposure relating to age, gender, socio-economic group, car availability, ethnicity, health, region of the country and day of the week were studied. 30% of males aged 11 to 15 cycled on the survey day but only 8% of females of this age cycled. There was no clear trend in the differences in the amount of cycling between different job categories, but manual workers made longer walking journeys. 72% of the respondents in London walked on the survey day compared with 65% nationally. At weekends respondents made fewer trips but spent more time walking. 68% of children whose parents do not have a car available to use walked to school compared to 55% of those children whose parents have a car.

Silcock et al (1998), video-recorded a range of locations in Britain where pedestrians are at risk. Computers were used to analyse the video tapes and extract data concerning the number of crossing movements and interactions between pedestrians and vehicles. The number of pedestrians crossing the road was taken as the indicator of exposure as the great majority of pedestrian accidents result from failed attempts to cross the road safely.

They called the interactions ‘rated events’ with the rating related to severity of risk. The less serious interactions between pedestrians and vehicles were coded as either:

Encounters - situations in which at least one of the traffic participants observably adapts his/her behaviour by a change of speed or a change of course,
or
Conflicts – two traffic participants maintain such course and speed that a sudden evasive manoeuvre of one of the participants is required to avoid collision.

The presumption is that a relationship exists between the numbers of accidents recorded and the numbers of encounters and conflicts observed.
Around 150 rated events per thousand crossing events were observed in zones with no crossing facilities or within 50 metres of a crossing facility, compared with rates of 30 or fewer rated events per 1000 crossings on refuges, Pelicans or at other light controlled junctions.

Analysis revealed that more males are involved in events relative to the number crossing. Age also has an influence with young males and older females appearing to be the groups more involved in more than the expected number of events, particularly away from formal crossings.

### 3.4.2 Cycling

Matthew (1995) reports cycle trips as a percentage of total trips for various European Countries, cities and towns as well as trend data in the amount of cycling, including targets set by individual towns.

*Table 13: Cycle trips as a percentage of total trips.*

| Country | Town | Past | % Cycle trips |
|---|---|---|---|
| Sweden | Malmo | | 20% |
| | Vasteras | | 33% |
| Denmark | National | | 18%(1993) |
| Finland | National | | 12%(1986) |
| Great Britain | National | | 2% |
| | Oxford | 26%(1984) | 21% |
| | York | | 22% |
| | Birmingham | | 2% |
| | Colchester | | 7% |
| | Leicester | | 4% |
| | Cambridge | | 34% |
| | Bradford | | 1% |
| | Nottingham | | 3% |
| The Netherlands | National | | 27% |
| | Groningen | | 57% |
| | Tilburg | | 36% |
| | Delft | 40%(1982) | 43%(1985) |
| | Houten | | 33% |
| Poland | Krakow | | 20% |
| Germany | National | | 11%(1991) |
| | Munich | 6%(1976) | 15% |
| | Hanover | 9%(1976) | 16% |
| | Munster | 29%(1981) | 43%(1992) |
| Austria | Salzburg | 11%(1985) | 19% |
| | Graz | 7%(1979) | 14%(1991) |
| Switzerland | Basle | 8%(1970) | 16%(1990) |
| | Geneva | | 20% |
| France | Strasbourg | | 12% |
| Italy | Padou | | 12% |

Parker (1996) shows how the number of cars in a Danish household affects the amount of walking and cycling. The data is from the Danish national travel survey (1992).

*Table 14: Kilometres walked/cycled per person per day.*

| | No car | One car | Two + cars |
|---|---|---|---|
| Walking | 1.0 | 0.5 | 0.4 |
| Cycling | 3.0 | 1.3 | 0.7 |

Edwards (1998) gives the percentage of journeys which are made on foot or by bicycle in the Netherlands and Great Britain. In total there were 4.4 billion km cycled in Great Britain in 1994. The figures for the Netherlands are for 1989 and for Great Britain are for 1985/86 from the National Travel Surveys in the two countries.

*Table 15: Cycle journeys in the Netherlands and Great Britain.*

| | The Netherlands | Great Britain |
|---|---|---|
| Journeys by cycle per week | 7.1 | 0.5 |
| Percentage of all journeys | 27.5% | 2.4% |
| Km by cycle | 22.8 | 1.4 |
| Percentage of all km | 9.4% | 0.8% |
| % walking and cycling of all journeys | 36% | 45% |

The WP2 report about cyclists (PROMISING, 2001b) presents slightly different data taken from Hansen (1994) and Carré (1997) for the modal share of cycling and also shows how bicycle ownership varies between the countries of Europe and how it relates to cyclist exposure.

*Table 16: Bicycle ownership and modal split.*

| | Inhabitants, thousands (1992) | No. of bikes, thousands (1991) | Bikes/ thousand inhabs. | Bike km per year, billions (1992) | Bike km per inhab. per year | Modal split % |
|---|---|---|---|---|---|---|
| Denmark | 5162 | 4500(1992) | 870 | 2.7 | 520 | 17 |
| Finland | 5029 | 3500 | 690 | | | 7 |
| France | 57206 | 19000 | 330 | 11 | 190 | 2.8 |
| Great Britain | 56388 | 25000 | 440 | 5 | 90 | 1.5 |
| Netherlands | 15129 | 15000 | 990 | 12.5 | 830 | 28 |
| Norway | 4286 | 3000(1992) | 700 | 1.3 | 300 | 4 |
| Sweden | 8643 | 6000 | 690 | 3.3 | 380 | 15 |

As well as discussing general exposure data in distance cycled Mynors et al (1994) look at the effect of weather and geography on exposure. The seasons create greater variations in traffic levels for bicycles than for cars. Only the Netherlands appears to maintain detailed national statistics on this (Centraal Bureau voor de Statistiek,1992). In 1991, these show that the fewest cycle trips were made in December – 21% fewer than for the average day – while the most cycle trips were in May and August, which registered 13% more daily trips than the average. For cycle kilometres, the variation was greater, with 33% less than average in December, and 34% more than average in August. Such figures as are available for Germany give a similar result. A study of office workers in Copenhagen in 1989 indicated that of those people who normally cycled to work in good weather, 60% still cycled when it was raining. In winter, 66% cycled except in slippery conditions, when the figure was reduced to 39% cycling.

O’Donoghue (1993) uses UK traffic census data and National travel survey data to investigate cycling on different classes of road. 81% of pedal cycle traffic is on minor roads, 14% on major built-up roads and only 5% on major non built-up roads. The report also gives similar statistics for motorcycles: 46% on minor roads, 25% on major built-up roads, 23% on major non built-up roads and 6% on motorways. 1989/91 NTS data shows that cycling was most common during May-July, averaging around one-fifth more than the rest of the year. In 1989/91 36% of households had at least one cycle and every 100 people owned 27 bicycles. An average person made 21 cycle journeys a year and cycles 41 miles a year. An average cycle travelled 153 miles per year.

Crampton et al (1990) discusses the relative safety of Heilelberg, Ingolstadt, Münster, Oxford, Peterborough and York.

*Table 17: Comparison of the amount of cycling and cycling facilities.*

| | Population (thousands) | Length of cycle facility | Estimated cycle modal split |
|---|---|---|---|
| Heilelberg | 137 | 63 | 20% |
| Ingolstadt | 93 | 215 | 27% |
| Münster | 265 | 160 | 40% |
| Oxford | 94 | 40 | 21% |
| Peterborough | 133 | 100 | 15% |
| York | 97 | 23 | 22% |

In York, 16 of the 23km of cycle facility are ‘cycle routes’, i.e. low density roads shared with motorised traffic. In Münster, the cycle modal split includes students, whereas in Oxford and York it does not. However, the Oxford and York figures are identical to those in Matthew (1995) and the Münster figure is less. It is not clear where the figures come from and whether the student populations have been included in the figures.

In Great Britain 43% of motorcycle accidents and 42% of pedal cycle accidents occur at T junctions (RAGB 1997) and of these most were on C class or Unclassified roads (largely residential roads with relatively lower traffic flows). Lockwood et al (1998) used video cameras to record the behaviour of two-wheelers (pedal cycles and motorcycles) passing through a range of junctions. This allowed the calculation of an exposure measure in terms of accidents per junction which may offer a better picture of the risk to two-wheelers than the more standard rate per distance travelled.

The calculation of the new exposure measure required a measure of the number of two-wheelers passing through different types of junction and a measure of the accidents at these junctions. A total of 13,917 pedal cycles and 7947 motorcycles were observed at 101 junctions. Recording took place only during daylight hours during the summer months and the number of accidents during these hours was used to calculate the accident rate.

Most of the junctions selected for the study were on minor roads since the accident statistics suggested that a high proportion of two wheeler accident occur at minor road junctions

*Table 18: Two-wheeler accidents per traverse of a junction*

| | Junction type | | | |
|---|---|---|---|---|
| | Major/minor | Minor/minor | Residential | Roundabout |
| No of sites | 24 | 19 | 38 | 20 |
| Accidents per million traverses | 1.16 | 1.74 | 1.27 | 3.34 |

The study has shown that two-wheelers are particularly at risk at roundabouts. Most of these were large roundabouts with several entry lanes. The study did not include mini-roundabouts which have been found in some European studies to reduce two wheeler accidents

### 3.4.3 Motorcyclists

In a survey carried out in Britain by the Social and Community Planning Research 1987/1988 (Lynn 1990) 10,000 questionnaires were sent to a random national sample of motorcycle owners. The questionnaires included questions on age, sex, riding experience, tests passed, exposure, engine size and details of accident involvement. 6245 questionnaires were returned by current riders.

The average yearly mileage of all motorcycle riders was calculated to be 3700 miles. Females rode on average 2083 miles a year and males 4020. 19 year olds had the largest mileage, 5561 compared to 1797 miles a year for those aged 55 and over. The average mileage for bikes up to 50cc was 2342 and for over 500cc was 5705. The majority of respondents did all or most of their mileage in built-up areas. 45% did most of their biking in daylight.

Broughton (1995) presents data from the UK National Road Traffic Survey and shows billion vehicle kilometres travelled by road class for motorcycle and pedal cycles (see Table 19).

Pedal cycles are not allowed on motorways. It can be seen that motorcycles travel further than bicycles on the main roads but the opposite is true on the minor roads. Roads are classified as built-up or non built-up according to the speed limit, a built-up road has a limit of at most 40mph (64km/h). Major roads are motorways and A class roads, minor roads are B and C class and unclassified roads. A roads are further classified into Trunk roads, for which the national government is responsible, and principal roads which are the responsibility of the local authorities.

*Table 19: Distance travelled by road class (billion vehicle km).*

| | | Motorcycles | Pedal cycles |
|---|---|---|---|
| Motorways | | 0.2 | 0 |
| Built-up major roads | Trunk | 0.1 | 0 |
| | Principal | 0.9 | 0.6 |
| | All | 1.0 | 0.6 |
| Non built-up major roads | Trunk | 0.4 | 0 |
| | Principal | 0.6 | 0.2 |
| | All | 1.0 | 0.2 |
| All minor roads | | 1.9 | 3.6 |
| All roads | | 4.1 | 4.4 |

### 3.4.4 Young drivers

As part of a survey carried out in Finland (Hatakka et al. 1992), 42,000 questionnaires were sent out to young drivers requesting accident and exposure data. There was a 75% response rate. The data consists of self-reported exposure data from 7605 young drivers aged between 18 to 20 with driving licences 6 to 20 months old. The average total mileage was 17520km and 1397 km/month. For comparison a group of 6730 new drivers aged 21 and older had a average total mileage of 9443km and 891km/month. The average mileage in km/month was 992km for females and 1797km for males.

# 4 FACTORS INFLUENCING EXPOSURE/MOBILITY

**Car availability**
Data from the 1992 Danish national travel survey shows how car availability affects the average distance walked. The distance walked per day drops from an average of 1km for those with no car to 0.4km for those with two or more cars. (Parker 1996)

**Ethnicity**
In a recent British national survey, of those children living in a household with a car, 30% of children from non-white backgrounds walked to school compared with 15% of white children.

**Age**
People aged over 65 make a higher proportion of their trips on foot than those aged under 65 but make fewer trips and walk on average less distance than younger people.

**Rural/urban**
30.5% of weekday trips in Paris are walking trips compared with only 17.6% of trips in districts with a population of less than 50,000. (Papon 1997).

**Socio-economic grouping**
Data from the French INSEE transport and communication survey shows that individuals without a job walk the most with 31.6% of their trips being on foot. Of those who work, employees walk the most and farmers walk the least (9.9%). (Papon 1997).

**Health**
The pedestrian study of Northampton carried out in 1994 asked respondents if they had difficulty going out on foot. Of those with such a difficulty 60% walked on the survey day compared with 50% of those registered as disabled and 76% of those with no difficulty walking. (Ward et al. 1994).

**Weather conditions**
In 1989 a survey of office workers in Copenhagen showed that 66% of those who would normally cycle to work, cycled if it was raining and only 39% cycled in slippery conditions. (Mynors et al. 1994).

**Time of year**
NTS data from Britain (1989/91) shows that cycling was most common during May-July, averaging around one-fifth more than the rest of the year. (O'Donoghue 1993).

# 5 DATA AVAILABLE ON ACCIDENTS

## 5.1 National data

National accident data collection systems vary between countries. In a survey for the EU project DUMAS, it was found that, in general, the police attend accidents and draw up an accident report if there is a casualty. In some countries (the Czech Republic, France, Germany), the police also draw up an accident report for accidents where there is material damage only, when the damage is serious enough to exceed a certain cost. In Italy material damage only accidents were recorded up to 1991 and in Austria up to 1994. However, inaccuracies in reporting the various values contained in the national road accident data collection form are observed in all nine DUMAS countries. Such inaccuracies are increasing due to the lack of proper training of the police officers collecting the information.

Definitions of the road accident types contained in national accident data show differences among the various European countries. Even a basic concept such as the definition of a fatal accident, shows important differences. The international definition of persons killed in road accidents, as the persons who died within 30 days from the day of the accident, is used in most of the European countries. However, different definitions are used in France (6 days), Italy (7 days), Spain, Greece and Portugal (24 hours). Correction factors are used by these countries for the conversion to the uniform European definition.

Table 20 gives the definitions of injury severity among the various EU countries. The minimum injury for which it is required that the accident is recorded is also different in each country. In particular, the distinction between seriously and slightly injured persons show significant differences among countries. For example in Italy there is no such distinction of injury severity.

*Table 20: Comparison of basic definitions of road accident terms used in the EU countries (DUMAS WP4)*

| | definition of person killed | Correction factor to the 30 days deaths | Definition of seriously injured | Definition of slightly injured | Criteria of injury degree | Definition of build-up area | Reporting of injury accidents | Reporting of material damage only accidents |
|---|---|---|---|---|---|---|---|---|
| Germany | 30 days | 1 | Hospitalised > 1 day | Other injuries | Duration to the hospital | Zone inside city / commune signs | yes | More than 4.000 DM |
| France | 6 days | 1,09 | Hospitalised > 6 days | Hospitalised < 6 days | Duration to the hospital | Zone inside city / commune signs | yes | no |
| Italy | 7 days | 1,07 | - | - | - | Built-up area | yes | up to 1991 |
| Netherlands | 30 days | 1 | - | - | - | Built-up area | yes | yes |
| Belgium | 30 days | 1 | Hospitalised > 1 day | Other | Duration to the hospital | Zone inside city / commune signs | yes | no |
| Luxembourg | 30 days | 1 | Hospitalised > 1 day | Other injuries | Duration to the hospital | Zone inside city / commune signs | yes | yes |
| Great Britain | 30 days | 1 | Hospitalised + serious injuries | Slight injuries | Hospitalised + injuries' type | Inside zone with speed limit of 30/40 km/h | yes | no |
| Ireland | 30 days | 1 | Hospitalised > 1 day | Other | Duration to the hospital | Inside zone with speed limit of 30/40 km/h | yes | no |
| Denmark | 30 days | 1 | Fractures, burns, crane injury | Slight injuries | Type of injuries | Zone inside city / commune signs | yes | At local level |
| Greece | On the spot | 1,12 | Hospitalised | Not Hospitalised | Hospitalised | Built-up area | yes | no |
| Spain | 30 days (1 day up to 1994) | 1 (1,3 up to 1994) | Hospitalised | Not Hospitalised | Hospitalised | Built-up area | yes | no |
| Portugal | On the spot / transport to the hospital | 1,3 | Hospitalised | Not Hospitalised | Hospitalised | Zone inside city / commune signs | yes | From 1987 |
| Europe 12 | 30 days | | - | - | - | - | 12 | 5 |

## 5.2 Hospital data

Hospitals collect data on attendance at emergency departments and admissions. This information often includes information on road traffic accident casualties. This information is useful for cross-checking data collected by police and to record deaths occurring after the accident. Whilst not as rigorously checked as police recorded accident data they provide a means for estimating the degree of under-reporting of accidents and casualties in the police files.

Comparison of accident data and the police record for a particular accident can also be used to check on the accuracy information contained within the records. For example, in England, in a comparison of hospital admission data with the national road accident data file, it was found that for every five casualty records reported to the police four matching hospital admission records had factual errors on items such as age. Another British study shows that in 11.6 per cent of cases examined, the recorded age of the casualty in the police data base has been erroneous.

## 5.3 Insurance company data

The files of insurance companies include information on both injury and damage-only accidents but they are not exhaustive, as at least two large categories of accidents are not included: 1) single vehicle accidents involving vehicles without full insurance and 2) accidents with minor material damage in which the persons involved prefer not to make insurance claims.

In general, it is difficult to use data from insurance companies and in many countries they are not used for accident analysis. However for small scale accident analysis e.g. for identifying black spots, it may be possible to obtain information on such accidents through insurance companies. Since material damage only accidents are far more numerous than accidents with casualties they may allow for a better statistical analysis, especially in urban areas where they occur more frequently. The best estimates currently in use in Britain of the ratio of damage only accidents to injury accidents is about 15:1. The use of insurance company data would help to refine these estimates.

However, problems with the commercial sensitivity of insurance company data and the fact that it is collected for a different purpose make access to, and use of it, difficult.

## 5.4 Location of accidents

In order to carry out detailed analysis a reliable system of location of accidents is necessary. The identification of the exact location of an accident is often a difficult task for the police. This is a problem which leads to varying levels of inaccuracy between countries and within countries when the urban and rural networks are considered separately. Within built-up areas accidents are usually located by street name and at intersections by the names of the intersecting streets. On urban links, non-junction accidents are usually located by street number or by reference to prominent buildings or squares. However, in rural areas there is no such convenient dense network of roads and junctions to use for locating accidents and reference to kilometre markers is one of the most frequently used methods. This has a high potential for error and many accidents cannot be located to within 100 metres or more.

With the advance of information technology the quality of the locational data should improve. Geographic Information Systems (GIS), already used in some EU countries, currently provide a means for systematic recording of accident locations and when they are more widely used, consequent improvements in recording of location are expected to occur. In the future, the use of Geographic Positioning Systems (GPS) will provide for the necessary accuracy in the recording of the accident location.

## 5.5 Comparison between national data sets

There are sufficient differences between countries to make it difficult to compare national databases across the whole range of casualties. Table 20 above showed the different definitions of injury severity in use. Until a systematic injury severity descriptor is in common use, only the comparison of fatalities between countries is reliable, and even then, adjustment factors need to be used for some countries' data.

Access to national road accident data files suffers from data confidentiality problems. In many countries, the users of the accident data, such as local authorities, cannot gain direct access to the national data base. The solution is to use the local databases which are held by the police, or to request tabulations and aggregations from the holders of the national database. There are also problems in accessing data due to the different methods used for data storage. Under the framework of the EU CARE project access to national disaggregate road accident data files has been granted to authorised administrations from some EU countries. In December 1997, seven countries were linked to each other's data through the CARE system. The access to national databases and, through the CARE system, to the databases of other countries, is useful mainly to those interested in international comparisons of accident data and accident risk. At a local level, the more useful comparisons are likely to be those between one town and another in a region.

# 6 UNDER-REPORTING OF ACCIDENTS

Under-reporting of accidents is a problem in all countries. The reason that under-reporting rates are calculated is to give road safety researchers and practitioners a better estimate of the real scale and risk of injury to different groups of road users. Not all accidents, nor all injured persons in reported accidents, are reported to the police even if they occur on the roads and involve vehicles. Under-reporting is likely to create a bias in the data because serious or fatal accidents are more often reported to the police than slight ones. Fatal accidents have a high level of being recorded as the police are usually called and spend some time at the site investigating the circumstances of the crash. When people are involved in an accident where there are injuries, but no-one goes to hospital, research has indicated that they are much less likely to report the accident to the police. These slight accidents are also less likely to result in the police attending the scene to control traffic or to take statements from those involved, this decreases the likelihood of them coming to the attention of the police.

In most countries under-reporting is a particular problem for vulnerable road users and the percentage of cyclist casualties whose accidents are in the hospital records and reported to the police may be as low as 10 percent in the case of slight injury. The commonest unreported cycle accident (Mills 1989) is a single vehicle accident often involving a child and away from a highway. People, including the police, tend to view these as domestic or recreational accidents rather than traffic accidents. The reporting rates for pedestrian injury tend to be higher across the range of injury than for the pedal cycles with up to 80 percent of slight injuries being reported. Pedestrian accidents most commonly result from motor vehicle impacts within the highway system boundaries and are unlikely to be viewed as anything other than traffic accidents. Table 21 gives an overview of the reporting rates in Britain.

However the levels of under-reporting cannot be assumed to be the same across countries, and ETSC have collated information on reporting levels to calculate a cost for non-reported as well as reported accidents. To take account of the effect of misclassification, under-recording and under-reporting the number of serious and slight casualties appearing in national figures it has been estimates that these should be multiplied by 2.76 and 1.70 respectively (OECD 1998).

Six hospital-based under-reporting studies carried out in Great Britain have been summarised in Table 21 below which gives the range of levels of under-reporting for different degrees of injury severity and for different road users.

*Table 21: Percentages of casualties reported (estimated from hospital-based studies in Great Britain.*

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

A hospital based study of casualties carried out in 1984-85 found that 74% of slight injuries and 61% of serious injuries sustained by pedal cyclists were not reported to the police, although no fatalities went unreported. (O’Donoghue 1993).

In a survey of motorcyclists the respondents claimed to have reported only 17% of their accidents, with only half of the serious injury accidents reported to the police. Accidents involving the largest bikes were more than twice as likely to be reported to the police as those involving smaller bikes. (Lynn 1990)

In the case of pedestrians, a study of pedestrian exposure and accident risk carried out in the English town of Northampton found that for all ages the level of under-reporting of pedestrian casualties to the police was about 24%. (Ward et al. 1994). This is in line with the results of the hospital based study shown in Table 21.

In Denmark, the Accident Analysis Group at Odense University Hospital has kept an account of the extent to which the police record road accidents involving casualties in the hospital’s area. For the years 1990-1994, 33-42% of pedestrian casualties in accidents with motor vehicles were recorded by the police (Accident Analysis Group, 1991-1995). Comparisons between hospital and police records show that the police records only include about 20% of casualties of road accidents. Hospital records include pedestrian casualties where no vehicle is involved but the pedestrian is injured due to tripping or falling; these accidents are registered as home or leisure accidents. 70-75% of pedestrian casualties occur in situations where no vehicle is involved. This study highlights sources of injury to pedestrians other than collisions with traffic. A similar study in Britain indicates that ten times as many people are injured by tripping and falling in the road environment as are injured by vehicles (Department of Trade and Industry).

In the Netherlands, hospital survey data was compared with accident data from the Traffic Accident Registration (based on police reports) of the Ministry of Transport. It showed that the registration of recordable accidents accounted for only 20% of accidents reported by those interviewed. However, accidents reported by interviewed casualties also included pedestrian falls which are not considered registrable as road traffic accidents. Completeness of the registration appeared dependent on injury severity, age and mode. The most under-recorded road user casualties were cyclists (9%), while the best were car occupants (37%).

A Swedish study carried out in 1983-84, compared an estimated number of injuries to adults aged 14 to 74 to the corresponding figures recorded in police reports Thulin 1989). It showed that only 37% of injuries were recorded in statistics (32% of the slight ones and 59% of the serious ones). When considering the various transport modes separately, it was found that coverage of cyclist accidents by the police was particularly low (15%), which may be in part due to cyclist falls without collision not being 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 1514 victims, and hospital data 1076: only 843 victims were found to have been recorded both by the police and the emergency department. Cyclists are shown to account for 15% of the victims in police data, and for 35% in hospital data. Information on pedestrians injured by falls is reflected in the hospital data alone (Berntman 1994).

A study of bicycle injuries was carried out in Finland (Olkkonen 1993). 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.

A study in Norway using exposure data from the National Norwegian Travel Survey 1991/92 and accident data from official accident statistics (police-reported accidents) and hospital statistics, showed that the official statistics cover approximately one third of the true number of road accidents with personal injury. (Bjørnskau 1994).

*Table 22: Number of injured and killed road users per million person km travelled.*

| | Official data | Hospital data | Ratio |
|---|---|---|---|
| Car drivers | 0.174 | 0.316 | 1.82 |
| Car passengers | 0.312 | 0.596 | 1.91 |
| Moped | 1.452 | 3.867 | 2.66 |
| Motorcycle | 1.667 | 4.646 | 2.78 |
| Bicycle | 1.258 | 13.46 | 10.7 |
| Pedestrian | 0.829 | 1.921 | 2.32 |

For mopeds, motorcycles and bicycles the figures relate to drivers and passengers.

A German study (reported in DUMAS WP6) found that:

- The number of accident fatalities is reported with a fairly high degree of accuracy; the number of unreported cases being less than 5%.
- For major injuries (requiring in-patient treatment) it was found that about 45% of motorised road user injuries, 70% of cyclist injuries and 50% of all pedestrian injuries remained unreported.
- For minor injuries (requiring out-patient treatment) 50% of car occupant injuries, 60% of motorised two-wheeler injuries, 80% of cyclist injuries and 65% of all pedestrian injuries remained unreported.
- The highest number of unreported cases were found among children and juveniles involved in accidents as cyclists, especially single vehicle accidents.

In an in-depth study carried out in Brescia (Italy) (reported in Ref DUMAS WP4) accidents with injuries which are unreported are a quarter of those reported. The distributions of reported and unreported accidents differed For example, under-reporting was found to be more frequent in the following types of accidents, in order of importance:

- light collisions, even with serious consequences,
- knocking into or over pedestrians, often with injuries due to falling,
- falling off two-wheel vehicles (accidental falls -even due to trying to avoid collisions with other vehicles-, collisions with parked vehicles -even due to door being opened suddenly-, collisions with moving vehicles),
- passengers falling off at the bus stop, either because of bus starting too soon or doors being closed too quickly,
- passengers falling or thrown from seat inside the bus due to sharp braking or collision with another vehicle.

# 7 FRAMEWORK FOR COST-BENEFIT ANALYSIS

## 7.1 The role of cost-benefit analysis in policy making and priority setting

The policy-making process can be divided analytically into a number of stages. Figure 2 shows one model of the stages of policy-making (Elvik, Mysen and Vaa 1997). The stages have been arranged in the order that appears to be logically the most natural one. No corresponding chronological order of the stages is implied. Figure 2 is, however, purely an analytical model and not meant as a literally correct description of policy making.

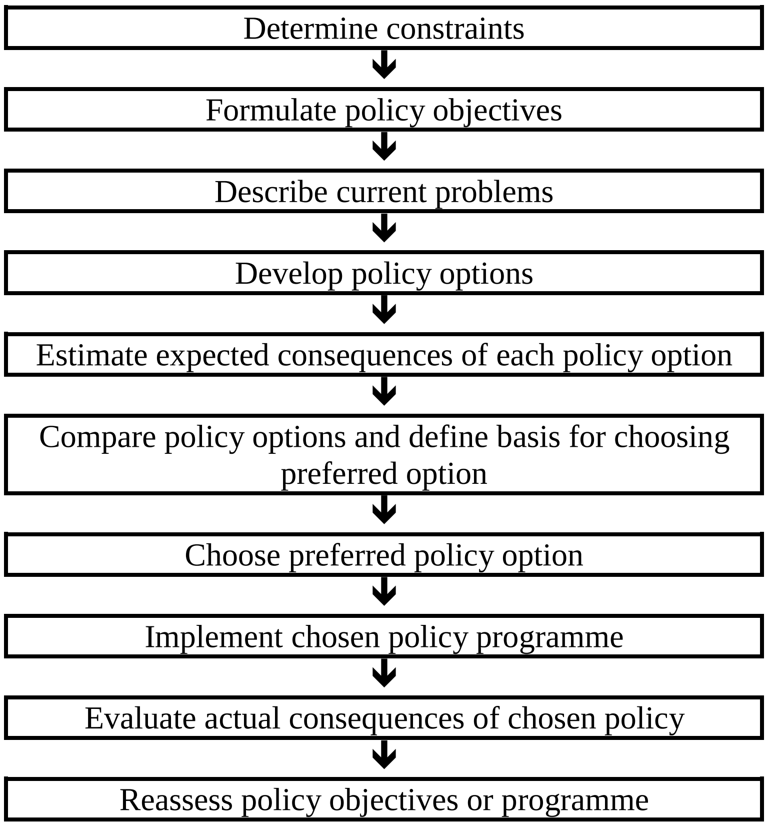


*Figure 2: The Stages of Policy-Making – Analytical Model.*

Logically speaking, the first stage of policy making is to determine constraints. By constraints is meant everything that is taken as given and not amenable to influence of any acceptable policy instrument. In most cases, the decision with respect to constraints is taken implicitly. Policy makers concentrate on aspects they think can be influenced and disregard those that they think cannot be influenced. In most road safety programmes, traffic volume is taken as a constraint; no attempt is made to influence it. Another commonly accepted constraint is current budget levels. In general, it is fair to say that guidelines for cost-benefit analysis do not advice policy makers with respect to how they can best determine the constraints of policy-making in a certain area.

Determining constraints is a very important step in the policy-making process. The subsequent steps of formulating policy objectives, describing problems, developing policy options and estimating the consequences of each policy option determine the set of measures to which formal techniques of priority setting, like cost-benefit analysis, are applied. Yet, these important steps are hardly dealt with at all in formal models of policy-making. Textbooks in cost-benefit analysis, for example, lay down principles for choosing between ready-made policy options with known effects. The textbooks do not tell how the options are developed.

There is, however, little point in setting priorities strictly according to economic criteria of efficiency if the potentially most effective measures have been left out of the programme. It is therefore essential to make sure that all the really effective measures are included in the set of measures to which the formal techniques of priority setting are applied. Choices are always made within a frame that is defined outside the framework of cost-benefit analysis.

To illustrate this, consider the following two frames for setting priorities. One frame is the policy objective of reducing the total number of traffic injuries in a country. If no other constraints are imposed, a broad range of measures will be relevant, and a fairly long list of alternative measures has to be developed in order to make sure that the most cost-effective measures have been taken into consideration. Another possible frame might be to provide school children with a safe crossing location in the vicinity of an elementary school. The number of potentially relevant measures is then much smaller and basing the choice of measures strictly on a cost-benefit analysis may be regarded as problematic.

## 7.2 Relevant impacts of measures

Which are the relevant impacts of safety measures that ought to be included in cost-benefit analyses? In general, the answer to this question is that every impact to which a preference is attached should be included, irrespective of whether the impact is intentional or not. This means that, in addition to impacts on the number of accidents or the number of injured people, cost-benefit analyses should generally include impacts on mobility, the costs of travel and the environment.

No standard taxonomy of relevant impacts exists. A preliminary list of potentially relevant impacts of measures is shown in Figure 3.

| *Main categories* | *Subcategories* |
|---|---|
| MOBILITY | The number and length of trips |
| | The speed of travel |
| TRAVEL COST | The direct outlays for travel |
| ROAD SAFETY | The number of accidents |
| | The severity of accidents |
| | The accident rate (accidents/km of travel) |
| ENVIRONMENT | The emission of noise |
| | The emission of air pollution (all types) |
| | The visual intrusion of road systems |
| | The insecurity (subjective safety) of road users |

*Figure 3: Taxonomy of relevant impacts of safety measures.*

When making such a list of impacts, it is important to avoid double counting of them. The problem of double counting is particularly relevant for environmental impacts, since there are many of them that are closely related. It is tempting to include, for example, both the insecurity (subjective safety or anxiety) of road users and the barrier effect of a road as environmental impacts. However, as these impacts are likely to overlap to a significant extent, including both of them would probably introduce an element of double counting into the list of impacts. In Figure 3 only security has been included.

## 7.3 Estimation of impacts

The estimation of the impacts of the measures on safety will be based on a model that allows account to be taken separately of:

(1) The exposure (amount of travel) of each road user group,
(2) The risk of injury,
(3) The effect of each measure on the exposure and risk of each road user group.

The basic model for estimating the number of injuries that can be prevented by each safety measure is:

Number of prevented injuries = Exposure x Risk x Effect of measure

The first two terms of this expression gives the expected number of injuries that can be affected by a measure. The effect of each measure will, to the extent available data make it possible, be partitioned into the following contributions:

Effect on safety = Change in exposure x Change in accident rate x Change in injury severity

This formulation allows the net change in the number of injuries to be broken down into contributions from changes in exposure, changes in the number of accidents per kilometre of travel (accident risk), and changes in the severity of injuries. A distinction can thus be made between measures seeking to reduce the number of accidents and measures seeking to reduce injury severity. Accident rate is defined as the number of accidents (all levels of severity) per million (vehicle or person) kilometre of travel:

$$\text{Accident rate} = \frac{\text{Number of accidents}}{\text{Million kilometres of travel}}$$

In general, the relevant measure of exposure for road related measures and police enforcement is vehicle kilometres of travel. For vehicle related and road user related measures, the relevant measure of exposure in most cases is person kilometres of travel.

A similar model will be applied to estimate the impact of a measure on the environment. Consider, for example, the impact of a measure on the emission of air pollution:

Effect on pollution = Change in exposure x Change in specific emission rate

With respect to environmental impacts, the term "exposure" denotes the population exposure to a certain concentration of ambient pollution. This, in turn, depends on the amount of traffic and the dispersion of emissions from traffic to people:

Population exposure = Traffic volume x Dispersion of emissions in time and space

There is adequate knowledge about how noise generated by traffic spreads to the surroundings. Less is known about how various forms of pollution spread. Simplifying assumptions will therefore be made with respect to population exposure for pollution.

In order to estimate the various impacts of a measure, data are needed about the following items:

(1) *Traffic volume*, which for road related measures and police enforcement denotes the AADT (annual average daily traffic) at the location where the measure is carried out and for vehicle related and road user related measures denotes the annual driving distance (kilometres per year) of a vehicle or road user.
(2) *Type of environment*, for which a rough distinction is made between urban and rural environments. It will be assumed that, except for global pollution and road user security, only the urban population is exposed to the environmental impacts of traffic.
(3) *Accident rate*, as defined above (number of accidents per million kilometre of travel). In general only injury accident rates should be used, as the reporting of

property damage only accidents, at least for specific roads, is too unreliable to estimate accident rates. Even injury accident rates are subject to incomplete accident reporting, which varies between countries. Indeed, not even the definition of a traffic fatality is the same in the EU countries.

(4) *Speed of travel*, when relevant. Some measures affect the speed of travel. The speed of travel is measured in terms of the mean speed of vehicles passing a recording station along the road.

(5) *Length of waiting times*, when relevant. Some measures, especially at junctions or other crossing locations, affect the length of waiting times for various groups of road users. Sometimes, there will be a trade off between different groups of road users in this respect. Traffic signals may, for example, shorten the waiting times for pedestrians and prolong the waiting times for motorists. Waiting time is measured as the mean, expected length of time a road user arriving at random at a certain location must wait (measured in seconds or minutes).

(6) *Vehicle operating costs*. Measures that affect the speed of travel or the length of waiting time, will generally also affect vehicle operating costs.

(7) *Noise emission*, when relevant. In general, measures that affect traffic volume or the speed of travel will also affect traffic noise. Traffic noise is generally measured in decibel (A).

(8) *Emission of air pollution*, when relevant. In general, measures that affect traffic volume, the speed of travel or mean waiting times will also affect the emission of air pollution. Measures that involve constructing new roads located further away from urban areas will also affect population exposure for pollution. Data on the emission of pollution are perhaps best given as emissions in grams per kilometre of travel, preferably specified according to type of emissions, for example carbon monoxide (CO), carbon dioxide ($CO_2$), nitrogen oxides ($NO_x$), sulphur oxides ($SO_x$), particulate matter ($PM_{10}$ or $PM_{2.5}$) and volatile organic compounds (VOC).

(9) *Road user insecurity*, when relevant. Some measures, especially those that affect traffic volume, the speed of travel and/or provide improved crossing facilities, are likely to affect the insecurity of road users. Ideally speaking, data ought to be provided on the current level of insecurity and how various measures affect road user insecurity. However, this is an area where little is known and relevant data are most likely to be missing. A universally accepted definition of insecurity and an accepted method for measuring it does not exist. Whatever knowledge there is about insecurity is therefore likely to be fragmentary and based on parochial methods for measuring it.

(10) *Effects of measures on relevant outcome variables*. In order to estimate the impacts of various measures on the relevant outcome variables, measured in physical units (changes in the number of accidents prevented, changes in the amount of pollution in kilograms or tonnes), the effects of measures on the relevant outcome variables must be known. These effects are perhaps best given as the percentage change a measure brings about in a certain outcome variable, for example the percentage change in the number of accidents or the percentage change in pollution emissions.

In addition to these variables, the direct implementation costs of a measure must be known in order to estimate the cost-benefit value or cost-effectiveness of the measure. The direct implementation costs of a measure may be of two types: investment costs and operating costs. Investment costs are all costs of introducing a measure. Operating costs are all costs that are incurred to maintain a measure or operate it on a continuous basis. The predominant type of cost differs between different types of measures. Often, investment costs will dominate for road related measures, whereas operating costs will dominate for training measures or police enforcement.

## 7.4 The duration of effects and service life of measures

The duration of the effects of various measures varies. Rough guidelines with respect to the duration of effects and length of service for various measures are given in Table 23. A few comments are needed for some categories of safety measures listed in the table.

The duration of the effects of road pricing or taxes imposed on motor fuel or the purchase of motor vehicles is not known. The effects are likely to differ in the short and long term (Fridstrøm and Rand 1993). In the short run, road users adapt to road pricing or increases in fuel prices by slightly reducing the amount of travel. The effect will usually be quite small, and may disappear within a year or two if real income rises. In the long run, increasing the prices of car ownership and use of cars can have greater effects. People will adapt to higher prices by buying cheaper cars and by driving fewer kilometres per year. These long-term effects will, however, take perhaps 10-15 years to become fully manifest.

Vehicle related safety measures are listed in Table 23 as having a service life of some 10-15 years. This is based on the assumption that the vehicle fleet takes 10-15 years to turn over completely. The effects of some vehicle related safety measures last longer. Seat belts, for example, continue to be effective as long as they are required in vehicles and worn by drivers and passengers, no matter how long it takes for the vehicle fleet to turn over. It is, however, inappropriate to estimate costs for a period lasting longer than the expected service life of a vehicle.

Information and enforcement are presumed to have contemporaneous safety effects only. This means that an information campaign, or some enforcement activity, is effective as long as it is carried out, but not after it has been terminated. This assumption may be somewhat too pessimistic. Some information campaigns and enforcement blitzes are known to have had effects some time after their termination. The effects do not, however, last very long and it is impossible to say in general how long any effects are likely to last after the termination of an information campaign or some enforcement activity. Some kinds of information can have very long-term effects, at least at an individual level.

*Table 23: Duration of effects (service life) of a number of road safety measures. Typical values.*

| Category of safety measure | Typical duration of safety effects (service life) |
|---|---|
| Land use planning; new residential areas | 25-40 years |
| Road pricing; fuel or vehicle taxation systems | 1-3 years for use of existing motor vehicles, 10-15 years through vehicle purchasing decisions |
| Changing the modal split of travel | Contemporaneous effect only |
| Major road investment projects (new roads) | 25-40 years |
| Minor road investment projects | 15-25 years |
| Traffic control by means of highway signs | 10-15 years |
| Traffic control by means of road markings | 1-10 years |
| Upgrading road maintenance | 1 year |
| Vehicle safety regulations (for new vehicles) | 10-15 years |
| Driver education and training (new drivers) | 1-3 years |
| Training of children | 1-3 years |
| Public information campaigns | Effect only during campaign, or a short time after |
| Conventional police enforcement | Effect only when operated, or a short time after |
| Automatic police enforcement | Effect only when operated, or a short time after |

## 7.5 Measures of efficiency

Cost-benefit analysis is based on the principle of social efficiency. Social efficiency is a technical term in welfare economics. A policy or a programme is regarded as efficient if it improves the welfare of at least one person without reducing it for anybody else. Policies that are efficient in this sense satisfy the criterion of Pareto-optimality. It has long been recognised, however, that Pareto-optimality is a much too stringent criterion of social efficiency.

Most economists therefore subscribe to a less demanding criterion (potential Pareto-improvement) stating that a project improves welfare if those who benefit from it can, at least in theory, compensate those who lose from it and still retain a net benefit. This is equivalent to saying that projects for which the monetary value of the benefits, estimated according to the willingness-to-pay principle, exceed the monetary value of the costs, estimated according to the opportunity cost principle, are efficient, whereas projects for which the benefits are smaller than the costs are inefficient.

Two measures of efficiency are used in cost-benefit analysis. These are the net present value of a project and the benefit-cost ratio. The net present value of a project is defined as:

Net present value = Present value of all benefits – Present value of all costs

The benefit term includes all effects that are valued monetarily in an analysis. Different benefits are usually added to obtain total benefits. Negative benefits, for example increased travel time are subtracted. The cost term usually denotes the implementation costs of a measure, expressed in terms of the opportunity cost from a social point of view. The benefit cost ratio is defined as:

$$\text{Benefit-cost ratio} = \frac{\text{Present value of all benefits}}{\text{Present value of implementation costs}}$$

As is easily seen, there is a simple definitional relationship between net present value of benefit-cost ratio. When the net present value is positive, the benefit-cost ratio exceeds the value of 1.0.

One of the greatest problems in cost-benefit analysis is to obtain valid and reliable monetary valuations of all relevant impacts. This objective is rarely, if ever, fully realised. It is therefore often relevant to carry out a cost-effectiveness analysis in addition to, or in stead of, a cost-benefit analysis. A cost-effectiveness analysis is an analysis in which the objective is to find the cheapest way of realising a certain policy objective. In cost-effectiveness analyses, only one policy objective is considered.

The cost-effectiveness of a road safety measure can be defined as the number of accidents prevented per unit cost of implementing the measure:

$$\text{Cost-effectiveness} = \frac{\text{Number of accidents prevented by a given measure}}{\text{Unit costs of implementation of measure}}$$

In order to estimate the cost-effectiveness of a road safety measure, the following information is needed:

(1) An estimate of the effectiveness of the safety measure in terms of the number of accidents it can be expected to prevent per unit implemented of the measure,
(2) A definition of suitable units of implementation for the measure,
(3) An estimate of the costs of implementing one unit of the measure,
(4) A method for converting all costs of implementation to an annual basis (in order to make measures with different time spans comparable)

The accidents that are affected by a safety measure will be referred to as target accidents. In order to estimate the number of accidents prevented per unit implemented of a safety measure, it is necessary to:

(1) Identify target accidents (which may, in the case of general measures like speed limits, include all accidents),
(2) Estimate the number of target accidents expected to occur per year for a typical unit of implementation,
(3) Estimate the percentage effect of the safety measure on target accidents. This defines the numerator of the cost-effectiveness ratio of a safety measure.

To estimate the denominator, the first step is to define a suitable unit of implementation of the measure. In the case of infrastructure measures, the appropriate unit will often be one junction or one kilometre of road. In the case of area-wide or more general measures, a suitable unit may be a typical area or a certain category of roads. In the case of vehicle safety measures, one vehicle will often be a suitable unit of implementation, or, in the case of legislation introducing a certain safety measure on vehicles, the percentage of vehicles equipped with this safety feature or complying with the requirement. As far as education and training is concerned, the number of trained pupils according to a certain training scheme may be a useful unit of implementation. The unit cost will be the cost of training one pupil. It is difficult to define a meaningful unit of implementation for public information. It seems reasonable, however, to rely on the assumption that the effects of public information depend on the total volume of information. In that case, there is no need for counting units of implementation; effects are related directly to the total costs, rather than the unit costs. For police enforcement, the number of man-hours of enforcement per kilometre of road per year may be a suitable unit of implementation.

Once a suitable unit of implementation is defined, unit costs can be estimated. In order to make the cost-effectiveness ratios of different safety measures comparable, it is necessary to relate both the number of prevented accidents and the costs of implementing the measure to a certain time reference. This need arises because the relationship between costs and the duration of effects varies a lot between safety measures. The duration of the effects of various measures was discussed in section 7.4.

In order to get comparable implementation costs for all safety measures, irrespective of the duration of their safety effects the easiest method is to convert investment costs to annual capital costs. This comparability can be accomplished by converting investment costs to an annuity. An annuity is a constant amount, which, if paid throughout the period it applies to, has the original investment cost as its present value. When investment costs are expressed as annuities, they can be added to the annual costs of operation and maintenance to get the total costs of a safety measure.

The cost-effectiveness criterion for priority setting has a number of advantages as well as shortcomings. The advantages of the criterion are:

(1) It is generally easier to calculate the cost-effectiveness of a safety measure than to calculate its benefit-cost ratio. Calculating cost-effectiveness requires knowledge about safety effects and costs of implementation only. To calculate benefit-cost ratios one needs more information, concerning, for example, accident costs and the effects of a safety measure on mobility.
(2) Cost-effectiveness highlights the safety effects of measures. A cost-benefit ratio, on the other hand, is determined not just by safety effects but also by the effects of a measure on mobility and on environmental factors.
(3) Cost-effectiveness does not require the use of accident costs. Accident costs can be difficult to estimate and the estimates are often controversial.

The major shortcomings include the following:

(1) The cost-effectiveness criterion cannot be used to compare safety effects for different levels of accident severity. Some safety measures (e g road lighting and speed limits) have different percentage effects for accidents of different degrees of

severity. For such measures, there will be different cost-effectiveness ratios for each level of accident severity. These different ratios cannot be compared without assigning weights to the different levels of accident severity. In cost-benefit analysis, such weights are assigned by means of the unit costs per accident or injury for each level of accident or injury severity.

(2) The cost-effectiveness criterion cannot be used to trade off safety against other policy objectives. The criterion does not say at what level of cost-effectiveness a measure becomes too expensive. Cost-effectiveness cannot, in other words, be used to determine the level of a safety programme that maximises welfare in an economic sense of that term.

(3) The cost-effectiveness criterion disregards the effects of safety measures on mobility and the environment. In practice, however, these effects are often important and in some cases decisive for the introduction of a certain measure.

Despite its major shortcomings, cost-effectiveness is an interesting criterion for ranking alternative safety measures. It informs decision-makers about the priorities that would result if improving safety were the only target of transport policy. Information of this kind is useful in discussing the potential conflicts that may exist between improving safety and other objectives of transport policy.

Cost-benefit analysis is particularly useful in those areas of policy making where: (1) there are multiple policy objectives, (2) the objectives are partly conflicting and (3) the objectives refer to goods that do not have market prices.

## 7.6 Valuation of relevant impacts

The most difficult part of a cost-benefit analysis is often to obtain theoretically correct and empirically valid and reliable monetary valuations of all relevant impacts. Literally hundreds of studies have been made to determine the value of goods that do not have market prices, like the reduction of environmental pollution. Cost-benefit analysis recognises the fact that something can have a value, even if it does not have a price. Perhaps ironically, a cost-benefit analysis is to a large extent based on the negation of the famous definition of an economist, given by Oscar Wilde: An economist is a person who knows the price of everything and the value of nothing. A cost-benefit analysis, on the other hand, is an undertaking that tries to find the value of everything, and usually accepts the price of nothing as a measure of its value.

There are a few basic principles of valuation of non-marketed goods in cost-benefit analysis. Foremost among these is the principle that the valuation of a good should be based on the willingness-to-pay of the potential purchasers of the good. In order to estimate the willingness-to-pay for a non-marketed good, a hypothetical market is set up, in which people are asked to state their willingness-to-pay for a certain amount of the good, or choose between various options that provide different amounts of the good. There is a host of methodological pitfalls in such studies. It would go beyond the scope of this report to discuss all these difficulties in detail. Fairly extensive discussions can be found in, for example, Elvik (1993), Kidholm (1995) and Schwab-Christe and Soguel (1995).

An important item in cost-benefit analyses of road safety measures is road accident costs. A detailed survey of current practice in estimating road accident costs in most of the EU countries and a few countries not members of the EU has been made by an international group of experts as part of the COST-research programme established by the European Union. The report from this survey (project COST-313) was published in 1994 (Alfaro, Chapuis and Fabre 1994). In addition to describing current practice in the countries included in the survey, the report discusses methods for estimating road accident costs from a theoretical point of view and presents some recommendations with respect to the choice of method of cost estimation.

The COST-report contains recommendations with respect to the cost items that ought to be included in estimates of road accident costs and with respect to the methods for estimating the various cost items. Five major cost items were identified:

(1) Medical costs,
(2) Costs of lost productive capacity (lost output),
(3) Valuation of lost quality of life (loss of welfare due to accidents),
(4) Costs of property damage,
(5) Administrative costs.

These five major cost elements can be divided into two main groups. The first group includes cost items 1, 2, 4 and 5. The other group consists of cost item 3, the valuation of lost quality of life. Whereas market prices exist for the four former cost elements, this is obviously not the case for the valuation of lost quality of life. It is only recently, which means during the latest ten or fifteen years, that any motorised country has tried to estimate the monetary value of lost quality of life. The other four cost items have, however, been estimated in many motorised countries for a long time, starting in the nineteen fifties in the United States, Great Britain and Sweden.

The costs of road accidents were first estimated in the nineteen fifties in Great Britain and the United States. Today, all the highly motorised countries try to estimate these costs, but the cost items included, and the methods used in estimating them, differs between countries. A detailed survey of the methods used in 20 motorised countries to estimate road accident costs, has been made by Elvik (1995).

The survey considered the valuation of fatalities only. Differences between countries with respect to the definition and level of reporting of non-fatal injuries make it difficult to compare the costs of non-fatal injuries. Figure 4 shows the official economic valuations of a traffic accident fatality in 20 motorised countries in 1991 in million Norwegian kroner (NOK).

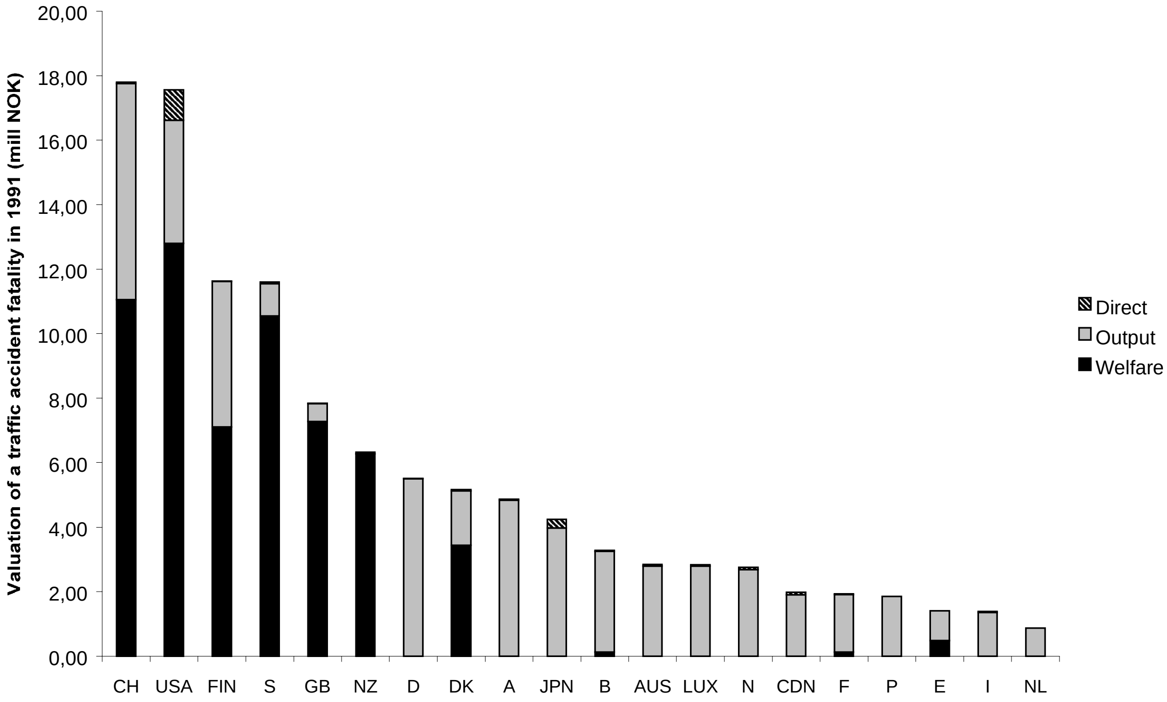


*Figure 4: Official economic valuation of a traffic accident fatality in 20 motorised countries in 1991. Million NOK per fatality.*

Three cost elements are identified in Figure 4: (1) The valuation of lost quality of life, termed ”welfare”, (2) The costs of lost output (”output”), and (3) Direct outlays (”direct”). The total costs per fatality vary from 17.8 million Norwegian kroner (NOK) to about 0.9 million NOK. Not all countries estimated the costs of lost quality of life in 1991. In countries that did include this cost item, it represented more than half of the total costs. On the average, including an estimate of the costs of lost quality of life added 8 million NOK to the costs of a fatality.

Several countries, including Norway, have revised their road accident costs since 1991. In Norway, a report published in 1993 (Elvik 1993) recommended including a valuation of lost quality of life in the accident costs. This resulted in a major upward revision of the costs of a traffic accident fatality in Norway. The cost of a fatality increased from 3.0 million NOK to 15.6 million NOK (1993 prices). The valuation of lost quality of life contributed 12.4 million NOK to this dramatic jump in costs.

The contribution of the main cost elements to current road accident costs in Norway is shown in Table 24.

*Table 24: Current road accident costs in Norway. Costs per injured person and per accident in Norwegian kroner (NOK); 1995-prices.*

| Unit for valuation | Direct and indirect costs | Valuation of quality of life | Total costs |
|---|---|---|---|
| *Injured person* | | | |
| Fatal injury | 3,480,000 | 13,120,000 | 16,600,000 |
| Very serious injury | 5,580,000 | 5,790,000 | 11,370,000 |
| Serious injury | 1,890,000 | 1,890,000 | 3,780,000 |
| Slight injury | 210,000 | 290,000 | 500,000 |
| Property damage only | 15,000 | | 15,000 |
| Mean per injured person | 550,000 | 880,000 | 1,430,000 |
| *Accident* | | | |
| Fatal accident | 3,940,000 | 14,860,000 | 18,800,000 |
| Injury accident | 775,000 | 1,225,000 | 2,000,000 |
| PDO accident | 30,000 | | 30,000 |

It is readily seen that the valuation of lost quality of life constitutes more than half the total cost. The contribution of this cost element is particularly important for fatal injuries, for which it makes up about 80% of the total costs.

As far as the valuation of other impacts of measures is concerned, a distinction must be made between measures that affect travel demand (traffic volume) and measures that do not affect travel demand. With respect to measures that affect travel demand, the relevant valuation is the change in consumers'surplus that results from the change in travel. This concept can be illustrated by means of an example. This example is given in Figure 5.

The amount of travel depends on the generalised costs of travel. By generalised cost is meant the sum of all costs, direct out of pocket costs as well as other costs incurred when travelling, like the use of time, the exposure to pollution and the exposure to the risk of accident. Figure 5 shows how the amount of travel done by an individual (measured, for example, as the number of trips done per day) depends on the generalised costs of travel. Suppose a measure is introduced that cuts the generalised costs of travel from 4 to 3 (arbitrary units). The amount of travel can then be expected to increase. The expected increase in travel demand is shown in Figure 5 by the lines connecting price and number of trips before and after the drop in the generalised costs of travel.

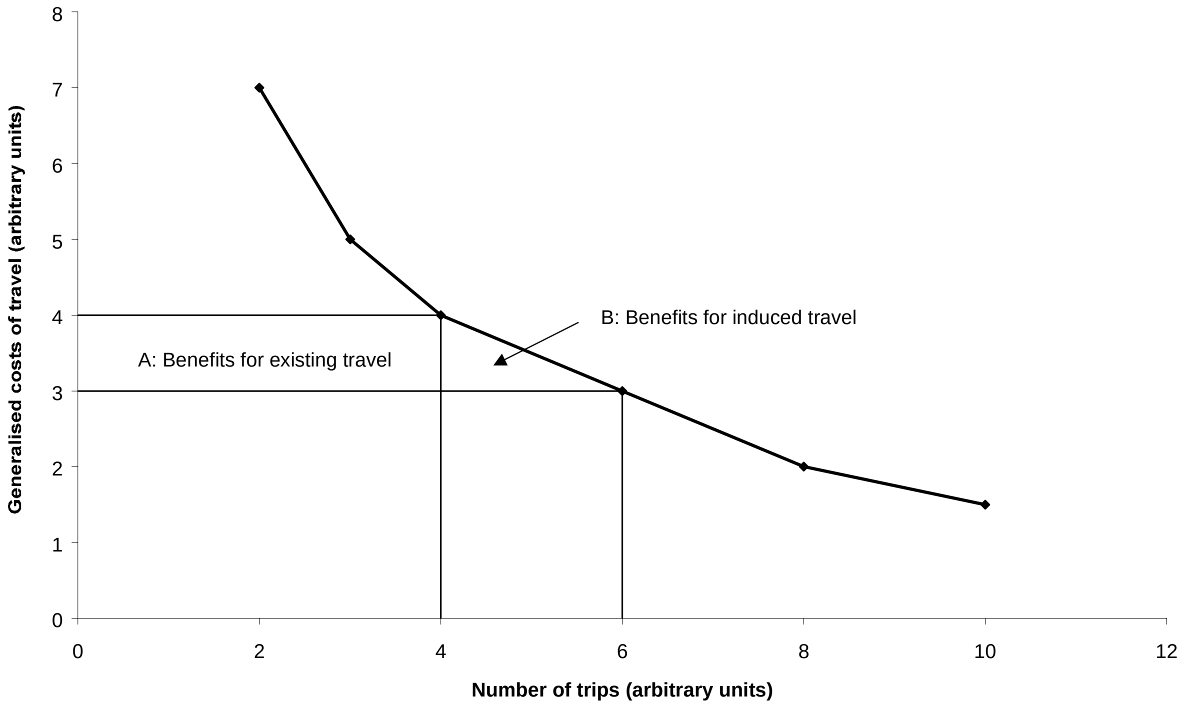


*Figure 5: Illustration of the valuation of changes in travel demand in terms of changes in consumers' surplus.*

The area denoted A in Figure 5 is the benefits to existing travel of the decline in generalised costs. The area denoted B in Figure 5 is the benefits of induced travel, that is of the increase in travel demand generated by the decline in the generalised costs of travel. By convention, the size of the benefits of induced travel is approximated by a triangle, the size of which is estimated by multiplying the increase in travel demand with the savings in generalised costs of travel, divided by two.

In practice the generalised costs of travel are rarely known with sufficient precision. It is not always obvious which items go into the generalised costs of travel. Are, for example, the harmful effects on human health of exposure to pollution included? We simply do not know. It can be hypothesised that pedestrians and cyclists try to avoid the most polluted roads. But what about car drivers? Some drivers may try to avoid the most polluted conditions for the sake of their own well being, but in general car drivers cannot be assumed to include the effects of pollution in the community at large in their generalised cost of travel. Hence, most of the costs of pollution are likely to be external from a car driver's point of view.

The generalised costs of travel are subjective and will vary from one individual to another. One of the problems of using the generalised costs of travel to estimate the benefits of induced travel, is the fact that some of the costs that go into the generalised costs of travel may be misperceived by road users. For example, many car drivers tend to reckon only fuel costs when they estimate vehicle operating costs. But vehicle operating costs include several other items, of which depreciation (the decline in the value of the car) is not the least important.

Misperception of risks, costs or other things that go into a cost-benefit analysis raises a dilemma, which will be discussed more in the next section. Let us merely note in passing that most economists tend to accept the observed demand for a commodity as the correct basis for estimating the value of the commodity, even if demand may in part be based on incomplete information or irrational behaviour.

It is beyond the scope of this study to carry out a survey of the literature dealing with the valuation of non-marketed goods. This literature is vast and surveying it would be a major project by itself. Rather than trying to undertake such a project, a set of illustrative valuations of impacts to be included in cost-benefit analyses is given in Table 25. The table is based on two recent Norwegian studies (Elvik 1998, Mysen, Solheim and Elvik 1998) that provide valuations of a number of impacts.

*Table 25: Valuation of impacts for use in cost-benefit analyses. Norwegian kroner (NOK). 1995-prices.*

| Main impact | Subcategories | Vehicle type, road user etc | Unit of valuation | Value per unit (NOK 1995) |
|---|---|---|---|---|
| MOBILITY | Travel time | Pedestrian | Person/hour | 73 |
| | | Cyclist | Person/hour | 59 |
| | | Car occupant | Person/hour | 48 |
| | | Bus passenger | Person/hour | 35 |
| TRAVEL | Vehicle | Passenger car | Km/travel | 0.86 |
| COST | Operating | Single truck | Km/travel | 2.22 |
| | Cost | Truck/trailer | Km/travel | 3.26 |
| | | Bus | Km/travel | 3.98 |
| SAFETY | Road | All (Police | Fatality | 16,600,000 |
| | Accidents | Reported | Critical injury | 11,370,000 |
| | | Injury | Serious injury | 3,780,000 |
| | | Accidents) | Slight injury | 500,000 |
| | | | Mean | 1,430,000 |
| ENVIRON- | Traffic noise | Small cars | Km/travel | 0.055 |
| MENT | | Heavy cars | Km/travel | 0.550 |
| | Air pollution | $CO_2$ | Tonne of $CO_2$ | 220 |
| | | $NO_x$ | Kg of $NO_x$ | 115 |
| | | $SO_2$ | Kg of $SO_2$ | 37 |
| | | VOC | Kg of VOC | 15 |
| | | $PM_{10}$ | Kg of $PM_{10}$ | 1,800 |

This list of valuations that have been used in cost-benefit analyses in Norway is far from complete. It does not include a valuation of insecurity or other elements of the generalised costs of travel for pedestrians and cyclists. The values of travel time for pedestrians and cyclists given in Table 25 are highly preliminary estimates based on the WALCYNG-project (Stangeby 1997). Values of travel time and vehicle operating costs for mopeds and motorcycles are not included in Table 25.

The road accident costs refer to police reported injury accidents in Norway. When estimating these costs, account has been taken of incomplete accident reporting. To the extent that underreporting is known, the costs include all accidents, irrespective of whether they are reported in official statistics or not. Recently (Elvik 1998), more detailed estimates have been made for various road user groups. According to these estimates, the mean cost of an injury accident is lower for cyclists than for motorists. The cost of a pedestrian accident is, however, higher than the cost of an accident involving motor vehicles only.

The effects on land use and business development of improving road infrastructure is a topic of long-standing controversy (see, for example, the survey paper by Gramlich 1994). The current majority opinion among economists is that what is often termed "regional impacts" are captured by the change in consumers' surplus for induced traffic attributable to road improvements. Hence, to add to this a valuation of growth in employment or the creation of new firms would constitute double counting of benefits. By the same token, one could argue that the benefits to shopkeepers of creating pedestrian streets is included in the generalised costs of walking, at least to the extent that a drop in these costs fully reflects the benefits to pedestrians of getting rid of cars.

## 7.7 Some results from the WALCYNG-project

As part of the WALCYNG-project, a stated preference survey was carried out in Norway for the purpose of valuing monetarily a number of aspects of cycling. Details of the study are found in Stangeby (1997). In this report, only the main results are presented.

Figure 6 shows the valuations of several aspects of cycling of a sample of commuters who used their own cars to travel to work. The valuations are expressed in terms of the daily parking fee car commuter were willing to pay to avoid cycling. Negative amounts are factors that discourage cycling. Positive amounts are factors that encourage cycling.

It can be seen that, for example, unsafe traffic conditions is one of the factors that inhibit cycling. Car commuters value unsafe traffic conditions at 9 NOK per (working) day, which amounts to about 2,000 NOK per year (with about 220-230 working days in a normal year).

It is tempting to interpret this value as an indication of the value of road user insecurity. However, it is not known precisely what respondents include in the concept "unsafe traffic conditions". Moreover, this is the value that car drivers attribute to unsafe traffic not the value that cyclists attribute to unsafe traffic. Besides, the costs of insecurity are likely to vary depending on local conditions. What is needed for cost-benefit analysis is a valuation formula that captures the variations in time and space of insecurity. An overall daily mean value, like the one given in Figure 6, does not meet this need.

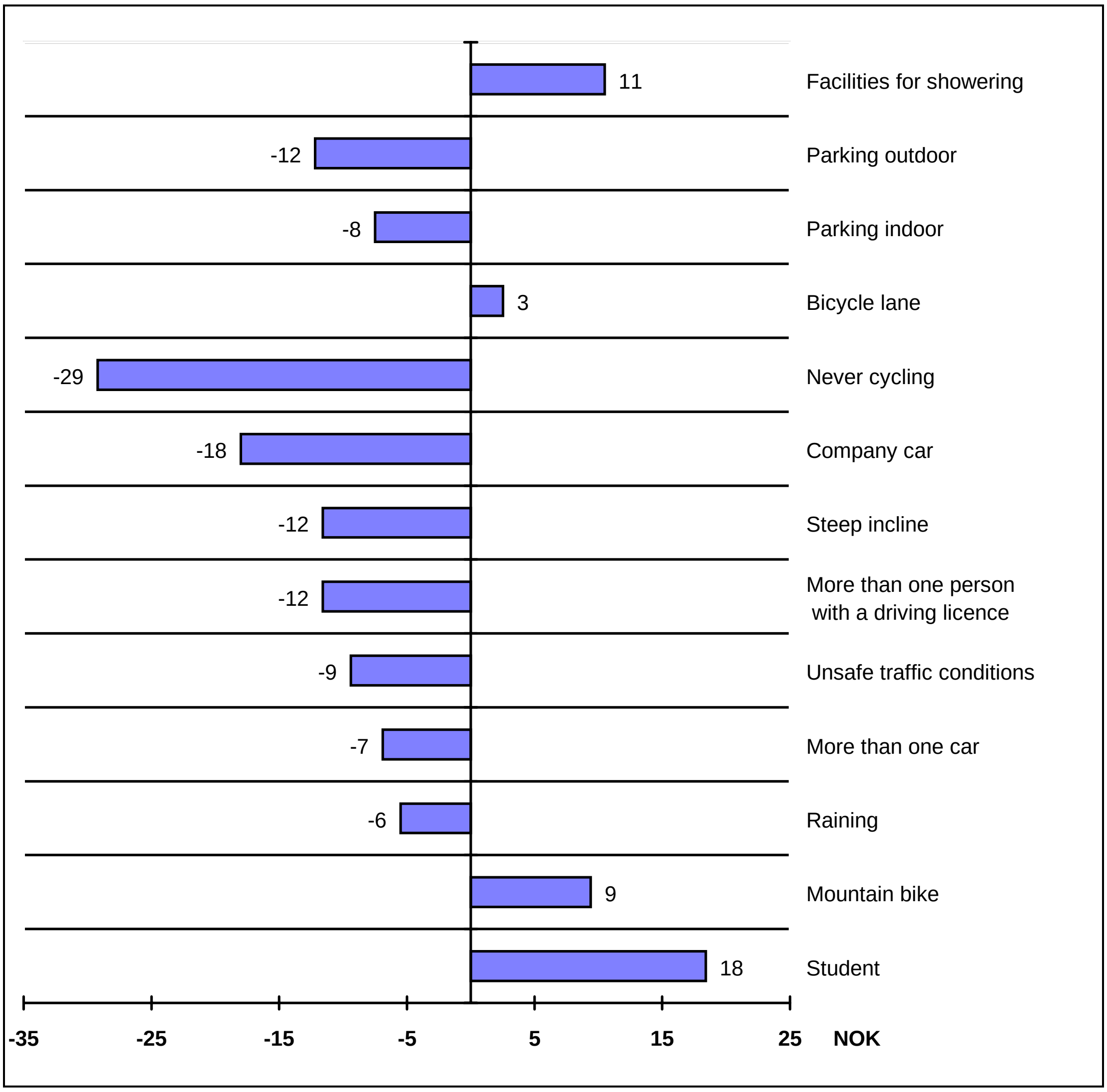


*Figure 6: Average parking fee per day for changing mode from driving a car to go by bicycle on the journey to work. NOK/day. The Norwegian Marketing/SP-survey*

## 7.8 Dilemmas in the application of cost-benefit analysis

Cost-benefit analysis is based on an efficiency criterion and is designed to help in finding the most efficient means to promote a set of policy objectives that have been converted to a common metric by means of monetary valuation. It is also designed to help policy makers decide about the amount of resources that should be used to attain certain policy objectives, that is to decide on how far one ought to go to realise those objectives. A number of dilemmas can arise when using cost-benefit analysis as an aid to priority setting in public policy. Some of these dilemmas will be briefly discussed below:

(1) Incomplete or incorrect valuation of relevant impacts,
(2) Valuations based on poorly informed or irrational choices,
(3) Profound disagreement about policy objectives,
(4) The trade off between efficiency and equity or distributional objectives,
(5) The trade off between efficiency and basic rights or constitutional principles.

These points will be discussed in turn.

Ideally speaking, the use of cost-benefit analysis requires a monetary valuation of all relevant impacts of a project. This includes not just policy objectives, but unintended side effects as well. At the current state of knowledge, a complete and theoretically satisfactory economic valuation of all relevant impacts of a project is not always possible. As argued above, important impacts of road safety measures designed for pedestrians, cyclists or riders of mopeds or motorcycles have not yet been valued monetarily. This means that cost-benefit analysis may discriminate against these groups of road users. Unless, for example, generalised costs of travel for pedestrians and cyclists and the costs of insecurity are included in cost-benefit analyses, these analyses do not necessarily show the most efficient way of setting priorities between safety measures.

The proliferation of items that are included in cost-benefit analyses raises the problem of double counting. This problem is particularly relevant with respect to environmental factors. There is no doubt that exposure to air pollution is a hazard to human health. One would therefore expect less pollution to produce benefits in terms of reduced morbidity and mortality. But how can one reliably partition the effects of pollution among specific pollutants? Can really the marginal contribution of, say, a certain dose of nitrogen oxides to human mortality be reliably identified? And, provided that it really can, how can people intelligently assign a monetary value to the benefits of reduced emission of nitrogen oxides? Pollution can affect your health even if you do not notice it. Some of the gases that damage health you can neither see nor smell. Their effects on health are, of course, noticeable, at least above a certain threshold, but how can a lay person know if a certain ailment was caused by nitrogen oxides and not by an unhealthy life style?

The danger of double counting has lead some economists to recommend keeping closely related environmental factors out of cost-benefit analysis. The trouble with this recommendation is that factors that are left out of cost-benefit analysis may, perhaps unconsciously, be given a lower priority than factors that are included. Some people argue that some things, like human life or an unspoilt natural environment, are infinitely valuable and therefore cannot be included in a cost-benefit analysis. Ironically, such a point of view entails the risk that saving human lives or protecting the environment get neglected in policy making, at least if it is based on cost-benefit analysis.

The relationship between road user insecurity and road safety (as measured by the count of accidents or an accident rate) illustrates both the problem of a possible double counting and the problem of valuations based on poorly informed or irrational choices. There is no doubt that a feeling of insecurity in traffic is a serious problem for many people. Parents, for example, will not allow children to play outside if there is motor traffic in the neighbourhood. Old people are often fearful to cross the road; if it is slippery during winter some old people do not dare to walk outside at all.

On the other hand, it is hard to resist the idea that an excessive feeling of security in traffic is an important cause of accidents. Road users feel safe and underestimate the risks involved in many situations. This may cause dangerous behaviour that necessitates regulations and police enforcement. Most road users want to feel safe, and when they do so, they tend to think that the risk of accident is negligible. Hence, measures that make people feel safer are often demanded, even these measures do not always reduce the number of accidents.

Figure 7 shows the possible effects of four measures on security and safety. It is seen that the use of seat belts is assumed to improve both safety and security. Higher speed is assumed to reduce both safety and security. The idea underlying this assumption, is that road users choose a speed that does not make them feel insecure; hence promoting higher speed would make some drivers feel insecure. Both these cases are uncomplicated in the sense that both safety and security move in the same direction.

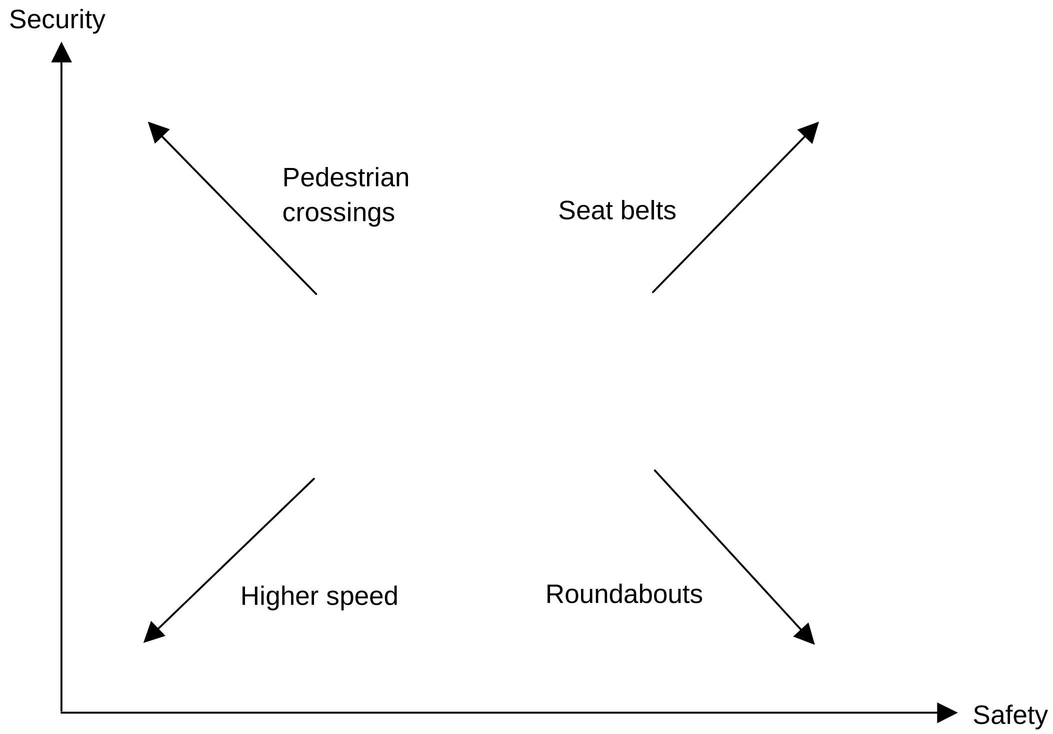


*Figure 7: Possible effects of four measures on safety (number of accidents) and security (feeling of safety)*

The other two cases present a conflict. An ordinary marked pedestrian crossing makes pedestrians feel safer (Schioldborg 1979), but actually increases the number of accidents (Elvik, Mysen and Vaa 1997). Introducing this measure is a dilemma. Surely, it cannot be right for public bodies to make people feel safer when the feeling rests on a false sense of security? Assigning a monetary value to increased security in this case raises an ethical dilemma. It cannot be ethically right to fool people into believing that road safety has been improved when that is not the case.

The final case is roundabouts. It seems likely that roundabouts make drivers feel insecure, and that, indeed, the enhanced feeling of insecurity may be one of the reasons why roundabouts reduce accidents. But is it right to inflict a feeling of insecurity on people? Well, as long as it only makes people behave more carefully it is difficult to see that any harm is done, even if road users would prefer not to feel insecure. But, as argued above, perhaps the most important problem today is that many people feel much too safe in traffic; they do not pay sufficient attention to it and become involved in accidents simply because they did not notice the other road user.

The fact that some measures are in demand because they make road users feel safer (increases security) may lead to conflicts. If cost-benefit analysis is to function as intended, it is essential to remain neutral with respect to priorities between specific measures. The surest way of making a mess of things is to turn certain measures into an end of their own, rather than a means to the end of promoting road safety. The valuation of safety refers strictly to safety as a policy objective, and not to specific measures designed to promote this objective. Yet, in actual policy making, maintaining this strict separation between ends and means is often difficult.

Ideally speaking, cost-benefit analysis assumes that there is agreement concerning policy objectives and their relative importance in relation to one another. Cost-benefit analysis is not designed to resolve profound disagreements about policy objectives. You cannot resolve political disputes by making calculations. Cost-benefit analysis is therefore best suited in those areas of policy making where there is widespread agreement on objectives and fairly extensive – and widely accepted - knowledge about alternative policy instruments that may realise the objectives.

Cost-benefit analysis can help in finding the priorities that maximise efficiency with respect to certain policy objectives. It helps, in other words, to select the most efficient means to realise given objectives. It will very often be the case, however, that maximum efficiency in the use of policy instruments is not an overriding principle of policy making. In many instances, this principle, although relevant, competes with at least two other principles that are not included in cost-benefit analysis.

Two of the most basic principles are those of social justice, or equity, and political legitimacy, or democratic process. It has been argued, for example, that it is unfair that pedestrians and cyclists are subject to a much higher injury accident rate per kilometre of travel than motorists. Some countries (like Sweden, see Vägverket 1995) have therefore set a target of reducing the accident rate for pedestrians and cyclists more drastically than for motorists. To realise a target of this kind, one may have to resort to more drastic measures to reduce the accident rate of pedestrians and cyclists than the measures taken to reduce motorist accident rates. This may imply a departure from priorities based on cost-benefit ratios exclusively.

Basic democratic rights and constitutional principles are absolute constraints that are not subject to cost-benefit analysis. You do not perform a cost-benefit analysis of freedom of speech, even if a lot of stupid things are said in many debates. You do not restrict the right to vote to people who will vote for the same party as you, or to people who are “sufficiently” informed to make an intelligent choice between political parties. Although it may happen that populist parties get a lot of votes you do not subject the right to vote to a cost-benefit analysis for that reason.

The point is that democracy has its price. Yet democratic rights are regarded as universal human rights that should not be infringed, even if those rights are not always exercised in the best interest of everybody. The scope for cost-benefit analysis does not extend to the larger issues of democratic government, but is restricted to priority setting at a much lower level of governing.

# 8 FACTORS AFFECTING THE RESULTS OF COST-BENEFIT ANALYSES

This chapter reviews some of the factors that influence the results of a cost-benefit analysis. These are factors that determine the size of estimated costs and benefits and, therefore, whether measures pass the compensation test of cost-benefit analysis.

## 8.1 A taxonomy of factors affecting the size of costs and benefits

The results of a cost-benefit analysis are affected by a number of factors. It is convenient to put these factors in two groups: (1) Confounding factors, which are factors unrelated to the preferences that determine the level of benefits, and (2) Variations in preferences and real income that determine the level of costs and benefits. The factors that will be discussed include:

(1) Varying levels of accident reporting in different countries,
(2) The relationship between amount of travel and accident rates,
(3) Varying effects of safety measures in different countries,
(4) Varying economic valuations of road safety in different countries,
(5) The extent to which other effects than safety can be included in cost-benefit analyses of road safety measures,
(6) The context of implementation of measures, especially with respect to previously introduced measures.

These factors will be discussed in turn.

***Varying levels of accident reporting***. This was discussed in detail Chapter 6. Figure 8 shows the best current estimate of the percentage of injuries treated at hospitals (including as outpatients) that are reported in official road accident statistics in eight European countries. The level of accident reporting is seen to vary from 21 to 57%. These differences are statistically highly significant and mean that it would be incorrect to base analyses on an average reporting level for all European countries. If such an average were to be used, it would underestimate safety problems and the benefits of safety measures in countries with a low level of reporting (below average) and overestimate them in countries with a high level of reporting. The varying levels of accident reporting means that, for example, accident rates based on official accident statistics cannot be compared between countries. Strictly speaking, not even the number of fatalities is comparable across countries, because the definition of a traffic fatality differs and not all fatalities are reported in official statistics (Hutchinson, 1984). However, the variation between countries in the reporting of fatalities is much smaller than the variation in the reporting of non-fatal injuries.

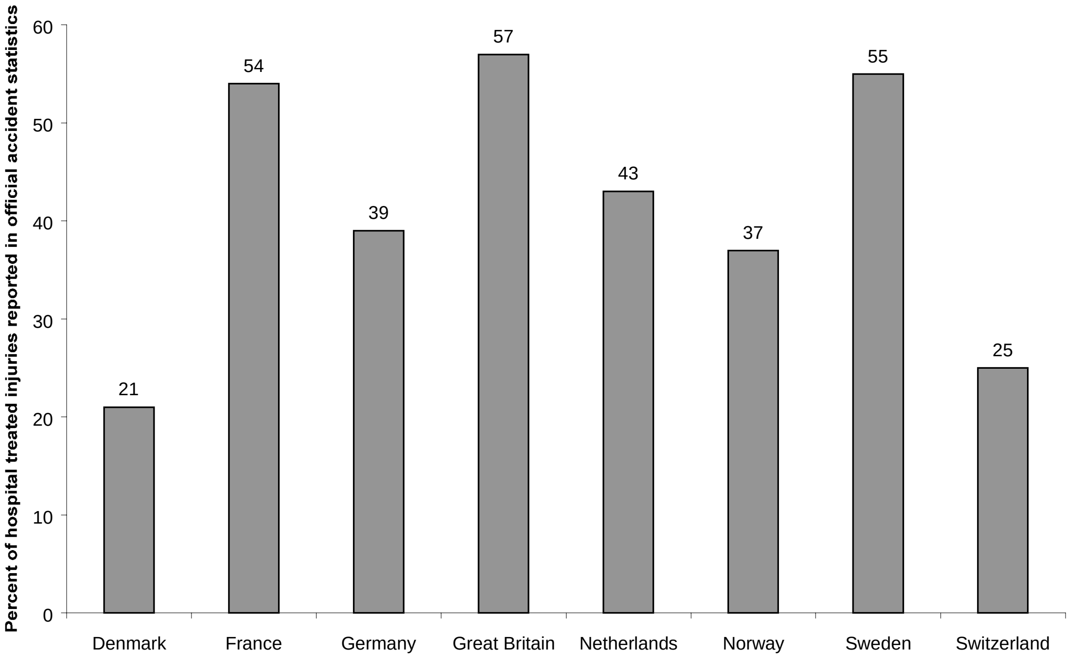


*Figure 8: Levels of accident reporting in official road accident statistics in eight European countries. Source: Elvik, 1999.*

It is important to include all accidents in cost-benefit analyses of safety measures, irrespective of whether they are reported or not. The importance of including non-reported accidents in cost-benefit analyses is clearly illustrated in the estimates made by the European Transport Safety Council (1997) of the costs of reported and non-reported accidents. These estimates are reproduced below in Table 26. According to these estimates, the costs of non-reported accidents amount to almost 50% of the total costs of road accidents. The average cost of a non-reported accident, is however, lower than the average cost of a reported accident. This difference in costs is mainly due to the fact that injuries are, on the average, less severe in non-reported accidents than in reported accidents.

In planning road safety measures, one is naturally confined to relying on information about the reported accidents only. According to Table 26, the average reporting level for injury accidents in EU-countries is about 45%. When the non-reported injuries are disregarded, the mean cost of an injury amounts to 58,000 ECU. However, when the non-reported injuries are included, and their cost allocated to the reported injuries, the mean cost of a reported injury increases to 71,500 ECU.

*Table 26: Total number of accidents in the European Union and associated costs.*

| | Total number in EU (thousands) | Costs (in billion ECU 1995-prices) | | |
|---|---|---|---|---|
| | | Economic cost | Value of human life | Total costs |
| Fatalities | 45 | 21 | 29 | 50 |
| Serious injuries | 505 | 23 | 33 | 56 |
| - reported | 355 | 16 | 23 | 39 |
| - non-reported | 145 | 7 | 10 | 17 |
| Slight injuries | 2,950 | 7 | 0 | 7 |
| - reported | 1,180 | 3 | 0 | 3 |
| - non-reported | 1,770 | 4 | 0 | 4 |
| PDO-accidents | 46,000 | 49 | 0 | 49 |
| - reported | 11,500 | 12 | 0 | 12 |
| - non-reported | 34,500 | 37 | 0 | 37 |
| Total reported | 13,080 | 52 | 52 | 104 |
| Total unreported | 36,415 | 48 | 10 | 58 |
| Total | 49,495 | 100 | 62 | 162 |

PDO = Property Damage Only

***The relationship between the amount of travel and accident rates***. In chapter 8.3 a model was described for estimating the effects of safety measures on the number of injuries. According to this model, the expected number of accidents is the product of exposure and accident rate. It is increasingly recognised, however, that the accident rate is not independent of the amount of exposure (Hauer, 1995). Figure 9 illustrates this for cyclist fatality rates for fifteen European countries. The figure was derived from information given by Schollaert et al (1997), supplemented with information for Norway given by Borger and Frøysadal (1993).

The figure shows the relationship between the amount of cycling per inhabitant per year and the fatality rate of cyclists, measured as the number of killed cyclists per hundred million cycle kilometres. A negative relationship between exposure (amount of cycling) and accident rate is clearly visible. The more people cycle, the lower is the accident rate of cyclists. This means that one does not remove the effect of exposure on the number of accidents by computing an accident rate. If, for example, the amount of cycling increases by 50%, the number of accidents will not necessarily increase by 50%, but according to Figure 9, probably by less than 50%.

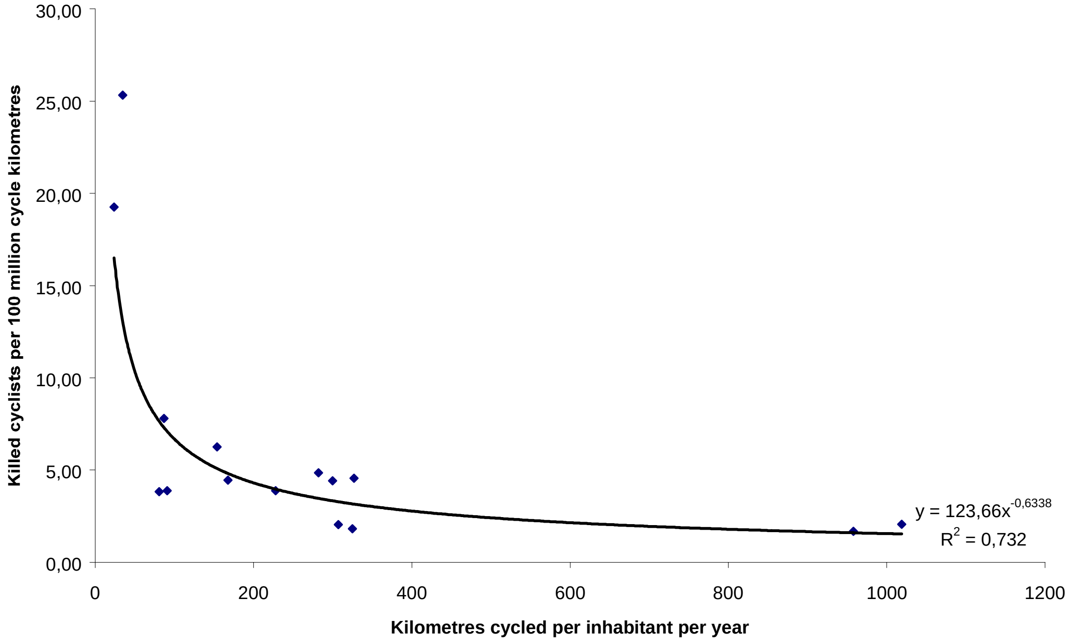


*Figure 9: Relationship between kilometres cycled per inhabitant per year and cyclist fatality rate (killed cyclists per 100 million cycle kilometres) in 15 European countries. Source: Schollaert et al 1997; Borger and Frøysadal, 1993.*

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

***Varying effects of safety measures in different countries***. The effects of safety measures can vary from one country to another. Figure 10 illustrates this for the case of traffic separation. By traffic separation is meant the provision of a physically separate road or track for cycling, sometimes reserved for cyclists, sometimes mixed with pedestrians. The figure shows the percentage change in the number of bicycle accidents found in evaluation studies made in different countries.

The effects attributed to traffic separation are seen to vary substantially between countries. The results obtained in Denmark, Germany, Great Britain, the Netherlands and Norway agree fairly well with one another. However, the results reported for Sweden and the United States are very different from the results reported for the other countries.

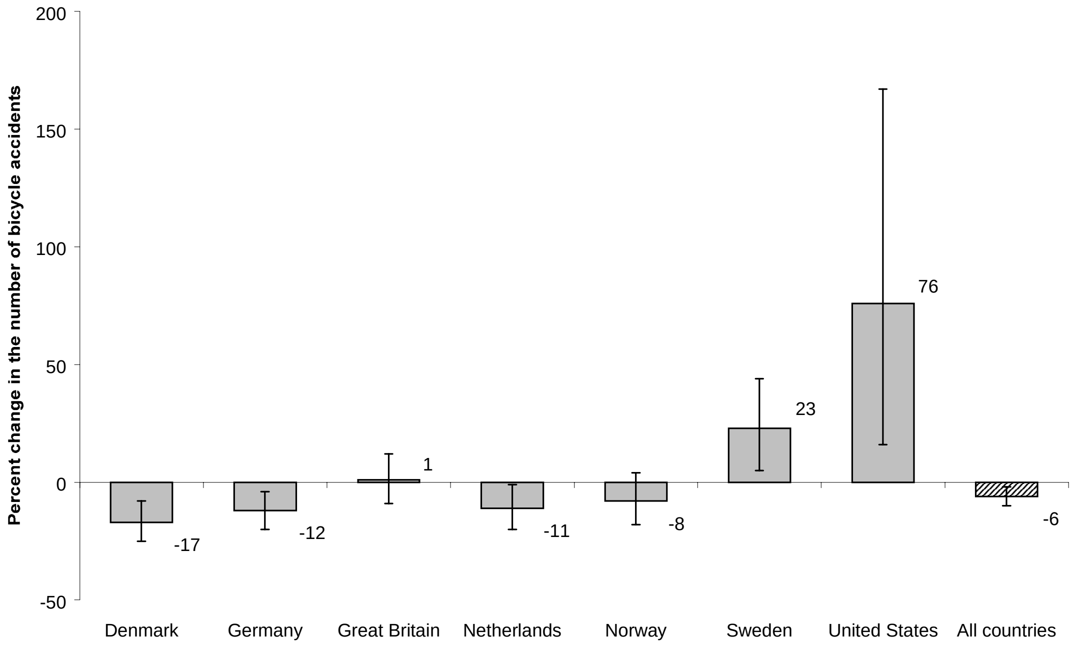


*Figure 10: Effects of traffic separation on the number of bicycle accidents in different countries*

What is the right thing to do in a case like this? Should one accept the results of evaluation studies at face value, as they have been reported in different countries? Or should a cost-benefit analysis be based on an average estimate of effect, based on evaluation studies made in numerous countries? What about countries in which no evaluation studies have been reported? What should constitute the basis for estimating the effect of a measure in those countries?

Evaluation research aims for general knowledge. But how far should the efforts to attain general knowledge be carried? Is it defensible to generalise the results of evaluation studies made all over the world, perhaps during a period of some thirty to forty years, into one overall mean estimate of effect? In most cases such a broad generalisation would probably not make much sense. The effects of a measure on safety are likely to vary from one place to another, depending on, for example, design features of the measure, road user behaviour, and a host of other factors.

One quickly realises, however, that it is impossible to consider all these factors when summarising the results of evaluation studies. It is no doubt true that the effects of a measure will vary from one location to another, but trying to account for all such variations almost leads to epistemological nihilism, that is to a denial that it is possible to obtain generally valid knowledge at all. If the effects that were attributed to a certain measure in study A are expected to be very different in study B, it hardly makes sense to publish study A because nothing of general interest can be learned from it. Hence, a belief in the possibility of attaining generally valid knowledge underlies all evaluation studies.

An assumption underlying the above discussion, is that one can take the results of evaluation studies at face value, that is as showing the true effects of the measures that have been evaluated. Unfortunately, this is almost never the case. Virtually all evaluation studies in road safety are non-experimental studies that do not fully control for the effects of confounding factors. Figure 11 clearly illustrates this point. It shows the mean effects on the number of bicycle accidents attributed to tracks for walking and cycling in Norway, depending on study design.

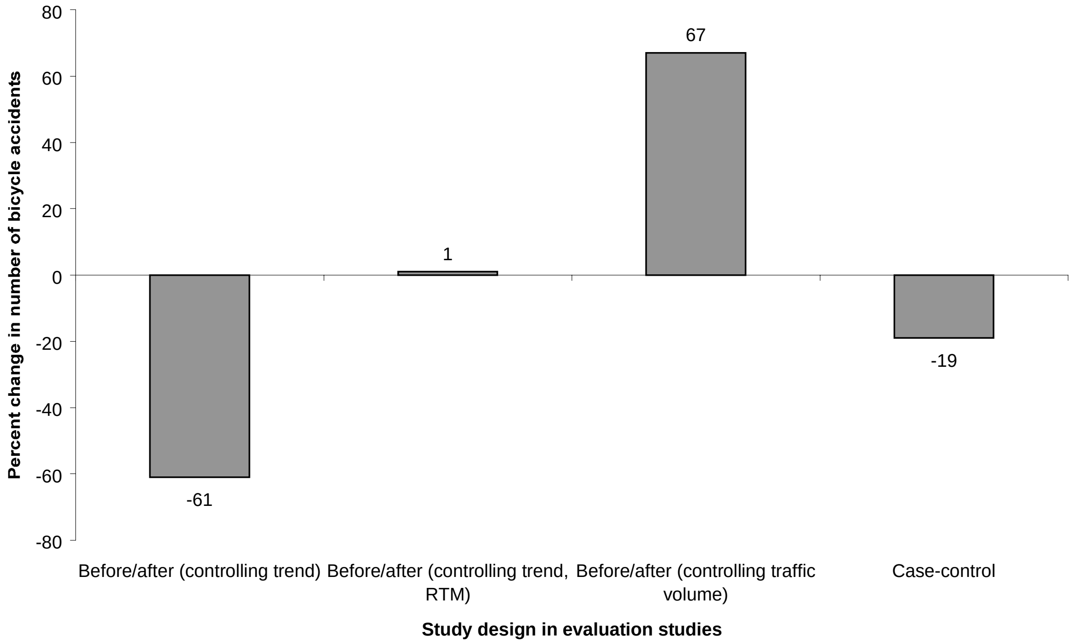


*Figure 11: Mean effects on the number of bicycle accidents attributed to tracks for walking and cycling in evaluation studies made in Norway depending on the design of the evaluation study*

The various study designs have been identified on the basis of which confounding factors they control. In before-and-after studies controlling for general trends in the number of accidents in a larger area, a decline of 61% in the number of bicycle accidents was found. Before-and-after studies controlling both for general trends and regression-to-the-mean (RTM) indicate that the number of bicycle accidents increase by 1%. Before-and-after studies controlling for changes in traffic volume indicate a remarkable increase of 67% in the number of bicycle accidents. Finally, case-control studies, that is studies that compare that accident for cyclists on roads with separate tracks to the accident rate of cyclists in mixed traffic, show a decline in accident rate of 19%. In other words, the results of evaluation studies range from 61% accident reduction to 67% accident growth, depending on study design. On top of this, it should be noted in passing that none of the estimates presented in Figure 11 is statistically significant. Nevertheless, the very large differences found underline the importance of critically considering study design when summarising the results of evaluation research.

What, then, is to be concluded from this discussion? The third edition of the Norwegian Traffic Safety Handbook, published in December 1997 (Elvik, Mysen and Vaa, 1997), summarises evidence from a very large number of evaluation studies that have been made to determine the effects of 124 road safety measures. In summarising the results of these studies, meta-analysis has been used to a very large extent. The following guidelines have been used to summarise the results of evaluation studies by means of meta-analysis.

(1) Road safety measures are *described at the most detailed level possible* on the basis of evaluation studies,
(2) Effects on accidents or injuries of *different levels of severity are*, if possible, *kept apart* for at least the following levels of severity: (a) Fatal accidents, (b) Accidents involving personal injury, (c) Property damage only accidents,
(3) *Different definitions of the effects of a safety measures are kept apart*, the most common definitions being: (a) Changes in the number of accidents, (b) Changes in accident rate, (c) Changes in injury severity,
(4) *The results of studies using different study designs are kept apart,* using the level of control of confounding variables as the key to distinguishing between different study designs,
(5) *Statistical uncertainty is estimated for all results,* in the form of a 95% confidence interval for the standard error of the mean,
(6) *The distribution of results around the mean value is examined*, to check for the possible presence of multimodality, skewness or outlying data points that unduly influence the results.

While these guidelines do not guarantee that important differences are not glossed over, and unimportant differences highlighted, they hopefully reduce the risk of erroneous conclusions.

***Varying economic valuations of road safety in different countries***. The fact that official estimates of road accident costs vary a lot between countries has been shown earlier (see Figure 4). The same issue arises with respect to these variations as with respect to variations in the effects of safety measures between countries: to what extent should the differences between countries be accepted, to what extent should they be replaced by an average that eliminates them?

The answer to this question depends in part on how one conceives of the role of cost-benefit analysis as an instrument of policy making. If one accepts the basic tenets of welfare economics, on which cost-benefit analysis is based, the rule to follow in sorting out relevant from irrelevant differences in the valuation of road safety can be simply stated. Differences in road accident costs that are attributable to either (a) differences in market prices or (b) differences in individual preferences for safety should be retained. All other differences should be eliminated.

Preferences for road safety are manifested in the amounts people are willing to pay in order to improve road safety. Since road safety is a normal good, willingness to pay for it depends on income. The higher your income, the more you are likely to be willing to pay to have road safety improved. The efficiency criterion of welfare economics implies that the provision of road safety should match exactly the demand for it.

Yet this rule is not literally followed anywhere. If one were to follow it, improving road safety for millionaires would be worth more than improving it for the less affluent. But, at least officially, no country differentiates the provision of road safety based on individual income. This means that the efficiency criterion of cost-benefit analysis is not strictly adhered to. At the international level, a strict adherence to this criterion becomes problematic, because the differences in income levels between countries are very large, even within Europe. On the other hand, disregarding these differences also involves problems. In the first place, the costs of providing a certain level of safety are likely to differ between countries. If an average value of safety is used for countries with different levels of cost, safety may be overprovided in low-cost (low-income) countries and underprovided in high-cost (high-income) countries. The terms overprovided and underprovided refer to the level of road safety provision that would be in line with the preferences of the general public.

In the second place, averaging the value of safety across countries only makes sense if the values being averaged include the same elements and have been estimated the same way in all countries. Otherwise, the average cannot be interpreted as representing an “average preference” in any meaningful sense.

In the third place, there is always going to be an element of arbitrariness with respect to the choice of countries an average value of safety applies to. Does a global average make sense? Probably not, because the differences between the richest and poorest countries are simply too large and the recording of even fatal accidents likely to be incomplete in the poorest countries. Does an average for the OECD-countries make sense? Perhaps. At least all these countries are generally counted among the rich and highly motorised countries. Still, their levels of income and safety vary substantially.

A recent analysis of value-of-life studies in several countries (Miller, 1998), provides the most comparable estimates currently available of the value of a statistical life at an international level. The analysis was based on studies of the willingness to pay for safety made in twelve countries. The analysis indicated that the income elasticity of the demand for safety is about 1.3 to 1.5. Based on this, Miller estimated the valuation of a statistical life in several countries. Figure 12 presents the results of the analysis.

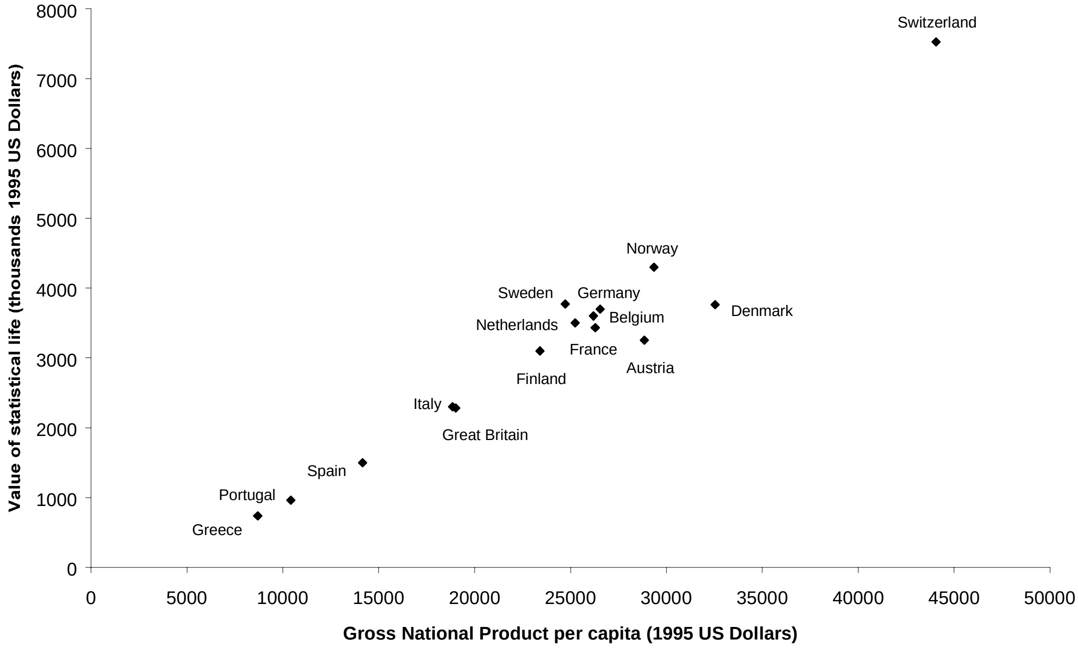


*Figure 12: Values of a statistical life in different countries as a function of average income level (GNP per capita). Source: Miller, 1998, Table 4.*

The value of a statistical life in the fifteen European countries represented in Figure 12 varies from 7.5 million US dollars in Switzerland to 0.74 million US dollars in Greece. These estimates are the best current estimates of the value people in these countries are likely to attribute to increased safety.

The value of a statistical life varies in inverse proportion to the level of fatality risk in traffic. This is shown in Figure 13, which shows the relationship between the value of a statistical life and the number of road accident fatalities per 100,000 inhabitants. The pattern found in Figure 13 makes one wonder about the direction of causality. Is the accident rate high in some countries because they put a low value on human life, or is the value of human life low because the accident rate is so high? Causality may flow in both directions. However, it may be regarded as a dilemma that by using the valuations in Figure 13, one will preserve, and perhaps even enlarge the differences in accident rate between countries. The largest expenditures to improve safety will be justified in those countries that have the highest value of a statistical life.

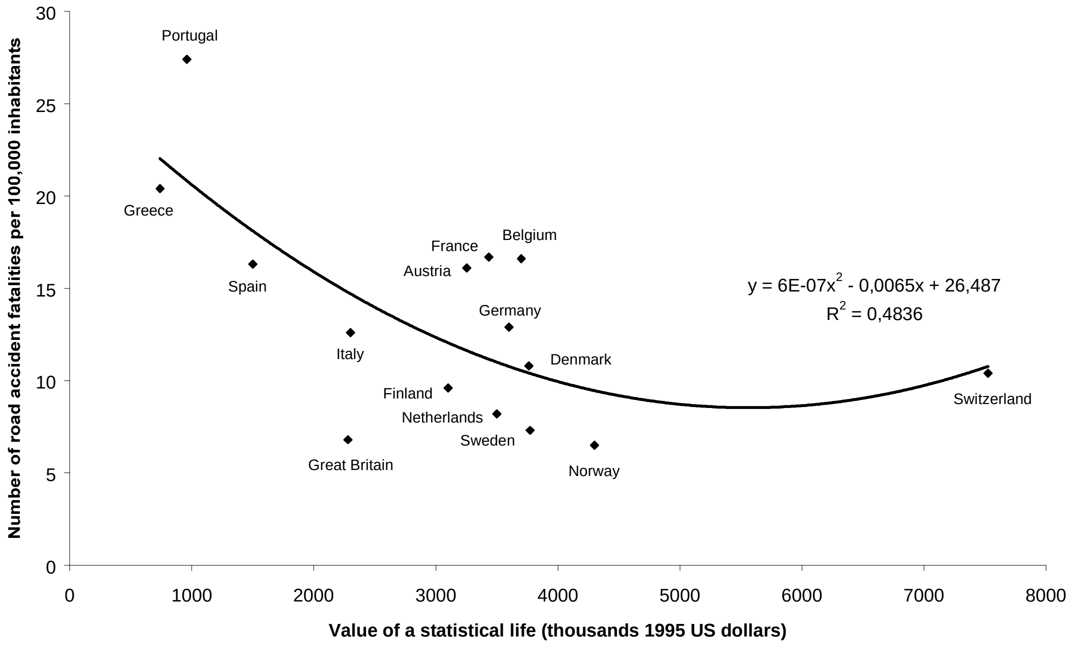


*Figure 13: Relationship between the value of a statistical life and road accident rate in fifteen European countries. Sources: Miller 1998 and IRTAD.*

What are the conclusions of this discussion? The main conclusion is that the valuation of road safety in a specific country ought to be based on studies of the willingness to pay for safety made in that country. For countries where no such studies are available, the valuation of safety ought to be based on the relationship shown in Figure 12.

***Inclusion of effects other than safety in cost-benefit analyses***. Most road safety measures have an effect on other policy objectives in addition to safety. This means that cost-benefit analyses ought to include these effects in addition to effects on safety. In some cases, these effects may be decisive for the results of a cost-benefit analysis. The effects that ought to be included in cost-benefit analyses have been listed in Figure 3, but it is not always possible to include all these effect in a cost-benefit analysis. The effects that are likely to be most difficult to include in cost-benefit analyses at the current state of knowledge are:

(1) All components of air pollution,
(2) The visual intrusion caused by road systems,
(3) Road user insecurity

Until a few years ago, it was not common to include an economic valuation of air pollution in cost-benefit analyses. Today, a number of estimates of these costs are available, but no consensus has emerged. There are at least three major problems involved in estimating the costs of air pollution and the effects of various measures on air pollution. The first problem concerns what types of air pollution to include. The second problem concerns what types of effects of air pollution to include, especially whether the effects should be assessed in terms of dose-response curves for well-defined medical outcomes like death or the onset of certain respiratory diseases or in terms of subjective expressions of annoyance caused by air pollution. The third problem is how one should add the costs of various types of air pollution and various effects of it in a way that is complete, while at the same time avoids double counting.

It is beyond the scope of this report to further discuss these problems. Only three brief observations will be made. There seems to be a tendency for the estimated costs of air pollution to become higher as more types of pollution and more effects of it are included in the estimates. Since none of the estimates made so far pretends to be complete, one may hypothesise that previous estimates of the costs of air pollution have underestimated those costs. The second observation is that the costs of air pollution are relevant for cost-benefit analyses of a number of important road safety measures. All measures that affect speed, for example, also affect air pollution, because vehicle emissions depend on speed. All measures that require the additional use of energy, like daytime running lights, may increase vehicle pollution emission. Measures that provide pedestrians and cyclists with a separate road system located at some distance from the main road will reduce the amount of pollution pedestrians and cyclists are exposed to, because the ambient concentration of vehicle pollutants falls rapidly as the distance from the source is increased. The third and final observation is that the current economic valuations of air pollution in various countries are likely to be at least as incompatible as the accident cost estimates.

The visual intrusion of a road system, or its ugliness, is a factor for which hardly any estimates of the costs to society can be found. In the short run the solution will therefore have to be to leave it out of cost-benefit analyses altogether.

The valuation and possible inclusion of road user insecurity in cost-benefit analysis has been discussed above. It is obvious that change in the level of road user insecurity is an important impact of very many road safety measures. Still, too little is known about these impacts to include them in cost-benefit analyses, except perhaps for illustrative purposes only.

***The context of implementation of measures – interaction between measures***. The effects of a certain road safety measure on the number of accidents may depend on whether it is introduced as a stand-alone measure or as part of a package of measures. The effects may also depend and on whether it is introduced into an environment where few measures have been implemented or into an environment where a lot of measures have been implemented. The differences in effect depending on the context of implementation could be large enough to affect the results of cost-benefit analyses of measures.

To illustrate this, consider the case of road lighting and bypasses. Suppose cost-benefit analyses have been made of these two measures for a small village. Suppose that the results, provided only one of the measures is carried out, are as given below (arbitrary monetary values for illustration only):

| | Bypass | Lighting |
|---|---|---|
| Benefits | 102 | 35 |
| Costs | 100 | 20 |

Now suppose the bypass is built. Traffic volume in the village is then cut in half and the expected number of accidents in the village is then also cut in half. The benefits of introducing road lighting are then reduced from 35 to 17.5, and the measure no longer gives a benefit that exceeds the cost. Suppose, on the other hand, that road lighting is installed before a bypass has been built. Road lighting cuts the number of accident by about 10%, and thus reduces the benefits of the bypass from 102 to 98.5. It is no longer good value for money to build the bypass. Hence, both measures give benefits that are greater than costs if carried out alone, but none of the measures give benefits that are greater than costs if the other measure has already been introduced. But if both measures were introduced at the same time, then what would their joint benefits be?

The benefits of introducing both measures would, essentially, be the sum of the benefits of measure A, given that measure B has been introduced and the benefits of measure B, given that measure A has been introduced. In the present example, that would be 98.5 + 17.5 = 116. The combined cost would be 120. Hence, a cost-benefit analysis would conclude that these two measures should not be introduced as a package.

Evidently, only one of the measures ought to be introduced in this case, although both of them pass the cost-benefit test when taken alone. In this case, road lighting should be introduced first, because it has both the best benefit/cost ratio and the highest net present value.

In general, denote by $E_i$ the effect of measure i on the number of accidents, expressed as a percentage change (in most cases a percentage reduction). Then $R_i$ is the residual number of accidents still expected to occur when measure i has been implemented:

$$R_i = 1 - E_i$$

If, for example, a measure affects 100 accidents and has a 20% effect on those accidents, the residual when the measure has been implemented is 0.8 (1 – 0.2). A simple model to estimate the combined effect of two measures on the number of accidents, when one of them reduces the number of accidents by 20% and the other by 30%, is:

$$\text{Combined effect} = 1 - (0.8 \times 0.7) = 1 - 0.56 = 0.44$$

That is, the combined effect of the measures is an accident reduction of 44%, not 50%, as the sum of their individual effects would seem to imply. This simple model of estimating the combined effects of several safety measures that affect the same target accidents assumes that the percentage effects of the measures remains unaffected when the measures are combined in a package. The validity of this assumption is unknown. It is, however, the simplest model that can be used. Until a more complicated model can be supported by empirical research, using the simplest possible model is defensible by virtue of the principle of insufficient reason.

## 8.2 Implications for the possibility of generalising the results of cost-benefit analyses

The results of cost-benefit analyses can probably only rarely be generalised from one country to another. The basic approach to cost-benefit analysis is, of course, universal. But the numerical values for costs and benefits that are put into the analyses are likely to vary widely from one country to another. Add to this the variation in accident reporting level, possibly varying effects of safety measures and varying initial levels of safety, and you get a picture of very widely varying results of cost-benefit analysis.

It is perhaps instructive to try to distinguish between legitimate and irrelevant sources of variation in the results of cost-benefit analyses. Among the legitimate sources of variation in results are:

(1) Varying *economic valuation of road safety* between countries, at least in so far as it can be traced to varying income levels and varying preferences for safety. Variation that are attributable to an incomplete estimation of costs are, on the other hand, irrelevant and should be disregarded (this argument assumes that the same basic cost components are relevant everywhere).
(2) Varying *levels of cost of implementing* a certain safety measure. The costs of implementing a certain safety measure are likely to vary between countries. The most comparable cost estimates are those that have been converted to a common currency, like the Euro, on the basis of exchange rates adjusted to purchasing power parity.
(3) Varying *adjustment factors for incomplete accident reporting* based on the level of reporting prevailing in each country.
(4) Varying *economic valuation of effects other than safety* of measures taken primarily to improve road safety. It may be the case, for example, that the costs used for travel time vary between countries. Such variations ought to be accepted on the same basis as similar variations in accident costs.
(5) Varying *discount rates* used to convert future costs and benefits to present value. Differences in discount rates that are related to the real level of interest rates in a country or to the average return on capital earned by investments in a country should be retained at an international level.
(6) Varying *effects of safety measures*, attributable to either (a) systematic and known differences in traffic environment between countries or (b) whether the measures are carried out as part of a package of measures or not.

If these factors are treated as legitimate sources of differences in the results of cost-benefit analyses, it means that no attempt should be made to standardise the analyses at an international level with respect to these factors. Irrelevant sources of variation should on the other hand be removed, and analyses standardised with respect to these factors. They include:

(1) Differences in road accident costs, attributable to *differences in estimation methods and cost components included*. Confer the report from COST-313 (Alfaro, Chapuis and Fabre 1994) for recommendations with respect to cost elements to be included and estimation techniques to be used.

(2) Differences in the valuation of other effects, like travel time, changes in pollution, and so on, related to *differences in items included and estimation techniques* used.
(3) Differences in the estimated effects on safety of a specific measure that *cannot be justified in terms of research findings* documenting that the true effects differ between countries (and preferably explaining why this is the case).
(4) Differences with respect to the *items included in a cost-benefit analysis*, unless there is research to show, for example, that a measure affecting travel time in one country has no effect on travel time in another country.

As these lists indicate, a fairly detailed examination a cost-benefit analyses performed in different countries is needed in order to determine if differences in the results are due to legitimate or irrelevant factors.

# 9 CASE ILLUSTRATIONS OF COST-BENEFIT ANALYSES

## 9.1 Conversion factors for the value of benefits and costs

In an attempt to make the results of the cost-benefit analyses as widely applicable as possible, conversion factors have been developed to translate results that apply to one country to another country. These conversion factors are based on comparisons of accident costs in different countries (ETSC, 1997; Miller, 1998) and adjustment factors for price levels (ESA, 1997). Table 27 presents the conversion factors.

*Table 27: Conversion factors for costs and benefits of road safety measures in the EU-countries and Norway. Sources: See text*

| | Relative levels. Average for EU = 100 | | | | |
|---|---|---|---|---|---|
| Country | Value of a statistical life ETSC 1997 | Value of a statistical life Miller 1998 | Accident costs | Prices of public consumption | Net correction factor |
| Austria | 166 | 116 | 116 | 116 | 100 |
| Belgium | 109 | 132 | 132 | 98 | 135 |
| Denmark | 70 | 134 | 134 | 122 | 110 |
| Finland | 157 | 111 | 111 | 97 | 114 |
| France | 63 | 123 | 123 | 111 | 111 |
| Germany | 189 | 128 | 128 | 130 | 98 |
| Great Britain | 103 | 81 | 81 | 87 | 93 |
| Greece | 38 | 26 | 26 | 57 | 46 |
| Ireland | 58 | NA | 58 | 78 | 74 |
| Italy | 126 | 82 | 82 | 91 | 90 |
| Luxembourg | 97 | NA | 97 | 141 | 69 |
| Netherlands | 122 | 125 | 125 | 104 | 120 |
| Norway | NA | 153 | 153 | 114 | 134 |
| Portugal | 63 | 34 | 34 | 45 | 76 |
| Spain | 38 | 54 | 54 | 77 | 70 |
| Sweden | 106 | 135 | 135 | 115 | 117 |
| Mean for EU | 100 | 100 | 100 | 100 | 100 |

NA = not available

The first column gives the relative level of accident costs (the value of a statistical life) in the EU-countries in 1995, according the report published by the European Transport Safety Council (ETSC, 1997). In this report, an attempt has been made to eliminate differences between countries in estimation methods affecting the level of accident costs. The costs given by ETSC include a valuation of lost quality of life ("pain, grief and suffering") caused by road accidents. The average cost for all EU-countries has been set to 100 and the costs for each country are given relative to this value. The second column gives similar estimates prepared by Miller (1998). Miller has summarised studies made in twelve countries of the willingness-to-pay for reduced risk of fatal injury. A best estimate was derived for each country. The estimates were then regressed on mean income per capita. An income elasticity of about 1.5 in the demand for safety was found. Based on this income elasticity, Miller estimated predicted values of a statistical life for several countries.

As can be seen from Table 27, the estimates of ETSC and Miller are very similar. There are some differences as well. In developing the correction factors, the values presented by Miller have been used for all countries for which they are available. For countries that Miller did not include in his survey, the values provided by ETSC have been used. The results are presented in the third column.

The fourth column gives the relative price levels for final government consumption in the EU as of 1995, according to the European Statistical Agency (ESA, 1997). The net correction factor to be used in cost-benefit analyses is the ratio of the correction factor for accident costs to the correction factor for price level. For Austria, for example, this (116/116) x 100 = 100, when setting the EU-average equal to 100. An example will show the use of the correction factors. If the benefit-cost ratio of a measure has been estimated to 1.5 for Austria, the benefit-cost-ratio of the same measure in Norway would be 1.34 x 1.5 = 2.0. For Greece it would be 0.46 x 1.5 = 0.7.

The conversion factors are very crude. They are based on accident costs and prices of government consumption only, and disregard all other impacts of road safety measures. Besides, the factors assume that the effects of the measures are the same in all countries. These assumptions are unlikely to be correct. It is nevertheless hoped that the conversion factors at least indicate the direction of the corrections that have to be made in order to transfer the results of cost-benefit analyses from one country to another.

The implications of using the conversion factors will not be explored in this report. It should be pointed out, however, that these implications are likely to be regarded as problematic in some cases. A measure that gives good value for money in, for example, Norway, will not necessarily do so in Greece and Portugal. This means that policy recommendations based on cost-benefit analyses may recommend further improving safety in countries that have a good safety record, while not introducing the same safety measures in countries that have a poorer safety record.

Some of the cost-benefit analyses presented below use ECUs to measure costs and benefits. These analyses rely on the cost estimates given in a report issued by the European Transport Safety Council (1997). According to this report, road accidents cost a total of 162 billion ECUs in 1995. The reported number of injured persons across the European Union was 1,580,000. The mean cost per injured person was therefore 102,500 ECU. Assuming that on the average, 1.35 persons are injured in each officially reported road accident, the average cost per reported accident becomes 138,500 ECU. It is further assumed that travel time is valued at a cost of 10 ECU per vehicle per hour. This is a mean value for all types of vehicle.

## 9.2 Selection of measures for cost-benefit analysis

This chapter gives some case illustrations of cost-benefit analyses of measures that have been proposed and discussed in previous chapters.

The report from Workpackage 1, dealing with pedestrian safety, lists and discusses a very large number of safety measures for pedestrians. It is not possible to conduct cost-benefit analyses of all these measures. For some measures, not enough is known about costs and effects to make cost-benefit analyses. The following measures discussed by workpackage 1 have been selected for analysis:

- Roundabouts
- Road lighting
- Integrated area wide speed reduction measures in urban areas
- Environmentally adapted through-roads
- Upgrading ordinary marked pedestrian crossings
- Parking regulations
- Side protection of trucks

Most of these measures will benefit cyclists as well as pedestrians. Workpackage 2 concerns bicycle safety. The report from this Workpackage also discusses a large number of safety measures, of which the following have been selected for analysis:

- Local bicycle policy intended to encourage mode switching from car driving to cycling
- Bicycle lanes
- Advanced stop line for bicycles at signalised junctions
- Mandatory wearing of bicycle helmets
- Improving bicycle conspicuity

In addition to these measures that are more or less targeted specifically at pedestrian and cycle accidents, the following measure has been shown to improve safety for pedestrians and cyclists:

- Daytime running lights on cars

Workpackage 3 concerns the safety of moped and motorcycle riders. There are not many technical and non-restrictive safety measures available to improve the safety of these road users, but the following measures have been selected for cost-benefit analysis:

- Daytime running lights for motorcycles
- Mandatory wearing of helmets for motorcyclists
- Design changes for motorcycles to improve safety

The subject of Workpackage 4 is the safety of young drivers and riders. Again this is a safety problem that does not have easy solutions. Most of the measures that are known to be effective in reducing the number of accidents among young and inexperienced drivers involve some kind of restriction on their mobility. A cost-benefit analysis has been made of the following measure:

- Graduated licensing, including the introduction of a lowered BAC-limit for new drivers
- The introduction of a lowered BAC-limit for new drivers
- Provision of Disco Buses to prevent impaired driving to and from discotheques

For simplicity, most cost-benefit analyses presented below refer to one junction, one pedestrian crossing, a road section of 1 kilometre length or one year's normal exposure for a road user. Some of the analyses refer to all of Europe (daytime running lights for cars), or to specific instances of application of a measure.

## 9.3 Roundabouts

The provision of roundabouts in urban and suburban areas has become increasingly more common in recent years. Modern roundabouts are designed according to the offside priority rule, which means that traffic entering the roundabout has to give way to circulating traffic already in the roundabout. This regulation, in addition to the deflection brought about by the central island in a roundabout serve to reduce speed. Moreover, the task of road users entering the roundabout is simplified, in that all traffic comes from one direction only. Roundabouts have therefore lead to substantial improvements in safety.

In addition, roundabouts have greater capacity than junctions controlled by give way signs or traffic signals. In junctions carrying large traffic volumes, which means more than an AADT (annual average daily traffic) of roughly 10,000 roundabouts therefore shortens travel time, despite the fact that speed is reduced. This shortening is brought about by shorter waiting time, especially in junctions with a high proportion of vehicles entering from the minor road.

The major assumptions made in the cost-benefit analysis and the results of the analysis are given below. The calculations are illustrative only, but the assumptions made are meant to be typical for the application of this measure in an urban environment. A distinction is made between three leg junctions and four leg junctions, because the effects of roundabouts on safety and mobility differ between these types of junction. No effects on pollution have been assumed, although in junctions with a high traffic volume, a certain reductions in vehicle emissions can be expected. A discount rate of five percent has been used. A time horizon of 25 years is used. This means that the present value of benefits equals 14.094 times the first year benefits. The results of the analysis are given in Norwegian kroner (NOK).

| Assumptions made and results of analysis | Number of legs in junction | |
|---|---|---|
| | Three legs | Four legs |
| Annual average daily traffic (typical value) | 7,500 | 15,000 |
| Injury accidents per million entering vehicles | 0.10 | 0.15 |
| Expected annual number of accidents | 0.27 | 0.82 |
| Effect on accidents of converting to roundabout | -25% | -35% |
| Annual number of prevented accidents | 0.07 | 0.29 |
| Present value of accident cost savings (25 yrs, 5%) | 1,540,000 | 6,480,000 |
| Travel time change per entering vehicle (seconds) | 0 | -3 |
| Present value of travel time savings | 0 | 6,430,000 |
| Total benefits | 1,540,000 | 12,910,000 |
| Costs of installing roundabout (investment) | 1,250,000 | 1,500,000 |
| Benefit/cost ratio | 1.23 | 8.61 |

It is seen that converting junctions to roundabouts gives benefits that exceed the costs under the assumptions made. In general, a roundabout is a good solution for junctions with a daily traffic of more than about 5,000 vehicles. Benefits exceed costs irrespective of whether travel time savings are included or not. The effects on travel time are therefore not decisive for the results of the analysis. Benefits would exceed costs even if there were a slight increase in travel time.

Roundabouts reduce the number of pedestrian accident by the same percentage as all other accidents (Elvik, Mysen and Vaa 1997). As far as bicycle accidents are concerned, the effect appears to be somewhat smaller, in the order of 10-20% reduction in the number of accidents.

## 9.4 Road lighting

Road lighting is a very effective accident prevention measure (Elvik 1995). It is particularly effective in reducing fatal accidents and accidents involving pedestrians. Since these types of accident involve higher costs than the average accident, road lighting gives large savings in accident costs. An average cost of 2,000,000 NOK per prevented injury accident in built up areas has been assumed. It has been assumed that roughly speaking one third of all accidents happens in darkness. The results of an illustrative estimate of costs and benefits are given below.

It should be noted that these estimates are conservative. It has been found that road lighting slightly increases driving speed (Bjørnskau and Fosser 1996). If the benefits of travel time savings were added to the safety benefits, installing road lighting would become even more beneficial than indicated below.

| Assumptions made and results of analysis | Location of application | |
|---|---|---|
| | Pedestrian crossing | Urban road section |
| Annual average daily traffic (typical value) | 10,000 | 15,000 |
| Injury accidents per million vehicles/vehicle kms | 0.10 | 0.40 |
| Expected annual number of accidents | 0.37 | 2.19 |
| Of which accidents in darkness | 0.15 | 0.65 |
| Effect on accidents of installing road lighting | -50% | -30% |
| Annual number of prevented accidents | 0.07 | 0.20 |
| Present value of accident cost savings (25 yrs, 5%) | 2,240,000 | 5,640,000 |
| Total benefits | 2,240,000 | 5,640,000 |
| Costs of installing road lighting (investment) | 200,000 | 400,000 |
| Present value of operating costs | 110,000 | 210,000 |
| Total costs | 310,000 | 610,000 |
| Benefit/cost ratio | 7.23 | 9.25 |

The effects on safety of installing road lighting vary, depending on the previous level of illumination and the quality of lighting. The relationship between the quality of lighting and the effects on injury accidents is indicated in Figure 14. The figure shows that when existing road lighting is partly switched off, the number of injury accidents will increase. The effect on accidents of a substantial upgrading of lighting is the same as the effect of installing lighting on a previously unlit road.

A trend line has been inserted in Figure 14 to highlight the relationship between the quality of lighting and the effect on accidents.

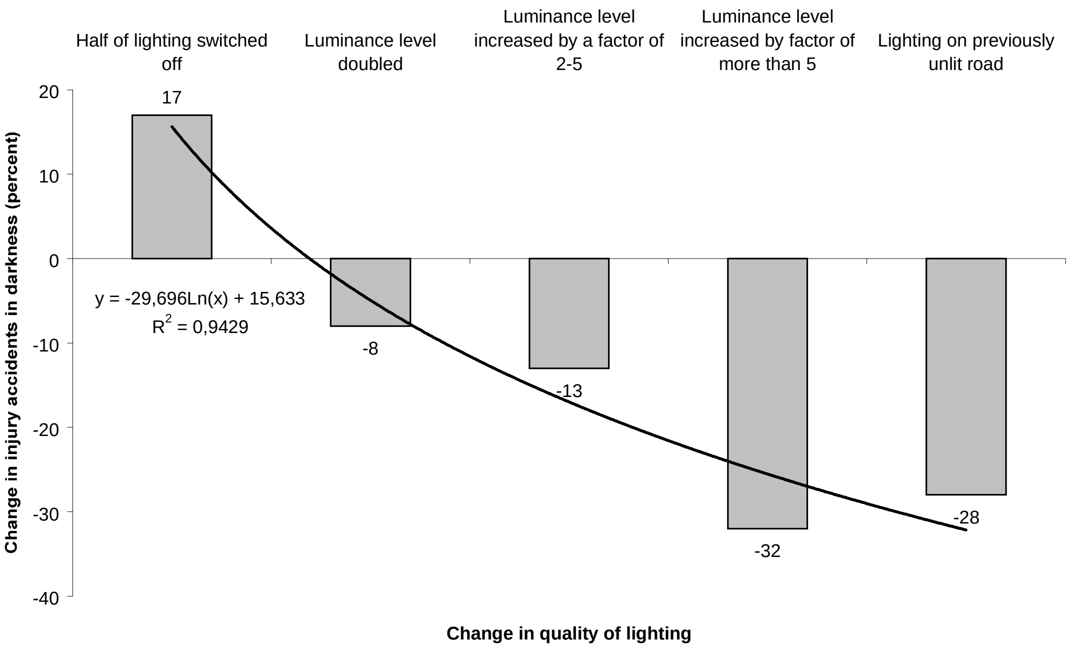


*Figure 14: Relationship between quality of lighting (change in luminance level) and effect of road lighting on the number of injury accidents.*

## 9.5 Integrated area-wide speed reduction measures

Driving speed has a major effect on the probability of becoming involved in an accident and on the severity of injuries once the accident has occurred. For example, the proportion of pedestrians who are killed rises rapidly when impact speed is more than 30 km/h (Anderson et al 1997). The lower the driving speed, the smaller becomes the chances of accidents involving serious injury to pedestrians or cyclists. In Great Britain, area-wide speed reduction measures have been applied in many areas. The Transport Research Laboratory (Finch 1998) has summarised experience from these schemes.

Just over half the schemes (56%) were located in urban residential areas with 29% occurring on main roads in rural locations and the remaining 15% in town centre areas. 74% of the schemes were aimed at reducing speed, with 64% aimed at accident reduction, and 36% at reducing the volume of through traffic. Nearly every scheme was intended to address two of these problems and many were aimed at all three. Environmental improvements were sought in 17% of the schemes, fairly evenly spread over the three types of location. This low proportion is probably related to the relatively high costs associated with environmental improvements. 60% of the schemes fell within the cost range £10,000 to £100,000. About 20% cost less than £10,000 and the same percentage cost over £100,000. Significantly 9% of the schemes cost more than £250,000, so traffic calming should not be seen as a cheap measure.

Figure 15 summarises the effects of the area-wide speed reduction schemes in three different types of area: (1) Town centres, (2) Rural main roads, and (3) Residential areas. Effects are given as the percent change in traffic volume, mean speed and the number of injury accidents from the before-period to the after-period.

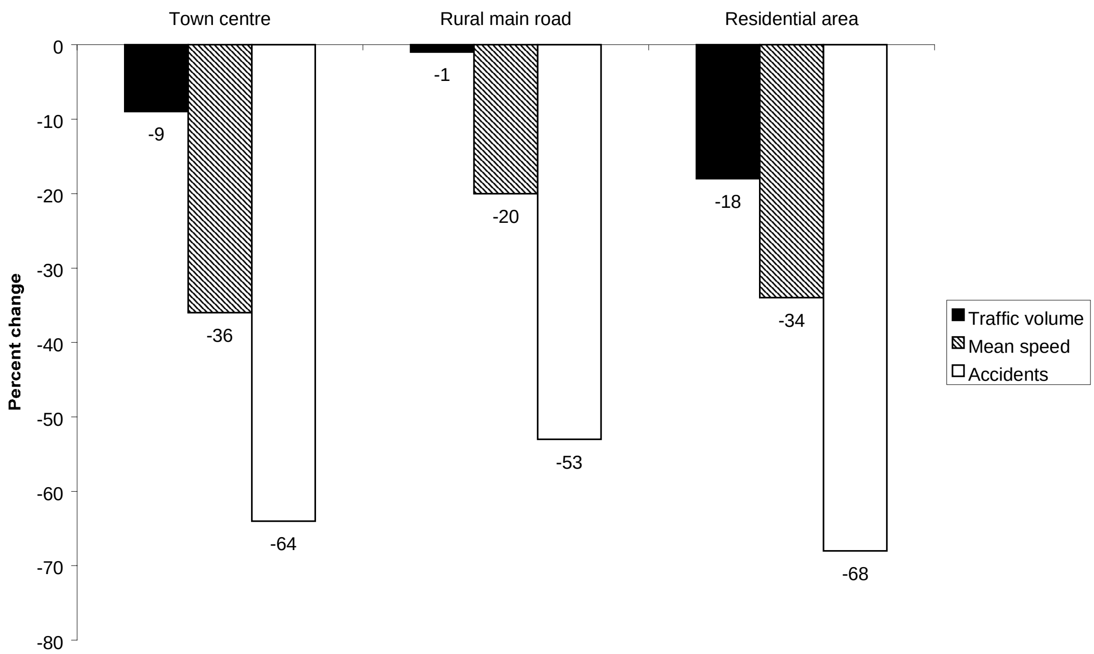


*Figure 15: Mean effects of area-wide speed reduction measures in Great Britain. Adapted from Finch 1998.*

Traffic volume was reduced in all areas, varying from 1% to 18%. Mean speed was sharply reduced, from 32.0 to 20.5 miles/h (36% reduction) in town centres, from 43.2 to 34.5 miles/h (20% reduction) on rural main roads, and from 35.6 to 23.5 miles/h (34% reduction) in residential areas. The number of injury accidents was reduced by 50 to 70%. These accident reductions are not implausibly large. In general, the number of injury accidents depends on the square of speed. Hence, a speed reduction of, for example 36%, would be expected to lead to a reduction of:

$$(\text{Speed after/Speed before})^2 = 0.64^2 = 0.41 = 59\% \text{ reduction}$$

In town centres, traffic volume was reduced by 9%. In addition to the reduction in accidents attributable to reduced speed, one would therefore expect an additional decline of 9%, leading to a total accident reduction of 0.41 x 0.91 = 0.37, corresponding to a 63% accident reduction. The observed value of 64% accident reduction is remarkably close to this value. Applying a similar reasoning to the other areas leads to identical results. The observed accident reductions are likely to be caused mainly by the speed reduction measures that were introduced.

The data available for the area-wide speed reduction measures are eminently suitable to cost-benefit analysis. Such an analysis is summarised below. Amounts are in Pounds sterling. For simplicity, it has been assumed that each scheme affects 1 kilometre of road.

| | Costs and benefits by type of area | | |
|---|---|---|---|
| Assumption made and results of analysis | Town centre | Rural main road | Residential area |
| Number of prevented injury accidents/year | 53 | 34 | 145 |
| Saving in accident costs (£, 25 years, 5%) | 33,350,000 | 21,400,000 | 91,260,000 |
| Increased costs of travel time (£, 25 years, 5%) | 21,900,000 | 21,930,000 | 53,250,000 |
| Loss of consumers’ surplus of travel | 2,415,000 | 460,000 | 9,300,000 |
| Total benefits | 9,035,000 | -990,000 | 28,710,000 |
| Costs of implementing measures (£) | 4,910,000 | 2,785,000 | 2,955,000 |
| Benefit/cost ratio | 1.84 | -0.36 | 9.72 |

The value of travel time was set at 7 pence per minute, based on a recent survey by Wardman (1998). The value of one hour of travel then becomes 4.2 Pounds. To illustrate how the cost of increased travel time was estimated, consider the case of town centres. 93,000 vehicles are affected each day of the year. Each vehicle is delayed by 0.0109 hours (the difference between driving 1 kilometre at 32 miles/h and 20.5 miles/h). The costs of increased travel time then become:

$$93{,}000 \times 365 \times 0.0109 \times 4.2 \times 14.094 = 21{,}900{,}000.$$

The estimates for rural main roads and residential areas were made the same way. 175,000 cars per day were assumed to be affected by increased travel time on rural main roads. 170,000 cars per day were assumed to be affected in residential areas.

In town centres, about 9,400 cars disappeared each day. This reduction in traffic volume entails a loss of consumers' surplus. It is difficult to estimate the size of this loss very precisely. However, it is at least equal to the size of the increase in the costs of travel time, given per kilometre of travel. Otherwise, this increased cost would not have deterred drivers from driving. For town centres, this amounts to 0.0109 x 4.2 = 0.045 Pounds per kilometre of driving. A value of 0.05 was assumed for all areas. For town centres, the loss of consumers' surplus then becomes:

9,400 x 365 x 0.05 x 14.094 = 2,415,000.

The estimates were made the same way for rural main roads and residential areas. When all effects are summarised, the net benefits are positive in town centres and residential areas, but negative on rural main roads. The fact that net benefits turn out to be negative on rural main roads is mainly attributable to the large increases in the costs of travel time. The increased costs of travel time more than offset the benefits of accident savings. A recent Norwegian study of measures designed to support reduced speed limits in urban areas came to the same conclusion (Elvik 1998). Increased costs of travel time are larger than the savings in accident costs.

The fact that the benefit-cost ratio is most favourable for residential areas is not surprising. Residential roads tend to have high accident rates and low speed is generally regarded as an improvement in residential quality.

These results illustrate several troublesome aspects of current cost-benefit analyses. In the analyses presented above, an average cost of 43,550 Pounds per injury accident at 1997-prices was used. There is no information on how the schemes affected accident severity. In general, however, a speed reduction will reduce accident severity. In order to bring this into a cost-benefit analysis, one would need to know how the speed reducing schemes affected accidents at each level of severity from fatal accidents through slight injury accidents. This shows that fairly detailed information about the safety effects of a measure is needed in order to do a correct cost-benefit evaluation.

In the second place, it is not obvious that the mean value of travel time, aggregated for all trip purposes and all groups of road users, ought to be used in every cost-benefit analysis. In residential areas at least, one may expect the proportion of heavy vehicles (lorries and buses) to be smaller than on rural main roads. Moreover, the proportion of trips that are business trips is likely to be smaller in residential areas than in other areas. The value of travel time is higher for heavy vehicles than for small vehicles, and higher for business trips than for other travel purposes. One would therefore expect the mean cost of travel time for trips done in residential areas to be lower than for trips done on rural main roads. However, detailed knowledge of the composition of traffic by type of vehicle and trip purpose by type of area is needed in order to account for these differences in a cost-benefit analysis.

In the third place, the effects of the speed reducing measures are evaluated strictly from a road user point of view. When car drivers are forced to slow down, that counts as an added cost. A similar point of view applies to reduced traffic volume. When travel becomes less attractive, there is less of it, and that counts as a loss for the potential travellers. But an important objective of speed reducing measures is to improve conditions for those who live or work in an area, or for those groups of road users who do not drive a car. A reduction of traffic is perhaps a reduction of benefit from the road users' point of view, but may well be perceived as a benefit from the point of view of residents or non-motorised travellers. Less motor traffic means less noise and pollution. It also means that crossing the road becomes easier. A cost-benefit analysis that does not include these benefits is incomplete and one-sided. It favours car drivers' point of view and interests at the expense of those who do not drive.

In a wider perspective, one may wonder how a long-term target of curbing the use of cars in the interest of environmental sustainability can fit into the current framework for cost-benefit analysis. Measures that reduce motor traffic, either by raising the direct costs or by slowing traffic down, will often fail a cost-benefit test, because less traffic counts as a negative benefit. In this sense, cost-benefit analysis can hardly be said to be neutral with respect to long-term policy objectives. Reduced cost and increased demand always counts as a benefit in cost-benefit analysis, whereas a reduction in demand – ceteris paribus – counts as a loss of benefit. Policies that aim to reduce travel demand are very difficult to justify by means of cost-benefit analysis. Yet it may be precisely such policies that are needed in order to promote a sustainable transport system.

## 9.6 Environmentally adapted through-roads

An environmentally adapted through-road is a main road passing through a village or small town which has been modified in order to reduce speed and improve the environment. Roads are reconstructed by providing humps or raised pedestrian crossings, by widening the pavement and narrowing the driving lanes, by planting flowers and trees to make the road look nicer, by regulating parking more strictly and by introducing other measures that are intended to beautify the road and its closest surroundings.

Environmentally adapted through-roads have been constructed in many small towns across Europe. A collection of examples, amply illustrated by photographs, is provided in a report by Herrstedt and other (1993), published by the Danish Road Directorate in 1993. Based partly on this collection, Elvik (1998) has performed cost-benefit analyses of environmentally adapted through-roads based on Norwegian data. These data are fairly representative of conditions in Northern Europe as far as investment costs, traffic volume and accident rates are concerned. Figure 16 presents a typical example of the results of the analyses.

Benefits are given as positive numbers, losses as negative numbers. Investment costs are given as a positive number. Figure 16 shows that accident costs are reduced, but all other travel costs are increased. Speed is reduced, leading to an increase in travel time costs. At the speeds relevant for this analysis – roughly speaking speeds between 55 and 40 km/h – vehicle operating costs tend to increase if speed is reduced. Perhaps surprisingly, even environmental costs are expected to increase slightly when an environmentally adapted through-road is built. The increase in environmental costs is attributable to an increase in specific pollution emissions at low speed. Specific pollution emissions denote the emission in grams per kilometre of driving of specific pollutants like $NO_x$, $CO_2$ and VOC. Traffic noise is reduced, but the benefits of this are more than offset by the increase of polluting gas emissions. The sum of all benefits is actually negative, implying that the measure should not be carried out even if did not cost anything at all.

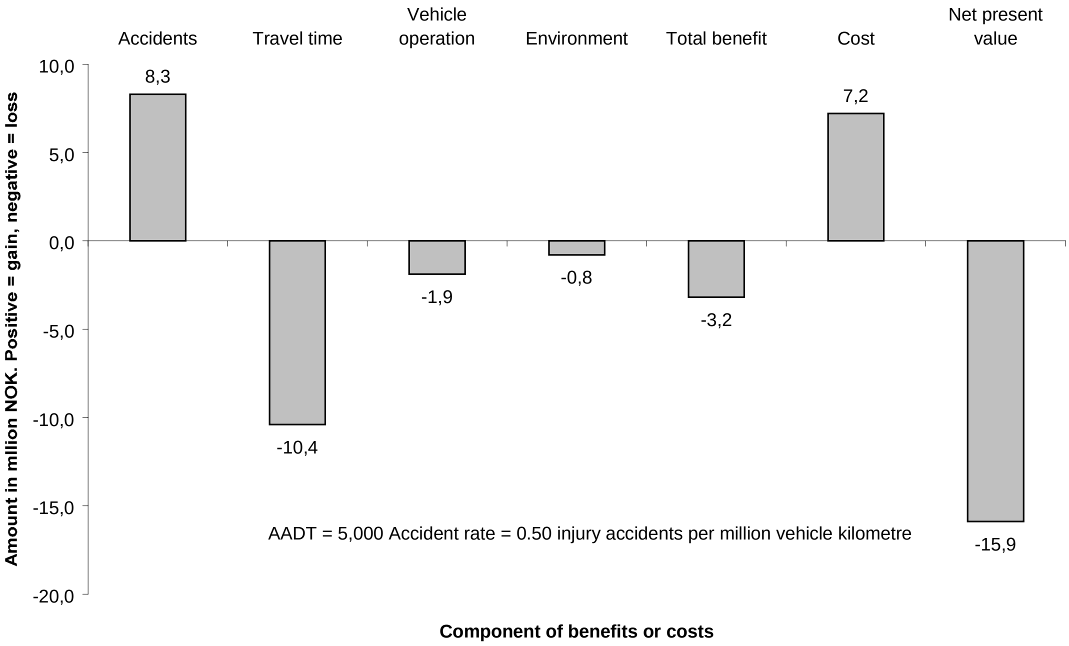


*Figure 16: Cost-benefit analysis of environmentally adapted through-road in Norway. Source: Elvik 1998.*

Once again, this kind of result leaves one wondering if there is something seriously wrong with the current framework for cost-benefit analysis. Briefly speaking, current cost-benefit analyses of road projects are based on the preferences of road users. It should not come as a great surprise that road users want cheap and fast transport, and that everything that makes it more expensive to travel or slows travel down is hardly perceived as an improvement from the traveller’s point of view. But this perspective is one-sided. Travel has substantial negative effects on the environment. Although these “external effects of transport”, as they are referred to in economic jargon, are supposed to be included in the above cost-benefit analysis, one may doubt if they have been given sufficient weight.

The right way of bringing environmental objectives into cost-benefit analysis depends in an important way on how one defines the right of ownership to environmental benefits. On the one hand, one could argue that road users collectively (as taxpayers) own the road and are entitled to use it as they wish. On the other hand, one could argue that those who are neighbours to a road have the right to clean air and to not being disturbed by traffic noise. Since both a public road and a cleaner environment are public goods, one cannot settle the matter by assigning formal rights of ownership to these goods in the same way, as private goods are individually owned. It is ultimately a matter of how one defines the rights citizens are entitled to exercise in a democratic society. It is beyond the scope of this report to settle such constitutional issues.

## 9.7 Upgrading pedestrian crossings

Ordinary marked pedestrian crossings, which are common in urban areas, do not improve safety. A review of studies made in different countries shows that an ordinary marked pedestrian crossing is associated with an increase in the number of accidents of about 25% (Elvik, Mysen and Vaa 1997). A number of measures can be introduced, however, to counteract this tendency. Road lighting, refuges, safety fences and raised pedestrian crossings all improve safety. Road lighting was discussed above. A package of measures, including, for example a raised pedestrian crossing and safety fences, is likely to reduce the number of pedestrian accidents at pedestrian crossings by about 60% and the number of vehicle accidents by about 35%.

A cost-benefit analysis of such a package of measures is given below. The cost of a pedestrian accident has been set at 2,260,000 NOK. The cost of a vehicle accident has been set at 1,240,000 NOK. It is further assumed that the measure imposes an additional delay on each motor vehicle of 3 seconds on the average. Pedestrians who took shortcuts outside the pedestrian crossing are now forced by the fence to use it. It is assumed that this imposes a mean delay of 3 seconds on all pedestrians. The value of travel time is set at 100 NOK per hour both for motor vehicles and for pedestrians.

| | Road user group | |
|---|---|---|
| Assumptions made and results of analysis | Pedestrians | Vehicles |
| Annual average daily traffic (typical value) | 1,500 | 15,000 |
| Injury accidents per million pedestrians/vehicles | 0.50 | 0.05 |
| Expected annual number of accidents | 0.27 | 0.27 |
| Effect on accidents of upgrading crossing | -60% | -35% |
| Annual number of prevented accidents | 0.16 | 0.10 |
| Changes in travel time per road user (seconds) | +3 | +3 |
| Present value of accident cost savings (25 yrs, 5%) | 5,230,000 | 1,670,000 |
| Present value of additional travel time | 643,000 | 6,430,000 |
| Total benefits | 4,587,000 | -4,760,000 |
| Costs of upgrading pedestrian crossing | 100,000 | |
| Benefit/cost ratio | -0.83 | |

It is seen that the measure gives a positive net benefit for pedestrians, but a negative net benefit for motor vehicles. When the effects are summed for these two groups of road users, the net benefit is negative. This case illustrates the fact that there can be a conflict of interest between various road user groups in urban traffic. Imposing delays on one group of road users for the benefit of another group will, in general, only be an efficient solution from an economic point of view when:

(1) The delays imposed on one group are compensated by corresponding gains for the other group,
(2) The group on which travel time delays are imposed is much smaller than the group that benefits from the measure,
(3) Travel time delays are imposed upon groups with a relatively low valuation of travel time (passengers in public transport),

(4) The travel time delays imposed are too small to matter from an economic point of view and are therefore assigned zero cost.

The term “efficient” as used here denotes a change for which the benefits exceed the costs, as valued by the people who benefit or who incur the costs. This concept is the one underlying cost-benefit analysis. It does not embody notions of fairness, for example. If, for example, one considers it unfair that cars impose delays on pedestrians, then the above calculations are less relevant. One may also think that delays or savings of only three seconds do not matter – you cannot use those three seconds to do anything meaningful.

The notion of a threshold value for travel time delays or savings is troublesome, however. Why would pedestrians want to cross the road outside a pedestrian crossing, only to save a few seconds? Why would safety fences be needed? Why are some drivers reluctant to give way to pedestrians at pedestrian crossings, if it only delays them by an insignificant few seconds? Why do we have to force drivers to slow down by installing raised pedestrian crossings?

It is perhaps not travel time as such which matters. Maybe it is the hassle of getting out of one’s routine, of having to change behaviour and pay more attention to traffic that explains behaviour in such situations. A pedestrian crossing outside a pedestrian crossing may not want to save time. He simply does not want to make a detour, because it is felt as unnecessary.

Yet, this does mean that there is an element of added cost – of inconvenience – to the pedestrian in using the formal crossing location. Whether this element of in-convenience is labelled “travel time” or something else matters less. It should be recognised that the concept of valuation of travel time, as used by economists, has a fairly broad scope and is intended to include all forms of behaviour in which travel time is traded off against other goods, no matter what the motives underlying those tradeoffs are.

## 9.8 Parking regulations

Parked cars are a traffic hazard for pedestrians, particularly children. Research has shown that prohibiting on-street parking improves safety (Elvik, Mysen and Vaa 1997). The number of accidents is reduced by about 25% in streets where on-street parking is prohibited. It is not known, however, whether removing parking from one street merely leads to a displacement of the problem to a neighbouring street.

To remove this complication from the analysis, it will be assumed that a garage is built and that all parking is moved from the street to the garage. It will be assumed that the costs of building and operating the garage is paid by those who use it, and that it does therefore not involve any additional public expenditure. For a one kilometre residential street with double-sided parking, parking capacity may be around 250 cars. It has then been assumed that the net space occupied by each car is 7.5 metres. This also includes the space occupied by junctions along the street.

Constructing a garage for 250 cars will cost about 25 million NOK. Annual operating costs for the garage will be about 2.5 million NOK. Assuming construction costs are amortised in 25 years, the total annual costs will be 4.275 million NOK at a 5% interest rate. This amounts to 17,100 NOK per parking space in the garage. In addition, signing the parking prohibition will cost about 25,000 NOK.

Assuming the street has an AADT of about 2,000 and an accident rate of about 0.70 injury accidents per million vehicle kilometres, a 25% reduction in the number of accidents corresponds to a saving in accident costs of about 2.9 million NOK (present value for 25 years). This is far more than the costs of signing the prohibition, but less than the costs of constructing the garage. Incurring this cost therefore cannot be defended by reference to safety effects alone. Garage parking does, however, provide other advantages to car owners. By renting space in a garage, one is always guaranteed a parking space. Theft of the car may be less likely and leaving it parked for a long time may be less of a problem than it is when parking onstreet.

## 9.9 Front, rear and side underrun guard rails on trucks

There exists very little knowledge concerning the effects of underrun protection devices for trucks (Elvik, Mysen and Vaa 1997). A recent British study (Knight 1998) has estimated the potential effects on fatalities of providing guard rails around all sides of trucks to prevent underriding and make crashes less severe. Based on this study, Table 28 has been drawn up.

Protecting all sides of trucks by means of energy absorbing devices with a low ground clearance (best currently available technology) is expected to reduce the number of fatal injuries by about 12% (158 out of 1358). The effect on injuries is likely to be smaller as some of those who otherwise would have been killed do not avoid injury altogether. An estimate in the range of 5-10% injury reduction appears to be reasonable.

A preliminary cost-benefit analysis has been made on the basis of Norwegian data. The results of this analysis were as follows (Table 28).
It was assumed that providing full protection against underriding would cost about 13,500 NOK per truck. The expected annual cost of accidents for a truck in Norway is about 39,000 NOK. If it is assumed that this cost is reduced 10% per year, the present value of the savings in accident costs (15 years, 5% discount rate) can be estimated to about 40,000 NOK. This easily exceeds the cost of providing protection against underriding. Benefits would exceed costs even if the safety effect was as small as 5%. It would therefore seem to be a good idea to provide trucks with protection against underriding.

*Table 28: Estimate of expected effects on fatalities of underrun guard rail protection on trucks. Adapted from Knight 1998.*

| Group of road user injured in crash | Current number of fatalities | Effect of underrun guard rail (%) | Number of fatalities prevented |
|---|---|---|---|
| Car occupants | 671 | | |
| - frontal impacts | 555 | -23% | 128 |
| - rear impacts | 42 | -33% | 14 |
| - side impacts | 74 | -5% | 4 |
| Pedestrians | 175 | 0% | 0 |
| Cyclists | 76 | -13% | 10 |
| Motorcyclists | 81 | -2% | 2 |
| Other groups | 191 | 0% | 0 |
| Total | 1385 | -12% | 158 |

## 9.10 Local bicycle policy to encourage mode switching

Car driving imposes external costs on society. By external costs are meant all costs that are not taken into account by drivers, and are, effectively, treated as zero costs. The major categories of external costs caused by motor travel include:

- Costs of air pollution
- Costs of traffic noise
- Part of the costs of traffic congestion
- Part of the costs of injury accidents

These costs are all related to unintended negative effects of transport and do to a major extent not have market prices. It is difficult to estimate the external costs of motor transport and no international consensus estimate exists. Depending on how costs are estimated, and which items are included, it is therefore possible to arrive at very different results.

Cycling does not generate the same external costs as car driving. The major item in the external costs of cycling is likely to be accident costs. Contrary to motorised transport, cycling may generate external benefits, not just external costs. The external benefits of cycling may include, for example, the savings in public health care spending obtained if the general physical fitness of the population improves as a result of more cycling.

In order to gain an impression as to whether it would make sense at all to try to make car drivers choose cycling instead of driving, an estimate of the external costs of car driving and cycling will be presented. Considering the great uncertainty in estimates of the external costs of transport, the numerical estimate presented below should be regarded as an example only. Nevertheless, the cost estimates are intended to be reasonable. They have been derived from a report published by the European

Conference if Ministers of Transport in 1998 (ECMT 1998). The cost estimates are given in NOK.

Estimates of the mean external costs per kilometre of driving a private car are given in Table 29.

*Table 29: External costs of driving 1 kilometre with a passenger car. Estimates applicable to Norway. NOK per kilometre. Rounded values*

| | Type of traffic environment | | |
|---|---|---|---|
| Type of cost | Countryside | Suburban | Town centre |
| Air pollution | 0.075 | 0.27 | 1.07 |
| Traffic noise | 0.025 | 0.08 | 0.23 |
| Injury accidents | 0.15 | 0.20 | 0.25 |
| Total cost | 0.25 | 0.55 | 1.55 |

It has been assumed that all costs of air pollution and traffic noise are external. For road accidents, it has been assumed that 40% of the costs are external (Elvik 1994). This external cost consists of about 30% that are costs external to the traffic system, that is imposed on society in general, and 10% that are an injury externality in accidents in which cars cause injuries to other road users. A mean cost per injury accident of 2.5 million NOK in the countryside, 2.0 million NOK in suburban areas and 1.6 million NOK in town centres has been assumed. An accident rate for passenger cars of 0.15 injury accidents per million kilometres of driving has been assumed for the countryside. For the suburban and town centre traffic environments, injury accident rates of 0.3 and 0.4 per million kilometres of driving, respectively, have been assumed.

Cycling can be assumed to generate no external costs relating to air pollution and traffic noise. The external accident costs of cycling differ from those of car driving for at least three reasons:

(1) Cycling has a higher accident rate than car driving. If single bicycle accidents not reported to the police are included, the injury accident rate for a cyclist in Norway is about 40 times higher than for a car driver.
(2) Injury severity in bicycle accidents is, perhaps surprisingly, on the average lower than injury severity in motor vehicle accidents. This is the fact when all bicycle accidents are included. It is not true, however, of accidents in which cyclists are struck by cars.
(3) Cyclists injure other road users less frequently than car drivers. Hence, the injury externality costs will be a smaller part of the external costs of accidents than for car drivers.

The mean external costs of bicycle accidents have been estimated to about 0.70 NOK per kilometre of cycling in Norway. This is an average applying to all types of traffic environment. These external costs exceed those of car driving for both the rural and suburban traffic environments. In town centres, the external costs of car driving are probably greater than those of cycling, which suggests that a reduction in the total external costs would be possible by switching from driving to cycling. On the other hand, cyclists are more at risk in town centres, which means that the external accident costs of cycling in town centres is likely to be higher than the average external accident costs.

Possible external benefits of cycling are difficult to estimate. A simple numerical example, given in Elvik (1999), shows that the savings from a reduction of 20% in the incidence of short term illness among 20 workers who take up cycling to work as a form of exercise could amount to about 580,000 NOK per year. This is the present value for 25 years, applying a discount rate of 7%. The amount of cycling that was assumed to be performed by the workers during one year in this example is 9,200 kilometres (230 x 2 x 20). Annual savings from reduced absence from work are 50,000 NOK. This is an external benefit of more than 5 NOK per kilometre of cycling. This dwarfs the external cost of accidents. Even if the external benefits of cycling were much smaller, they would still more than offset the external accident costs.

This shows that it would make sense from an economic point of view to encourage cycling, even when the external costs of cycling are greater than the total external costs of car driving. Cycling generates external benefits in the form of improved health that car driving does not. It is important to include these external benefits in a cost-benefit analysis, otherwise erroneous conclusions may be drawn from a comparison based on the external costs exclusively.

## 9.11 Bicycle lanes

Bicycle lanes are a cheap and effective way of improving the conditions for cyclists in urban areas. There is conflicting evidence on the safety effects of bicycle lanes (Elvik, Mysen and Vaa 1997). However, in countries with a well-established tradition of cycling, like the Netherlands, bicycle lanes appear to affect safety favourably. The provision of bicycle lanes may lead to a slight decline in driving speed, because the lanes reserved for motor vehicles become a bit narrower. Cyclists may save travel time, because they can travel unencumbered on their own lanes, not having to adapt to motor vehicles or pedestrians all the time. This can make cycling a more attractive mode of travel in urban areas.

In the cost-benefit analysis presented below, it has been assumed that the provision of cycle lanes reduces the number of bicycle accidents by 10%, and in addition to that reduces the generalised costs of travel for cyclists (excepting that part of these costs related to accidents) by 20%. This is assumed to lead to a 15% increase in cycling. For motor traffic and pedestrians, a reduction in accidents of 30% is assumed. Speed is assumed to go down about 5%, from a mean of 50 km/h before the measure to 47.5 km/h after. The mean cost of accidents in urban areas, 1,600,000 NOK per police reported injury accident, has been used.

It is possible to give some highly preliminary estimates of the generalised costs of travel for pedestrians and cyclists, and some elements of those costs, based on the findings of the stated preference survey conducted as part of the WALCYNG-project (Stangeby 1997). Since none of these costs have so far been estimated in other studies, they are used for illustrative purposes only. These values should not be regarded as definite.

According to the WALCYNG-report, the cost of travel time is 73 NOK/hour for a pedestrian and 59 NOK/hour for a cyclist. Other studies (Elvik 1998) show that the mean speed of travel is about 6 km/hour for a pedestrian and about 9 km/hour for a cyclist. This gives costs of travel time of 12.17 NOK/km and 6.56 NOK/km, for pedestrians and cyclists, respectively. It is assumed that the cost of travel time is the dominant element of the generalised cost of travel for pedestrians and cyclists. It is further assumed that the costs of insecurity represent the other important element in the generalised costs of travel for pedestrians and cyclists. If the cost of insecurity is assumed to be 2,000 NOK per pedestrian or cyclist per year, they come to about 6.7 NOK/km of travel for pedestrians (mean annual walking distance 300 km) and about 4.5 NOK/km of travel for cyclists (mean annual cycling distance 440 km). A conservative estimate of the generalised costs of travel based on these assumptions is 15 NOK/km for pedestrians and 10 NOK/km for cyclists. This corresponds to about 1 ECU per km for cyclists. The results of the cost-benefit analysis are presented below.

| | Road user group | |
|---|---|---|
| Assumptions made and results of analysis | Cyclists | All others |
| Annual average daily traffic (typical value) | 1,500 | 15,000 |
| Injury accidents per million road user kms | 0.80 | 0.40 |
| Expected annual number of accidents | 0.44 | 2.19 |
| Effect on accidents of bicycle lane | -10% | -30% |
| Annual number of prevented accidents | 0.04 | 0.66 |
| Present value of accident cost savings (25 yrs, 5%) | 988,000 | 14,816,000 |
| Present value of additional travel time | | 8,122,000 |
| Benefits of reduced generalised costs of travel | 16,660,000 | |
| Total benefits | 17,648,000 | 6,694,000 |
| Costs of marking bicycle lane (renewal after 5 yrs) | 2,500,000 | |
| Benefit/cost ratio | 9.74 | |

It turns out that the benefits of the savings in the generalised costs of cycling, and the attendant induced cycling, are far greater than the savings in accident costs. For motorists, the savings in accident cost exceed the increase in the costs of travel time. Marking bicycle lanes on both sides of an urban road (1 kilometre) has been assumed to cost 700,000 NOK initially. Marking will have to be renewed every five years to maintain the effects. The present value of initial and future costs for marking bicycle lanes is about 2,500,000 NOK. Benefits exceed costs by a wide margin.

It should be noted that the assumptions made with respect to changes in travel time and the volume of cycling are not decisive for this result. Even if bicycle lanes are considered as an accident prevention measure exclusively, benefits still clearly exceed costs.

## 9.12 Advanced stop lines for cycles at junctions

Advanced stop lines for cycles at junctions have been found to reduce the number of accidents (Elvik, Mysen and Vaa 1997). In addition, it has been argued that advanced stop lines will reduce cyclist exposure to pollution from automobiles (Lidström 1980). This sounds reasonable, since cyclists would be closer to the exhaust pipes if they stop alongside cars or behind them than if they stop in front of them.

Advanced stop lines for cyclist may impose a very slight delay on motor traffic, since it has to stay behind the cyclists when traffic lights turn green. In the analysis presented below, a mean delay of 2 seconds has been assumed. This has not been documented, but is used as an illustration of the order of magnitude of a possible effect only (if any delay at all is imposed, it will at most amount to seconds, not minutes).

The benefit of a possible reduced exposure of cyclists to pollution is very difficult to put a monetary value on. There exist a number of estimates of the external costs of air pollution from cars in towns, amounting in general to some 0.25 to 0.50 NOK per vehicle kilometre for light cars. The duration of exposure during the red phase at a signalised junction is fairly short. On the other hand, cars are running on empty and therefore emit more pollution than when they are moving. Simply to see what difference this factor could make to the results of a cost-benefit analysis, the benefits of reduced cyclist exposure to pollution have been fixed to 0.10 NOK per car entering the junction. This is of course an illustrative and exploratory estimate only. The mean cost of a police reported injury accident in urban areas (1,600,000 NOK) has been used. Stop lines have been assumed to require renewed marking every five years. It has been assumed that marking them costs 250,000 NOK per junction. The results of a cost-benefit analysis are presented below.

The analysis indicates that benefits are greater than costs by a wide margin. This conclusion applies even if the non-safety related effects of the measure are disregarded. The estimated benefit of reduced exposure to pollution, in particular, is surprisingly large and possibly shows that the assumptions made with regard to this effect are erroneous.

| | Road user group | |
|---|---|---|
| Assumptions made and results of analysis | Cyclists | All others |
| Annual average daily traffic (typical value) | 1,500 | 15,000 |
| Injury accidents per million entering road users | 0.50 | 0.10 |
| Expected annual number of accidents | 0.27 | 0.55 |
| Effect on accidents of advanced stop line | -25% | -50% |
| Annual number of prevented accidents | 0.07 | 0.27 |
| Present value of accident cost savings (25 yrs, 5%) | 1,543,000 | 6,173,000 |
| Present value of additional travel time | | 4,290,000 |
| Benefits of reduced exposure to pollution | 7,720,000 | |
| Total benefits | 9,263,000 | 1,883,000 |
| Costs of marking stop line (renewal after 5 yrs) | 890,000 | |
| Benefit/cost ratio | 12.52 | |

## 9.13 Mandatory wearing of bicycle helmets

Mandatory wearing of bicycle helmets has been introduced in Australia, New Zealand and some of states of the United States (in the United States mostly for school children). The evaluation studies that have been made indicate that a law requiring cyclists to wear helmets generates three effects (Elvik, Mysen and Vaa 1997):

(1) *The helmet effect*, which reduces the likelihood of sustaining a head injury in an accident. This effect manifests itself in a decline in the proportion of all injuries to cyclists that are head injuries.
(2) *The behavioural adaptation effect*, which means that some cyclists may cycle less carefully when they feel protected by a helmet than when they do not wear one. This effect manifests itself in an increase in the accident rate per kilometre of cycling once helmets become more commonly used.
(3) *The exposure effect,* which means that some people stop cycling when helmet wearing becomes the law. This effect manifests itself in a decline in the number of kilometres cycled once helmet wearing is made mandatory.

Laws requiring the wearing of helmets are controversial and not always popular among cyclists. Robinson (1996) claims that such laws are actually harmful to public health, because the lack of exercise resulting from a decline in cycling increases the risk of disease more than the decline in head injuries brought about by increased helmet wearing. It is, according to Robinson, better to cycle without a helmet and hurt your head, than to sink into the couch in front of the TV-set and get a heart attack after a few years.

It is, of course, very difficult to evaluate the validity of this argument. In principle, it could be correct, but it could also be wrong. It does not seem likely that those who cycle for the exercise are going to give up exercising altogether even if they stop cycling. If they enjoy the exercise, a more reasonable assumption would be that these people take up other forms of exercise, like jogging, swimming or playing football. If those forms of exercise are safer than cycling, a net benefit to public health may be the result of less cycling.

On the other hand, long-term sustainability in the transport system is promoted by the use of non-polluting forms of transport and counteracted by the use of polluting forms of transport. Until a clean car can be manufactured, an objective of environmental sustainability is an argument in favour of increased use of non-motorised forms of transport.

According to a synthesis of evaluation studies available until mid 1997 (Elvik, Mysen and Vaa 1997), the net effect of laws requiring the use of bicycle helmets can be decomposed into the following partial contributions:

Net effect = Behavioural adaptation effect x Helmet effect x Exposure effect

Net effect = 1.15 x (0.75) x 0.70 = 0.80

A decline in the number of injured cyclists of about 20% has been found. This is the net result of an increase of about 15% in accident rate and a decline of about 30% in the amount of cycling. The helmet effect, put in parentheses above, does not enter this calculation directly, as it does not greatly affect the total number of injured cyclists, only the proportion of injuries that are head injuries. Use of a helmet may, however, affect the total number of injured cyclist if a cyclist who would otherwise have sustained a head injury exclusively avoids injury altogether by using a helmet. Such cases are comparatively rare, however.

Based on these data, it is not obvious how a cost-benefit analysis of a law requiring the wearing of a cycle helmet should best be performed. On the one hand, one could treat the decline in the amount of cycling as a loss in consumers' surplus, generated by the increased cost of cycling attributable to helmet wearing. On the other hand, the fact that those who continue to cycle apparently sustain a higher accident involvement rate suggests than they regard the helmet as providing so much protection that they can enjoy a more leisurely style of cycling, perhaps cycling faster or simply paying less attention to traffic. To these cyclists, then, one might assume that the generalised costs of travel have been reduced.

The simplest form of analysis would be to compare the costs of a helmet to the benefits in terms of fewer and less severe head injuries for an average cyclist, while assuming that the amount of cycling and the accident rate per kilometre of cycling remain unchanged. Such an analysis would show whether wearing a helmet makes sense for each cyclist, provided he or she did not otherwise change behaviour.

Estimates based on these assumptions have been made for Norway (Elvik, Mysen and Vaa 1997) and are reproduced below. For child cyclists (age 7-14 years), the expected annual number of injuries is 0.009. The corresponding number for young adult cyclists (15-29 years) is 0.004 and for adult cyclists (30 years and older) 0.002. These figures are based on hospital records and include unreported as well as reported injuries.

It was assumed that wearing a helmet would reduce injury probability, given current cycling distance and the accident rate per kilometre cycled, by 25%. The cost of a cycle helmet was expressed as an annuity. The results of the analysis is given below:

| | Annual amounts in NOK | | |
|---|---|---|---|
| Group of cyclists | Benefits | Costs | B/C-ratio |
| 7-14 years | 750 | 120 | 6.2 |
| 15-29 years | 300 | 90 | 3.3 |
| 30- years | 150 | 55 | 2.7 |

It was assumed that child cyclists use a helmet for three years. It then has to be replaced. Young adults were assumed to use their helmet for six years and adult cyclists were assumed to use it for ten years.

The benefits of wearing a helmet clearly exceed the costs for all groups of cyclists. On the other hand, cyclists may misjudge the risk of accident, feel that wearing a helmet is uncomfortable and therefore "costs" more than just the outlays for buying the helmet and do not personally have to pay all the costs of an accident. Besides, a large part of the savings in accident costs are external from the cyclist's point of view that is they do not translate into a monetary benefit for the cyclist. Factors like these may explain why only a few cyclists wear helmets, despite the fact that the savings in accident costs exceed the costs of the helmets.

It is concluded that the assumptions one would have to make to do a cost-benefit analysis of mandatory bicycle helmet wearing are still too uncertain for such an analysis to make sense.

### 9.14 Improving bicycle conspicuity

Darkness is a major risk factor for cyclists. If the risk of injury in daylight is set to 1.0, the relative risk in darkness is about 1.8 according to a Swedish report (Andersson et al 1998).

An important reason why bicyclists run a higher injury risk in darkness than in daylight is that many bicycles are poorly lit and difficult to see. Reflective devices on the bicycle or the rider can improve conspicuity substantially and thereby make bicycles easier to detect and identify. Available evaluation studies (Elvik, Mysen and Vaa 1997) do not indicate how improving bicycle conspicuity affects the number of accidents. The studies do, however, show that detection distances become greater when conspicuity is improved. If the inverse value of detection distance is taken as a measure of potential accident risk, then the potential decline in risk when detection distance is increased can be estimated. If, for example, detection distance increases from 100 metres to 150 metres, risk is reduced from 1/100 to 1/150, or by 33%. Table 30, which is copied from the Traffic Safety Handbook indicates the effects of the various reflective devices on potential accident risk.

*Table 30: Effects of bicycle safety devices on potential accident risk.*

| | Percent change in potential accident risk | | |
|---|---|---|---|
| Type of equipment | Accidents that are affected | Best estimate | 95% confidence interval |
| Reflective pedals | Multi-party accidents in dark | -75 | (-85; -60) |
| Spoke reflectors | Multi-party accidents in dark | +9 | (+1; +18) |
| Ankle light on bicyclist | Multi-party accidents in dark | -22 | (-35; -9) |
| Reflective jacket for bicyclist | Multi-party accidents in dark | -10 | (-15; -5) |
| Lit rear light | Rear-end collisions in dark | -80 | (-67; -90) |
| Mean effect of one device | Multi-party accidents in dark | -35 | (-40; -29) |
| Combined effect of all devices | Multi-party accidents in dark | -95 | (-97; -93) |

The effects vary greatly from one type of device to another. The mean effect of a single reflective device, including a lit rear light, is a reduction of 35% in the risk of multi-party accidents in darkness. The combined effect of using all devices is a decline of 95% in the risk of multi party accidents in darkness. Use of the various devices varies. According to a Norwegian survey, about 65% of bicycles, use spoke reflectors (the least effective device according to Table 29).

In the following analysis, it will be assumed that a combination of devices that reduce the number of multi-party accidents in darkness by 50% is used. It is further assumed that these devices cost about 500 NOK per cycle and have an effect lasting for five years.

The average number of police reported injury accidents per cyclist per year in Norway is about 0.00035 (950 accidents and 2,650,000 cyclists). The true number of accidents is substantially higher, about 0.005 per cyclist per year. It is assumed that 20% of all accidents are affected by the safety devices, and that these accidents are reduced by 50%, amounting to a 10% reduction in the total number of accidents (50% of 20% equals 10% of the total). This amounts to about 0.0005 prevented injuries per cyclist per year.

According to cost estimates for Norway, the present value of the savings in accident costs during five years amounts to 510 NOK. This is nearly equal to the assumed costs of the measures (500 NOK) and indicates that the measures are likely to give benefits that exceed the costs.

## 9.15 Daytime running lights on cars

Daytime running lights an effective accident countermeasure that is being introduced in more and more countries (Elvik 1996). It is, however, a controversial measure, especially with respect to the effects on accidents involving pedestrians or cyclists. It has been argued, for example, that a widespread use of headlights on motor vehicles would tend to make pedestrians and cyclists comparatively less conspicuous and thus more easy to overlook. On the other hand, interaction between road users involves their mutual observation, not just one group observing the other. Headlights on motor vehicles make them easier to see by pedestrians and cyclists. Whether one likes it or not, it is in the majority of cases pedestrians or cyclists who take evasive action to prevent accidents in encounters with motor vehicles (see, for example, Howarth 1985). It thus helps to prevent accidents that pedestrians and cyclists are better able to see motor vehicles.

The effects of daytime running lights on cars for various types of accident have been examined by Elvik (1996). Figure 17 presents the main results of this study.

Figure 17 contains three measures of the effects of daytime running lights that have been used in evaluation studies. The first one is the accident rate, which is defined as the number of multi-party daytime accidents per million vehicle kilometres. The second one is the simple odds, which is defined as the odds of multi-party daytime accidents to all other accidents. The third one is the odds ratio, which is defined as the odds of a multiparty daytime accident to a single daytime accident, divided by the corresponding odds for night-time accidents. The choice of measure of effect has also been controversial in studies that have evaluated the safety effects of daytime running lights. The effects given in Figure 17 refer to laws requiring the use of daytime running lights. Such laws have been introduced in Canada, Denmark, Finland, Hungary, Norway, and Sweden.

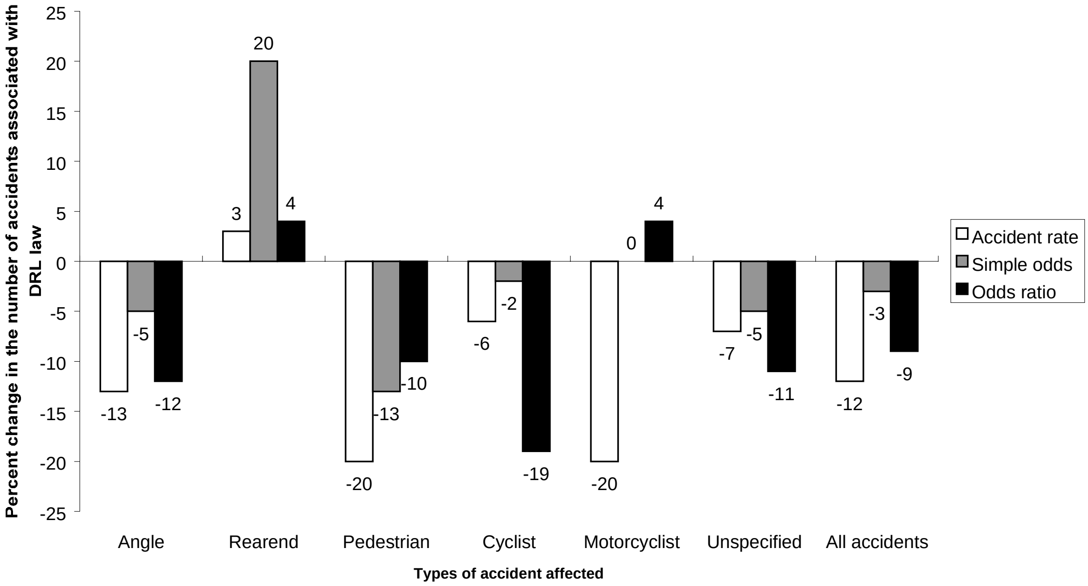


*Figure 17: Effects of daytime running lights on cars with respect to various types of accident. Source: Elvik 1996.*

It is seen that no matter how one measures the effects of daytime running lights, the number of pedestrian accidents is reduced. The reduction is between 10 and 20%. The number of bicycle accidents is also reduced. Depending on how effects are measured, the decline is from 2% to 19%.

Koornstra, Bijleveld and Hagenzieker (1997) have made an extensive and detailed survey of the literature concerning the effects of daytime running lights. They have converted all measures of effect to a common definition, which refers to the effects of going from 0% to 100% use of daytime running lights. Based on this comprehensive review, Koornstra et al estimate that a 100% use of daytime running lights in all countries of the European Union would reduce that number of fatalities by 12%, the number of injured persons by 10%, and the total number of accidents (including property damage only accidents) by 6%.

Koornstra et al performed a cost-benefit analysis of a law requiring the use of daytime running lights throughout the European Union. In the most conservative version, the results of this analysis are as follows:

| Costs or benefits | Amount in billion ECU |
|---|---|
| Total benefits | 4.78 |
| Costs of installing daytime running lights | 0.08 |
| Additional fuel consumption | 1.13 |
| Additional light bulb consumption | 1.26 |
| Additional emission of pollution | 0.18 |
| Total costs | 2.65 |
| Benefit/cost ratio | 1.80 |

They also present two more optimistic versions of the cost-benefit analysis, in which benefits are estimated to 5.5 billion ECU and 11 billion ECU. Even if the most conservative estimate of the benefits is correct, there is no doubt that the benefits of this measure clearly exceed the costs.

## 9.16 Daytime running lights on motorcycles

Motorcycles are less easy to see than cars because of they are smaller. It is well established that poor conspicuity is a contributory factor in many accidents involving motorcycles. It is therefore reasonable to expect the compulsory use of daytime running lights on motorcycles to improve conspicuity and reduce the number of accidents.

A review of studies that have evaluated the effects of daytime running lights on the number of motorcycle accidents (Elvik, Mysen and Vaa 1997) concludes that the best current estimates are as follows:

| | Percent change in the number of accidents | | |
|---|---|---|---|
| Measure evaluated | Type of accident affected | Best estimate | 95% CI |
| Use of DRL vs non-use | All accidents | -10 | (-35;+23) |
| Law requiring DRL-use | Multi-party daytime | -7 | (-10; -4) |
| Law requiring DRL-use | All accidents | -3 | (-7; +1) |

These estimates are consistent with each other. Motorcycles that use daytime running lights have an accident rate, which is about 10% lower than motorcycles that do not use daytime running lights. When a law requiring the use of daytime running lights is introduced, the number of multi-party daytime accidents is, on the average, reduced by about 7%. This effect is smaller than the difference in accident rate between motorcycles using daytime running lights and those not using it, since the increase in the use of daytime running lights upon introduction of a law is seldom from 0% to 100%. Finally, multi-party daytime accidents are only about 50% of all accidents. Hence, the effect of daytime running lights on all accidents is likely to be smaller than the effect on multi-party daytime accidents.

Based on Norwegian accident data, the annual expected number of injury accidents for an average moped rider is about 0.005. The corresponding figure for an average motorcycle rider is about 0.01. Using these annual injury frequencies, the benefit of a law requiring the use of daytime running lights has been estimated to 215 NOK per year per moped rider and 430 NOK per year per motorcycle rider (Elvik, Mysen and Vaa 1997).

The cost of using daytime running lights amounts to about 40 NOK per year for a moped and about 60 NOK per year for a motorcycle (Elvik, Mysen and Vaa 1997). Hence, the benefit-cost ratio is about 5.4 for mopeds and about 7.2 for motorcycles. These results are likely to have general validity, since the assumptions made are rather conservative. It is therefore quite likely that the benefits of requiring mopeds and motorcycles to use daytime running lights will exceed the costs in most European countries.

## 9.17 Mandatory wearing of helmets for moped and motorcycle riders

The wearing of helmets is mandatory for riders of mopeds and motorcycles in most European countries. There are, however, still a few exceptions to this rule. In the Netherlands, riders of the smallest kind of mopeds – really bicycles with a very small engine – are exempt from the law requiring helmets to be worn. The wearing rate for helmets among riders of these mopeds is almost zero. In Greece, the overall wearing rate for helmets is estimated to about 20%. The report from Workpackage 3 provides more details concerning the wearing of motorcyclist helmets in different countries.

Wearing a helmet makes a major difference to the risk of injury for a moped or motorcycle rider. Experience shows that helmet wearing rates close to 100% can be attained, by making the wearing of helmets mandatory. This is the case for both Norway and Sweden.

To illustrate the possible benefits and costs of mandatory helmet wearing for motorcyclists, estimates applying to Norway are briefly reproduced. The mean injury frequency for a motorcyclist or moped rider in Norway is about 1% (I e 1% of all riders are injured during one year). The benefit of wearing a helmet has been estimated to about 4,300 NOK per motorcyclist or moped rider per year (Elvik, Mysen and Vaa 1997). The cost of purchasing a helmet is about 1,000 NOK. Assuming that the helmet is written off in five years, the annual costs (annuity) comes to 250 NOK. Benefits are, in other words, about 17 times greater than costs (4,300/250).

This result is not surprising. All cost-benefit analyses of crash helmets that have been reported in the literature come to the same conclusion: Mandatory helmet wearing is a measure for which benefits exceed costs by a wide margin.

## 9.18 Design changes on motorcycles

Motorcycle travel is known to carry a high risk of injury. Some of the most effective measures to reduce this risk have already been implemented, or are at least widely used. These measures include helmet wearing, the wearing of protective clothing and the use of daytime running lights. Restrictions on the engine capacity of motorcycles are also very common. Despite these measures, the risk of injury remains high.

A review of studies for the Traffic Safety Handbook (Elvik, Mysen and Vaa 1997) shows that slightly changing the design of motorcycles could reduce the risk of injury. Among the design changes that have been shown to reduce the risk of injury are:

(1) Slightly prolonging the front wheel fork,
(2) Constructing a frangible footrest, which is torn off when it touches the ground,
(3) Slightly lowering the seat,
(4) Providing a windshield,
(5) Providing a fairing to protect knees and legs.

A conservative estimate of the combined effect of these design changes on injury probability is 25% reduction. The costs are not well known. It is possible, to estimate a critical value for the costs, by estimating the benefit of a 25% reduction in motorcyclist injury risk.

The injury risk of motorcyclists varies from country to country. In Norway, the average annual injury risk of a motorcyclist is about 0.01, or 1%. Assuming an average cost of 100,000 ECU per injury, the present value for a ten year time horizon of a 25% reduction in injury risk at this level of is 1,930 ECU per motorcyclist. This means that if the design changes cost more than this per motorcycle, and if they have an effect only on safety, benefits will be smaller than costs.

## 9.19 Graduated licensing systems – lowered age-limit for driver training in Sweden

In 1993, Sweden introduced a new lower age limit for starting driver training. The age at which training was permitted was reduced from 17 ½ years to 16 years. The licensing age remained 18 years. The objective of this reform was to give novice driver more opportunities for training before becoming fully licensed drivers. It was assumed that by driving more before passing the licensing examination, novice drivers would start with more experience and hence a lower accident rate than before this reform.

The Swedish Road and Transport Research Institute (VTI) has evaluated the effects of the 16-year age limit on accidents (Gregersen 1997). The evaluation found a reduction of 35% in the injury accident rate of those who started driver training at 16 compared to those who started at 17 ½. The accident rate for property damage only accidents was reduced by 25%. Both these reductions were statistically significant. Data collected as part of the evaluation study show that those who started driver training at 16 had an average of 118 hours of training before licensing. Those who started at

17½, before the new age limit was introduced, had an average of 48 hours of training. This difference was almost exclusively related to the amount of behind-the-wheel training. Hence, the objective of increasing the amount of training was realised.

It is well known from other studies (see, for example, Sagberg 1997) that the accident rate among novice drivers is inversely related to their driving distance. The longer a person drives per year, the lower is his or her accident rate per kilometre of driving. It is therefore reasonable to expect an increase in the amount of driver training to reduce the accident rate.

On the other hand, only about half of 16-year olds in Sweden chose to start driver training at new permitted age. The rest chose to wait. There is therefore a certain possibility that part of the difference in accident rate found between those who started driver training at 16 and those who started at 17 ½ could be attributable to selective recruitment, and not an effect of the training itself. This possible source of bias does not necessarily mean that the additional training obtained by those who started at 16 was ineffective, but could mean that the effect has been overestimated.

60 additional hours of pre-licensing training may correspond to about 1,800 kilometres of driving, assuming that an average speed of 30 km/h is maintained during training. The evaluation report by Gregersen does not contain an estimate of the costs of this additional training. However, based on a Norwegian estimate (Christensen 1997), the costs of 60 hours of private driver training can be estimated to:

60 hours x 62.8 NOK per hour = 3,768 NOK in costs of travel time
1,800 kilometres x 0.90 NOK per kilometre = 1,620 NOK in vehicle operating costs

The costs of travel time applied in this calculation are those that apply to leisure trips for car drivers. The vehicle operating costs used in this estimate, are the costs to society of driving a car. The private costs are higher, as they include petrol taxes that are excluded from the costs to society. The total costs come to 5,388 NOK, which is rounded to 5,000 SEK per driver in this analysis.

According to the report by Gregersen, the mean accident rate for a novice driver who started training at 16 is about 7 injury accidents per 1,000 drivers per year in the first year of driving after licensing. If taken at face value, the results of the evaluation study suggest that the savings in injury accidents attributable to the 16 year age limits is about 3.5 injury accidents per 1,000 drivers per year. (A reduction of 35% in the injury accident rate implies that an accident rate of about 10.5 per 1,000 drivers per year would be expected in the absence of additional training).

For 1997, the official accident costs for Sweden were 14,200,000 SEK per fatality, 6,100,000 SEK per severely injured person, and 360,000 per slightly injured person in police reported injury accidents. Applying current official Swedish accident costs, the average cost of a police reported injury accident comes to about 2,400,000 SEK. A saving of 3.5/1,000 per driver per year therefore amounts to 3,500 SEK.

The report by Gregersen states that 16.8% of those who started driver training at 16 were involved in a self reported accident during their first year of driving after licensing. The great majority of these accidents are probably minor property damage only accidents. Assuming, as stated in the report, that starting training at 16 reduces the risk of a self reported accident by 25%, an accident saving of about 5.5 accidents per 100 drivers per year can be calculated. Applying the current Swedish mean cost of 13,000 SEK per property damage only accident, this amounts to a saving of 715 SEK per driver per year. The results of the cost-benefit analysis can be summarised as follows:

| | |
|---|---|
| Savings in injury accidents in the first year of driving | 8,400 SEK |
| Savings in PDO accidents in the first year of driving | 715 SEK |
| Total accident savings | 9,115 SEK |
| Costs of additional training | 5,000 SEK |
| Benefit-cost ratio | 1.82 |

The savings in accident costs obtained during the first year of driving outweigh the additional costs of training.

It seems likely, though, that any effect during the second and third years of driving will be smaller than during the first year of driving. Moreover, the true effects of the additional training may be smaller than assumed in this calculation, due to the selective recruitment effect adduced to above.

## 9.20 Graduated driver license – license on probation in Austria

In recent years, several countries have introduced a graduated licensing system for new drivers. One version of such a system – driver’s license on probation – was introduced in Austria in 1992. The driving license on probation was introduced in Austria on January 1, 1992 in order to reduce the increasing number of accidents caused by novice, especially young, drivers. The law prescribes a probation period of two years for novice drivers. In addition the legal BAC-limit (blood alcohol concentration) for novice drivers was lowered from 0.08% to 0.01%. For other drivers, the legal BAC-limit was not changed. During the probation period, the following offences lead to an obligatory participation in a driver improvement programme as well as to an extension of the two years period of probation for an additional year:

- offence against the 0.01%-BAC limit
- causing an injury or fatality
- committing a dangerous offence, for example, seriously exceeding the speed limits

Five years after the introduction of this measure an analysis was carried out concerning the number of passenger car drivers involved in accidents with personal injuries and fatalities. In this analysis holders of driving licences on probation were compared with all the other drivers. The results indicate a 32.5% decrease in the number of accidents within the group of novice drivers. The decrease within the group of all the other drivers was merely 8.9% in the same period.

In the year of the introduction of this law (1992) 19.2% fewer new licences were issued compared to the year before. Even taking into account this declining number of novice drivers, the analysis still indicates an accident reduction of 18.7% (number of novice drivers involved in accidents with personal injuries and fatalities related to the number of holders of driving licences on probation). These results are described in Table 31.

*Table 31: Number of car drivers injured in Austria before and after introduction of license on probation. Source: Kaba 1998.*

| | 1991 | 1996 | Change |
|---|---|---|---|
| Number of injured novice drivers | 9,035 | 6,099 | -32.5% |
| Percent of novice drivers involved in accidents | 4.11% | 3.34% | -18.7% |
| Number of injured drivers in total | 44,372 | 40,434 | -8.9% |

The best estimate of the effect of license on probation based on these figures is probably the excess decline in the accident rate of novice drivers compared to the accident rate of all other drivers. This is estimated by the ratio 0.813/0.911, which comes to 0.892 or a 10.8% decrease.

Kaba (1998) presents a cost-benefit analysis based on the assumption that driver's license on probation reduced accidents by 18.7%. By re-estimating his figures based on accident reduction of 10.8%, one gets:

| | |
|---|---|
| Savings in accident costs | 579 million Schilling |
| Costs of measure | 65 million Schilling |
| Benefit/cost ratio | 8.91 |

The benefits outweigh the costs by a wide margin. This would be the case even if the true safety effects were much smaller than assumed in the analysis.

## 9.21 Disco buses in Germany

In order to reduce the high number of late-night road accidents among 18 to 24-year-olds at weekends, numerous public transport services, in particular disco buses, have been set up in Germany since the early nineties.

The disco buses are intended to contribute to road safety is by offering a safe alternative to young people unfit to drive (especially owing to alcohol) and to young people dependent on taking lifts from unfit drivers. The following data about these bus services were collected by BASt for the PROMISING project.

22.2% of disco-goers are under 18 years of age, 42% between 18 and 20, 25.5% between 21 and 24 and 10.3% between 25 and 31. In rural areas, however (The districts of Forchheim and Osterholz), there is a much higher proportion of adolescents under 18 (27% and 34.9% respectively).

The potential contribution to road safety by late-night transport services for people involved in leisure-time activities therefore focuses on target groups of 15 to 17 and

18 to 24-year-olds. Bus services in three areas are included in this analysis: Wupperthal, Osterholz and Forchheim.

***Wupperthal***. The late-night bus service has been running since May 1992 by the Wuppertal Stadtwerke AG, a local public transport company owned by the town of Wuppertal. The bus service is operated according to an efficiently co-ordinated timetable, with a star-shaped route network, linking all suburbs with the town centre. A total of eight routes operate every hour on Friday and Saturday nights and on nights before public holidays between 12.45 a.m. and 3.45 a.m.

***Osterholz***. The HotLine bus service run by Bremen/Lower Saxony Public Transport Services has been in operation since November 1990. Initially, there were three routes but since February 1993 there have been four operating in the district of Osterholz and Scharmbeck.

One of these bus routes was set up solely for the purpose of transporting passengers to a disco in the district of Cuxhaven, which borders to the north. In 1993, the HotLine bus network was enhanced by seven additional routes, which partly serve the districts of Rotenburg and Verden to the east and south-east respectively. The HotLine service is solely a disco bus service connecting the central residential areas to the discos. Its aim is to contribute towards increasing road safety for young people. The bus terminal is at Bremen Main Station. At each of the three discos in the district there are connections to and from the other bus routes in the system.

Routes and timetables are adapted to coincide with the opening times of the discos. On Friday nights the service begins at about 8.30 p.m. and the buses run at different times and at different intervals, depending on the route, until about 6.00 a.m. On Saturday nights, the service does not start until 9.00 p.m. Again, each route has its own specific timetable and the service ends at about 4.00 a.m. During the school summer holidays, the service is suspended for nine weeks.

***Forchheim***. In February 1990, the District of Forchheim set up a so-called «Leisure Time Bus Service». Eight routes in all connect the main residential areas with the four discos in the district. Two routes go to two communities in the District of Bamberg to the north.

Here again, the aim of the service is to reduce the problems surrounding leisure time transport for young people as well as to increase road safety. The route network is star shaped and focuses on the two largest towns in the district, Forchheim and Ebermannstadt where there are connections between the various routes. The service only operates on Saturday nights and during the «Anna Festival» in Forchheim. Each route provides a bus to the discos at about 6.30 p.m., a later bus and two return journeys at about 1.00 a.m. and about 3.00 a.m. Unfortunately, there are no available details concerning the user group.

***Cost-benefit analysis***. The operating costs of these three bus services in 1996 were 760,000 Deutsche Mark (DM) for the Wupperthal service, 430,000 DM for the Osterholz service and 182,000 DM for the Forchheim service. Accident statistics are available only for the years 1990-1996. The statistics for 1990 refer to the older Bundesländer (West Germany), the statistics for 1991 through 1996 refer to the whole of Germany. This means that it is only possible to a before-and-after study for two of the three areas included: Wupperthal and Osterholz. For Wupperthal, the year 1991 is used as the before-period, the years 1993-1996 are used as the after-period. The analysis for Osterholz refers to the extension of the service in 1993. The years 1991 and 1992 form the before-period, the years 1994-1996 form the after period. Table 32 shows the number of injured persons in police-reported accidents before and after introduction of the Disco Buses in Wupperthal and Osterholz.

*Table 32: Changes in the number of injured persons following introduction of Disco Buses in Wupperthal and Osterholz in Germany. Based on data provided by BASt.*

| Area | Age group | Period | Disco Bus group | Comparison group |
|---|---|---|---|---|
| Wupperthal | 15-17 years | Before | 47 | 22,833 |
| | | After | 220 | 98,259 |
| | 18-24 years | Before | 299 | 120,955 |
| | | After | 926 | 430,332 |
| Osterholz | 15-17 years | Before | No data | 45,083 |
| | | After | 193 | 75,764 |
| | 18-24 years | Before | 410 | 238,376 |
| | | After | 544 | 317,943 |

The data presented in Table 32 can be used to estimate the effects of the Disco Buses. The effect of the Disco Buses can be estimated by forming an odds ratio based on these figures. Among 18-24 year olds in Wupperthal, for example, there was an increase from 299 to 926 from before to after introduction of the Disco Buses. For the whole of Germany, used as a comparison group, there was an increase from 120,955 to 430,332. The odds ratio is (926/299)/(430,332/120,955), which is 0.87, indicating a reduction of about 13% in the number of injured persons. Three estimates of effect can be derived from Table 32 (no estimate can be derived for 15-17 year olds in Osterholz, as before-data are lacking):

Wupperthal, 15-17 years old: 1.09 = 9% increase = 18 more injured people
Wupperthal, 18-24 years old: 0.87 = 13% reduction = 138 fewer injured people
Osterholz, 18-24 years old: 0.995 = 0.5% reduction = 3 fewer injured people

The net effect is 123 fewer injured people per year. Current average costs of injuries in Germany are 1,200,000 DM per fatality, 54,000 DM per severely injured person, and 4,100 DM per slightly injured person. Using statistics for 18-24 year olds for the whole of Germany, about 1.9% of all victims are killed, 25.0% are severely injured and 73.1% are slightly injured. This gives a weighted average cost of 39,300 DM per injured person. An annual saving of 123 injured persons then amounts to 4,833,900 DM per year.

In addition to saving road accident costs, the Disco Buses allow savings to be made in the costs of operating a car. It is difficult to quantify these benefits, as it is difficult to the amount of car travel replaced by bus trips. No attempt has therefore been made to estimate these savings. Assuming that the savings in accident costs estimated above represent the total savings in Wupperthal and Osterholz, the following comparison of costs and benefits can be made:

| | |
|---|---|
| Savings in accident costs | 4,833,900 DM |
| Operating costs of Disco Buses (Wupperthal and Osterholz) | 1,190,000DM |
| Benefit-cost ratio | 4.06 |

Benefits exceed costs by a wide margin. This would be true even if the Disco Buses provided far smaller accident savings than estimated above.

# 10 CONCLUSIONS AND RECOMMENDATIONS

## 10.1 Conclusions

***Exposure and accidents***.

(1) Monitoring of exposure is clearly important if valid conclusions are to be drawn from changes in casualty numbers. It is also needed if estimates of the safety benefits of policies are to be calculated and understood. However the means to monitor exposure accurately, especially for pedestrians and cyclists, are not routinely available.

(2) A range of research data has been identified but comparability of either exposure or accident data is difficult because of differences between the methods of collection, the scale and detail of the surveys.

(3) Accident data needs to be related to the detailed exposure data if risk is to be calculated and evaluated. Similarly, when costs and benefits of measures are calculated it will be essential to use accidents and exposure which relate to the specific measure being evaluated.

It appears from studies in a number of countries that accidents with fatal injuries are almost always recorded by the police and by the hospitals. The level of recording of injury to pedestrians and pedal cycles seems to vary somewhat between countries. This may well be due as much to recording protocols in the various countries as to true under-reporting to the police. What does seem to be prevalent in the literature is a problem with the level of reporting to the police of pedal cycle injuries in particular. The basis on which an accident is defined as a traffic accident may be the issue here. Many studies report about 10 per cent concurrence between hospital and police records for the less severe injuries and indicate that this figure includes all falls from a bicycle, whether or not a motor vehicle was involved. Similarly highlighted is the discrepancy between some studies of pedestrian injury where all injuries are included even when a vehicle is not involved. Care needs to be taken when comparing studies and databases as definitions of what is a pedestrian or pedal cycle accident may differ in important ways between hospital based researchers and road safety researchers.

***Applicability of cost-benefit analysis***. The main conclusions can be summarised as follows:

1 Cost-benefit analysis is a technique designed to help policy makers find the most efficient way of realising policy objectives. It is based on economic welfare theory and the definition of efficiency given in that theory. Very briefly stated, a measure is regarded as efficient if the benefits are greater than the costs.

2 In order to apply cost-benefit analysis to support policy making, it is necessary to:
   (a) State all policy objectives in as precise terms as possible,
   (b) Assign monetary values to the policy objectives,
   (c) Conduct a broad survey of possible policy instruments and measures,
   (d) Determine the effects of the measures with respect to all policy objectives,
   (e) Convert these effects to monetary terms, and
   (f) Estimate the costs to society of implementing the measures.

   In short, these requirements restrict the application of cost-benefit analysis to measures whose effects are well known and situations in which policy objectives are clearly articulated and widely supported.
3 Cost-benefit analysis cannot be used to settle constitutional issues or profound disagreements over policy objectives. Nor is the technique intended to help in finding fair or equitable solutions to social problems. Matters that mainly concern justice or fairness must be decided on another basis.
4 The results of a cost-benefit analysis are determined by the assumptions that are made. The assumptions made should fit national or local conditions. If, for example, there is reason to believe that the effect of a safety measure on the number of accidents varies systematically from one country to another (as is the case for daytime running lights on cars), the analysis should reflect this condition. It is important to rely on national estimates of accident costs, and not try to harmonise these at the EU-level.
5 The results of cost-benefit analyses will vary between countries, and it will in general not be correct to generalise the results of these analyses across countries. For some road safety measures, however, general statements can be made concerning factors that influence the size of costs and benefits.

***Results of cost-benefit analyses***. As part of this project, cost-benefit analyses have been made of a number of measures designed to improve safety and mobility for vulnerable and inexperienced road users. The results of these analyses can be summarised as follows:

1 Cost-benefit analyses have been made of the following measures designed to improve safety and mobility for vulnerable and inexperienced road users:
- Roundabouts
- Road lighting
- Integrated area-wide urban speed reduction schemes
- Environmentally adapted through-roads
- Upgrading pedestrian crossings
- Parking regulations
- Front, side and rear underrun guard rails on trucks
- Bicycle lanes
- Bicycle paths
- Advanced stop lines for cycles at junctions
- Mandatory wearing of bicycle helmets
- Improving bicycle conspicuity
- Daytime running lights on cars
- Daytime running lights on mopeds and motorcycles
- Design changes on motorcycles
- Graduated licensing – driver’s license on probation
- Disco buses

2 In general, measures that improve both safety and mobility, or are neutral with respect to mobility, tend to have good benefit-cost ratios. Measures that reduce mobility, particularly by substantially reducing speed, tend to have a less favourable ratio of benefits to costs.
3 There exist very few technical and non-restrictive measures that can improve safety for inexperienced drivers and for riders of mopeds and motorcycles.
4 Measures that improve visibility or conspicuity (lighting, reflective devises, daytime running lights) or reduce driving speed are generally very effective in improving safety for pedestrians and cyclists.
5 The analyses presented are in most cases based on data taken from one country. Only for daytime running lights on cars has a cost-benefit analysis encompassing all of Europe been performed.

For results of the specific analyses, the reader is referred to chapter 9.

## 10.2 Recommendations

The recommendations made on the basis of this report have been divided into two groups. The first group consists of recommendations for further research and development of policy making instruments, particularly cost-benefit analysis. The second group of recommendations concerns the use of various measures to improve safety and mobility for vulnerable and inexperienced road users.

***Recommendations for research and development***. The following recommendations are put forward with respect to research and development.

An international conference or research project should be held in order to establish consensus with respect to identification of the relevant effects of measures that affect safety and mobility for vulnerable and inexperienced road users. It is particularly important to discuss and agree on how these measures affect the environment and road user security (subjective safety).

In current cost-benefit analysis, measures that reduce speed in urban areas to levels below about 40 km/h are often rejected in cost-benefit analyses because increased costs of travel time defeat any gain in safety or environmental amenity obtained by the measures. These results are often regarded as problematic and a critical examination of possible biases in current cost-benefit analyses of speed reducing measures in urban areas is called for.

The methods used to estimate the cost of accidents, costs of travel time and other costs of non-marketed goods used in cost-benefit analyses should be standardised between countries to the highest possible extent. However, variations in cost rates that are attributable to differences in income and population preferences should be respected.

***Recommendations for use of measures***. The following recommendations are put forward with respect to the use of measures to improve safety and mobility for vulnerable and inexperienced road users.

Measures that *improve conspicuity and visibility* will often improve safety for all road users, but particularly for pedestrians and cyclists. An increased use of daytime running lights on cars, reflective devices worn by pedestrians and cyclists, and road lighting is encouraged. These measures are in many cases likely to give benefits that widely exceed the costs.

Measures that *reduce driving speed*, especially in urban areas, will improve safety, and sometimes mobility, for pedestrians and cyclists. Measures that reduce speed may, however, impose additional travel time on motorists. Measures that reduce speed for motorists in urban areas will not always pass a cost-benefit test. There are, however, alternatives to basing speed limits in urban areas on cost-benefit analysis. An alternative that deserves careful attention is to determine speed limits according to the principles of Vision Zero, as stated by the Swedish National Road Administration.

The *wearing of helmets* protects both cyclists and riders of mopeds and motorcycles from head injury. It is at the present state of knowledge not possible to perform an adequate cost-benefit analysis of mandatory helmet wearing for cyclists. For moped and motorcycle riders, on the other hand, helmet wearing should always be mandatory.

The possibility of improving safety for motorcyclists by *design changes on motorcycles* should be explored carefully. For the time being, however, most design changes that have been proposed remain experimental and both their costs and effects are highly uncertain.

There exist few technical and non-restrictive measures that can improve safety for inexperienced drivers. *Graduated licensing* and *driver's license on probation*, are promising measures for inexperienced drivers. The continued use of these measures is encouraged.

# 11 REFERENCES


Accident Analyses Group (1991-1995). Ulykker 1990-94, Tilskadekomme registreret på skadesruen, Odense Universitetshospital.

ADONIS (1998). Behavioural factors affecting modal choice: Analysis and Development Of New insight Into Substitution of short car trips by cycling and walking – ADONIS. Swedish National Road and Transport Research Institute VTI, Linköping.

Alfaro, J-L.; Chapuis, M.; Fabre, F. (Eds.) (1994). COST 313. Socioeconomic cost of road accidents. Report EUR 15464 EN. Brussels, Commission of the European Communities.

Anderson, R.W.G., McLean, A.J., Farmer, M.B.J., Lee, B.H. and Brooks, C.G. (1997). Vehicle travel speeds and the incidence of fatal pedestrian crashes. Accident Analysis and Prevention, 29, 667-674.

Andersson, G., Brüde, U., Larsson, J., Nilsson, G., Nolén, S. and Thulin, H. (1998). Trafiksäkerhetspotentialer och trafiksäkerhetsreformer 1994-2000. VTI-meddelande 831. Linköping, Väg- och transportforskningsinstitutet.

Berntman, M. (1994). Methods for collecting information about seriously injured traffic victims. Department of Traffic Planning and Engineering, Lund University of Technology, Bulletin 6, Sweden.

Bjørnskau, T. (1994). A Comparison of Risks of different Road User Groups dependent on types of Accident Data. Proceedings of the third international conference on safety and the environment in the 21st century: lessons from the past, shaping the future, p189-98 Transportation Research Institute, Technion-Israel Institute, Israel.

Bjørnskau, T. and Fosser, S. (1996). Bilisters atferdstilpasning til innføring av vegbelysning. Resultater fra en før- og etterundersøkelse på E-18 i Aust-Agder. TØI rapport 332. Oslo, Transportøkonomisk institutt.

Borger, A. and Frøysadal, E. (1993). Sykkelundersøkelsen 1992. TØI-rapport 217. Oslo, Transportøkonomisk institutt.

Breithaupt, U. (1994). Driven Out, Sent Off. Results of an investigation into the influence of the increasing number of cars and the treat of danger from traffic on the freedom of movement of children on the streets. Proceedings of the conference Strategic Highway Research Program and Traffic Safety on Two Continents, VTI konferens No1A, Part 2 1994.

Broughton, J. (1995). Sources of national Exposure data in Great Britain. Seminar Proceedings , International Road Traffic and Accident Databases, 11-13 September 1995, Helsinki, Finland.

Crampton, G., Hass-Klau, C. and Thrush, J. (1990). Bicycle Safety in German and English towns. PTRC 10-14 September 1990, Seminar G.

DETR (1998). A new deal for transport: better for everyone. Department of Environment, Transport and the Regions. London.

DUMAS (1998). Developing Urban Management And Safety; Workpackage 4: Accident investigation. DG VII European Commission Brussels.

DUMAS (1998). Developing Urban Management And Safety; Workpackage 6: Safety for pedestrians and two-wheelers. DG VII European Commission Brussels.

Edwards, G.G. (1998). The development and promotion of measures for vulnerable road users with regard to mobility integrated with safety taking into account the inexperience of the different groups. TRL unpublished report PR/SE/44/98. Transport Research Laboratory, Crowthorne.

Elvik, R. (1993). Økonomisk verdsetting av velferdstap ved trafikkulykker. Dokumentasjonsrapport. TØI-rapport 203. Oslo, Transportøkonomisk institutt.

Elvik, R. (1995). An analysis of official economic valuations of traffic accident fatalities in 20 motorized countries. Accident Analysis and Prevention, 27, 237-247.

Elvik, R. (1995). A Meta-Analysis of Evaluations of Public Lighting as an Accident Countermeasure. Transportation Research Record, 1485, 112-123.

Elvik, R. (1996). A meta-analysis of studies concerning the safety effects of daytime running lights on cars. Accident Analysis and Prevention, 28, 685-694.

Elvik, R. (1998). Opplegg for konsekvensanalyser av tiltak for gående og syklende. TØI-notat 1103. Oslo, Transportøkonomisk institutt.

Elvik, R.(1998). Støttetiltak for lavere fartsgrense i tettbygde strøk. TØI-notat 1107. Oslo, Transportøkonomisk institutt.

Elvik, R. (1999). Incomplete accident reporting: A meta-analysis of studies made in twelve countries. Paper 990047. Submitted for the 1999 Annual Meeting of the Transportation Research Board, Washington DC, January 10-16, 1999.

Elvik, R., Mysen, A.B. and Vaa, T. (1997). Trafikksikkerhetshåndbok. Oversikt over virkninger, kostnader og offentlige ansvarsforhold for 124 trafikksikkerhetstiltak. Tredje utgave. Oslo, Transportøkonomisk institutt.

Eurostat (1997). Comparison in real terms of the aggregates of ESA. Table 2 Price level indices. Provided by Statistics Norway.

European Transport Safety Council (1997). Transport accident costs and the value of safety. ISBN 90-801936-9-0. Brussels, European Transport Safety Council.

Federation of European Pedestrian Associations (1993). Elderly Europeans on Foot.

Finch, D.J. (1998). Promising: Cost benefit data for area-wide schemes. Unpublished note prepared in October 1998 for the PROMISING project. Crowthorne, Berkshire, Transport Research Laboratory.

Fridstrøm, L. and Rand, L. (1993). Markedet for lange reiser i Norge. TØI-rapport 220. Oslo, Transportøkonomisk institutt.

Glad, A. (1985). Research on drinking and driving in Norway. A survey of recent research on drinking and driving and on drinking drivers. State-of-the-art report 15 in the Transport and Communications series. Oslo, Institute of Transport Economics.

Glad, A. (1996). Alkolås Beskrivelse av og redegjøring for effekter av teknisk innretning som skal hindre promillekjøring. I: TemaNord rapport 1996:597, 135-157. København, Nordisk Ministerråd.

Gramlich, E.M. (1994). Infrastructure Investment: A Review Essay. Journal of Economic Literature, 32, 1176-1196.

Hatakka, M., Keskinen, E., Laapotti, S., Katila, A. and Kiiski, H. (1992). What makes young drivers risky? Proceedings of fourth European Workshop on Recent Developments in Road Safety Research 1991.

Hauer, E. (1995). On exposure and accident rate. Traffic Engineering and Control, 36, 134-138.

Herrstedt, L., Kjemtrup, K., Borges, P. and Anderesen. P.S. (1993). An Improved Traffic Environment. A Catalogue of Ideas. Report 106. Road Data Laboratory, Road Standards Division, Road Directorate, Copenhagen.

Howarth, C.I. (1985). Interactions between drivers and pedestrians: Some new approaches to pedestrian safety. In Evans, L.; Schwing, R. C. (Eds): Human Behavior and Traffic Safety, 171-185. New York, NY, Plenum Press.

Hutchinson, T.P. (1984). Medical statistics on road accident injury in several countries. In Yagar, S. (Ed): Transport Risk Assessment, 43-76. University of Waterloo Press, Waterloo, Ontario.

Jensen, S.U. (1998). Pedestrian Safety – Analyses and Safety Measures. Division of Traffic Safety and Environment, Danish Road Directorate, Copenhagen.

Kaba, A. (1998). Necessity and benefits of driver improvement. In Proceedings of European Seminar on Cost-Effectiveness of Road Safety Work and Measures, Luxembourg, November 26-27, 1997. Luxembourg, PRI.

Kidholm, K. (1995). Estimation af betalingsvilje for forebyggelse af personskader ved trafikulykker. Udgivelse 21 i serien: Afhandlinger fra det samfundsvidenskabelige fakultet på Odense Universitet. Odense.

Knight, I. (1998). Accidents involving commercial vehicles in the United Kingdom. Paper presented at the DEKRA Symposium on the Passive Safety pf Commercial Vehicles, Stuttgart, Germany, October 1998.

Koornstra, M. J.; Bijleveld, F.; Hagenzieker, M. P. (1997). The safety effects of daytime running lights. Report R-97-36. Leidschendam, SWOV Institute for Road Safety Research.

Lidström, E.-B. (1980). Exposition för bilavgaser vid cykling. Examensarbete i Kemiteknik och miljö, våren 1980. Göteborg, Chalmers tekniska högskola, institutionen för teknisk kemi.

Lockwood, C., Winnett, M., Osborn, R. and Wells, P. (1998). Two-wheeler exposure and accident causation. TRL unpublished report PR/TT/31/98. Transport Research Laboratory, Crowthorne.

Lowe, E. (1999). A new survey methodology for measuring pedestrian and cyclist exposure. TRL unpublished report PR/TT/008/99. Transport Research Laboratory, Crowthorne.

Lynn, P. (1990). Factors affecting the accident liability of motorcyclists – an analysis of survey data. Contractor Report 146, Transport Research Laboratory, Crowthorne.

Matthew D. (1995). More Bikes – Policy into Best Practice. Cyclist Touring Club.

Miller, T.R. (1998). Variations between countries in values of statistical life. Unpublished manuscript. Landover, MD, National Public Service Research Institute.

Mills, P.J. (1989). Pedal cycle accidents – A hospital based study. RR220 Transport Research Laboratory Crowthorne Berks.

Mynors, P. and Savell, A. (1994). Comparisons of Cycle Provision in Four North European Countries. Transportation Planning Systems, Vol 2, No 3, pp.59-67.

Mysen, A.B., Solheim, T. and Elvik, R. (1998). $NO_x$-utslipp fra vegsektoren – effekter av ulike tiltak. TØI-notat 1101. Oslo, Transportøkonomisk institutt.

O’Donoghue, J. (1993). How much cycling is there? How safe is it? Report of the Velo-City Conference, Nottingham, 1993.

OECD (1997). Safety of vulnerable road users. Organization for Economic Co-operation and Development, Paris, France.

Olkkonen, S. (1993). Bicycle injuries: incidence, risk factors and consequences. Report 39/1993. Liikenneturva, Helsinki.

Parker A.A. (1996). Bicycle Friendly Roads are safer for all users. Velo Australis International Bicycle Conference, Oct 27-Nov 1996. Promaco Conventions Pty Ltd.

Poppe, F. (1993a). Verkeersrisico’s in Nederland 1. De cijfers. R-93-57. Leidschendam, SWOV.

Poppe, F. (1993b). Verkeersrisico’s in Nederland 2. Verantwoording. R-93-58. Leidschendam, SWOV.

PROMISING (2001a). Measures for pedestrian safety and mobility problems. Final report of Workpackage 1. Contribution of NTUA National Technical University of Athens, Greece. SWOV Institute for Road Safety Research, Leidschendam, the Netherlands.

PROMISING (2001b). Measures to promote cyclist safety and mobility. Final report of workpackage 2. Contribution of VTT Technical Research Centre of Finland. SWOV Institute for Road Safety Research, Leidschendam, the Netherlands.

Rennesson C., Lourdaux H. (1998). French National Report on Pedestrian Safety, Report for workpackage 1, Promising project.

Robinson, D. L. (1996). Head injuries and bicycle helmet laws. Accident Analysis and Prevention, 28, 463-475.

Rumar, K. (1996). The Swedish National Road safety Programme - a new approach to road safety work. Swedish National Road Administration.

Schioldborg, P. (1979). Fotgjenger og bilfører - to forskjellige verdener? Psykologisk institutt, Universitetet i Oslo.

Schollaert, U., Coppieters, M.-C., Flaxen, D. and Bergerhoff, J. (1997). Transport Demand of Modes not covered in International Transport Statistics. Cycling. Final Report. European Union contract no E1-B96-B2 7040-SIN 6051-ETU. Brussels, European Commission.

Schwab-Christe, N.G. and Soguel, N.C. (Eds.) (1995). Contingent Valuation, Transport Safety and the Value of Life. Boston, MASS, Kluwer Academic Publishers.

Silcock, D.T., Walker, R. and Selby, T. (1998). Pedestrians at risk. Ross Silcock Limited.

Stangeby, I. (1997). Attitudes towards walking and cycling instead of using a car. TØI-report 370. Oslo, Institute of Transport Economics.

Summersgill, Kennedy and Baynes (1996). Accidents at three arm priority junctions on urban single carriageways. TRL Report 184 Crowthorne, Berks.

Thulin, H. (1989). Uppskrivningsfaktorer för polisrapporterade olyckor och polisrapporterade skadade. VTI notat T 53. Linköping, VTI.

Tight, M.R. and Carsten, O.M.J. (1990). Problems for Vulnerable road users in Great Britain, the Netherlands and Sweden, Drive Project V1031. Institute for Transport Studies, University of Leeds.

Tingvall, C. (1995). The Zero Vision - a Road transport System Free from Serious Health Losses. Swedish National Road Administration.

Vägverket (1995). Nationellt trafiksäkerhetsprogram 1995-2000. Trafiksäkerhetsrapport 1994. Borlänge, Vägverket.

WALCYNG (1996). Short Trips in European countries, Internal report of workpackage No 1.

Ward, H.A., Cave, J., Morrison, A., Allsop, R. and Evans A. (1994). Pedestrian activity and accident risk. AA Foundation for Road Safety Research, AA Foundation for Road Safety, Basingstoke.

Wardman, M. (1998). The value of travel time: A review of British evidence. Journal of Transport Economics and Policy, 32, 285-316.

Wouters, P.J.J. (1994). Urban safety strategies in the Netherlands. In: International Conference on Living and walking in cities, Brescia, 1994.