Detailed cost-benefit analysis of potential impairment countermeasures

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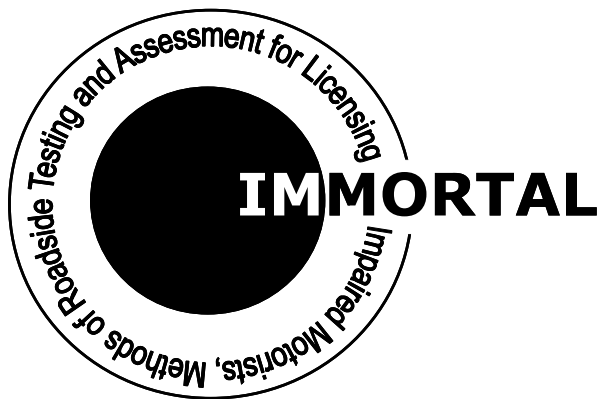
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Summary

Introduction
Traffic accidents in Europe as in other parts of the world are an enormous problem. In general road safety can be improved by measures regarding infrastructure, vehicle, or behaviour. The behaviour of the driver is influenced by his competences and capabilities. These competences and capabilities are the basis for the IMMORTAL research programme in which impairments (chronic and acute) and their influence on traffic safety are determined.

In order to decide on possible policies for impairment countermeasures it is necessary to have an insight in the socio-economic effects of the policies. This is provided in this report by means of a cost-benefit analysis. A socio-economic cost-benefit analysis provides an unambiguous appraisal method, which takes into account all relevant social effects.

Efficiency assessment
In this report we use a *cost-benefit analysis* to assess the potential impairment countermeasures. Another method for efficiency assessment is the *cost-effectiveness analysis*. Both methods have a common point of departure, namely the project-effects matrix (the overview of costs and effects). In a cost-benefit analysis the advantages and disadvantages are expressed in terms of costs and benefits and are wherever possible expressed in monetary terms. All effects are taken into account, both intended effects and side effects, including effects for those not directly involved.

The main difference is that in the cost-effectiveness analysis, only the intended effects are included (in this case safety effects) and only the costs to obtain these effects are expressed in monetary terms. This type of analysis proves to be valuable for cases in which the effects have to be maximized within a given budget or the costs have to be minimized guaranteeing a certain level of effect. However in order to make policy decisions it is necessary to have insight in all relevant social effects, not just the intended ones.

Impairment factors
In Deliverable R1.1 within the IMMORTAL programme, a review of relevant epidemiological studies has been made in order to evaluate the effects of various impairments. In a meta-analysis the studies were summarized leading to estimates of the *relative risks* associated with various impairments. If the value of the relative risk ratio is larger than one, the impairment leads to an increased risk of accident involvement. The higher the relative risk ratio is, the larger the contribution of a certain risk factor to accident involvement of the impaired drivers. Values below one indicate that the impairment leads to a reduction of the risk of accident involvement. This could be caused by *behavioural adaptation*. If for instance a driver is aware of his eyesight deficiencies he might avoid difficult circumstances such as driving at night or with reduced headway distances.

The results from the meta-analysis show that most medical impairments only have a small effect on the accident involvement. The estimates of the relative risk ratios associated with the impairments are in most cases in the range between 0.8 and 2.0. The estimates are in no case greater than 6. Hence, the effect on accident involvement of the different impairments tends to be smaller than the difference in accident involvement normally found between an 18-year old driver and a middle-aged driver. However, there are some limitations to the use of epidemiological data. In this report, most of the epidemiological evidence is taken as a basis for doing the cost-benefit analysis, but evidence that is weak (from just a few studies or from studies without a rigorous design) is not included.

Policy options

A driver has to perform certain tasks in order to reach his destination safely. Whether he/she is able to meet the *task demand* depends on his *competences* and *capabilities*. These are influenced by respectively chronic and acute impairments. The directions for policy options to control impairments can be based on these three elements:

- *lowering task demands* by vehicle adaptations or driving licence restrictions (no driving in the dark etc);
- *improvement of competences* by medical treatment, psychological rehabilitation or training;
- *withdrawing drivers with low competences*; selection based on tests or on self-selection;
- *improvement of capabilities;* deter drivers not to impair themselves, use of warning systems (such as fatigue warning systems).

In order to perform a cost-benefit analysis a concrete countermeasure for specific impairments needs to be defined. From all possible policy measures for all possible impairments a selection is made. This selection is made based on 1) the increase in accident risk of the impairment, 2) the prevalence of the impairment, 3) the effectiveness of the countermeasure and 4) the political and public support for the countermeasure.

This has led to the following selection of countermeasures that have been assessed for four countries on the North, South, East, and West boundaries of Europe (Norway, the Netherlands, Spain and the Czech Republic):

- mandatory eyesight testing (three specific types of tests);
- increasing random road side breath tests (combined with a zero BAC limit for young drivers);
- installation of alcohol lock for drivers with an alcohol problem.

Because the cost-benefit analyses in this report are only carried out for the four mentioned countries, the results are not representative for Europe. In fact there is no 'European average' for a certain countermeasure. Even between neighbouring countries that have many political and cultural aspects in common, due to minor differences between the two legal systems in those countries, the outcome of a cost-benefit analysis for a particular countermeasure may differ considerably. The four countries were chosen for practical reasons (all within the IMMORTAL-consortium and therefore fast access to data sources) and heterogeneity (different parts of Europe).

Cost-benefit analysis
As mentioned, in a cost-benefit analysis the relevant impacts of the countermeasure must be identified and expressed in monetary terms. The impacts that are assessed in the cost-benefit analysis of impairment countermeasures are:

– *changes in number of road accidents.* The change is determined by using the relative risk ratio to estimate the number of attributable accidents for a specific impairment. The reduction of these attributable accidents depends on the type of countermeasure (when a driving licence is withdrawn and compliance is 100% (which is off course questionable), all attributable risks are gone). In case of treatment we have assumed that the treatment is 100% successful, leading to a normal relative risk ratio of one. The valuation of the safety effects is based on the social costs of accidents in a country divided by the annual traffic fatalities. This method is described by the European Commission and is sometimes called the One Million Euro Test .

– *changes in amount and type of mobility.* When a driving licence is withdrawn, the car driver is forced to either stop travelling or use another mode of transport, assuming all drivers comply with the withdrawal of the driving licence. For both the loss of trips and the shift of trips to other modes of transport, the loss of benefits is valued. The cost-difference method is used for the generalized costs (time costs and variable vehicle costs), assuming a common demand function for all transport modes. The effects are different for private drivers and commercial drivers. This difference is taken into account. Also, a shift in use of transport modes may lead to an increase of accidents in those 'new' transport modes. This second order safety effect is also determined and is in some cases rather substantial.

– *changes in environmental effects.* The change in amount and type of mobility also leads to environmental effects. The reduction in environmental effects due to the decrease of car driving (first order effect) has to be corrected for the change of environmental effects due to the increase of other modes after the modal shift (second order effect).

– *costs of countermeasure.* All related project costs during the introduction period and operational period are taken into account, regardless of who is paying the costs.

Results of analyses for countermeasures
The results of the analyses are benefits and costs, expressed in million euros. The socio-economic yield is expressed in terms of the benefit/cost-ratio. If this ratio is larger than one it means that the social benefits are larger than the costs. When the benefits are negative, this ratio will be negative as well (and therefore smaller than one). The annual effects are expected to remain the same over the project period, thus mathematically the benefit-cost ratio will not be influenced by the chosen time period.

	Netherlands			Norway			Czech Republic			Spain		
	B	C	B/C	B	C	B/C	B	C	B/C	B	C	B/C
Testing eye sight												
Visual acuity	-210	-30	-7	-10	-5	-2,0	4	-1.1	4,0	-	-	-
Standard eye test	-805	-40	-20	-29	-6	-4,8	n.p.	n.p.	n.p.	-	-	-
Standard eye test incl. UFOV	-1047	-60	-17	-44	-20	-2,2	n.p.	n.p.	n.p.	81	-55	1.5
Alcohol – breath test												
Increased breath test	314	-42	7.5	35	-17	2.1	25	-4	6.4	271	-102	2.7
Incl. 0 BAC limit young drivers	376	-42	9.0	36	-19	1.9	-	-	-	280	-116	2.4
Alcohol – lock	168	-41	4.1	32.5	-7.2	4.5	9	-6	1.6	69	-99	0.7

(-) means not relevant; (n.p.) means not performed due to lack of data. In Spain mandatory eyesight testing (excl. UFOV) is already in place. In the Czech Republic the alcohol limit for all drivers is 0 BAC.

Tabel 0.1. *Results of different measures for different countries (€ million, annual effects).*

Eyesight testing
The socio-economic yield of mandatory eyesight testing is in general negative. This is mainly caused by the loss of welfare due to the withdrawal of the driving licence. Especially when the driving licence is withdrawn at a relatively young age, the mobility effects may have a large negative impact.

Besides the large negative mobility effects, the traffic safety benefits are small, due to the rather small relative risk ratios and the rather large negative second order safety effects. The negative second order safety effects depend on the modal shift to other modes of transport. Sometimes these new modes have an even higher risk ratio than the impaired car driving (for instance mopeds). The first order safety effect due to the decrease of impaired car drivers is thus partly undone by the second order safety effects due to the increase on other modes of transport.

The only eyesight test that might lead to positive results is the reduced field of view test. This eyesight impairment leads to considerable relative risk ratios, the car drivers that suffer from this impairment are older and therefore the mobility effects of withdrawing the driving licence will be less decisive. The disadvantage of the UFOV test is that the data regarding prevalence and effectiveness is not completely reliable. Most epidemiological studies stem from the same source, which is not completely independent. This makes the UFOV test, at this moment, less qualified as a decisive test for acquiring a driving licence. The sensitivity and selectivity of the test is, compared to other medical tests, acceptable but there is also a risk to include false positives and exclude false negatives.

In general, the withdrawing of driving licence leads to large negative socio-economic effects, especially when the driving licence is withdrawn at a young age. It seems thus more promising to focus on various treatments rather than on driving licence regulations.

Alcohol related measures
Three countermeasures for drunk driving have been assessed, namely increased roadside breath testing, a zero BAC limit for young drivers, and the installation of an alcohol lock. All measures seem promising. This is mainly due to the fact that the countermeasures aim at preventing drinking and driving by means of deterrence. In principle these countermeasures will not cause any mobility effects and thus also no second order safety effects. Although in principle the measures do not prevent driving (only drunk driving), it may be possible that drivers rather prefer to drink and not to drive than to drive and not to drink. This mobility effect is only accounted for in the Norwegian cost-benefit analysis on zero BAC limit for young drivers.

The Czech Republic already has a zero BAC limit for all drivers. In the Czech Republic the data regarding drunk driving and the accidents related to this drunk driving are rather poor. For instance, statistics show that the percentage of road fatalities caused by drunk drivers is 8% as opposed to about 30% in the Netherlands. Despite the fact that this country seems to suffer from underreporting (and the effects are thus underestimated), the effects seem promising. Only for Spain the costs for alcohol-lock are slightly higher than the benefits. It seems likely that this negative effect for Spain is caused by the assumptions that had to be made due to lack of input data.

General conclusions and recommendations
The title of the report is *Detailed cost-benefit analysis of potential impairment countermeasures*. The word 'detailed' in the title is somewhat misleading. The presented cost-benefit analyses are detailed in the sense that as much as possible all the effects of the measures are taken into account, but the word 'detailed' in this case doesn't imply preciseness. Cost-benefit analysis is a rather complex instrument and the results depend heavily on the quality of the input. Some input, especially regarding the different aspects of traffic safety, is missing or is rather speculative. Therefore it is necessary to make assumptions. The assumptions made in this study however will probably not change the general conclusion, namely that withdrawing driving licence (especially at a young age) based on mandatory eyesight testing will push towards a negative socio-economic yield. Preventing drunk driving through random road side tests and installing an alcohol lock all seem promising, although the prevalence of alcohol abuse and the contribution to the road fatalities seems to be underreported especially in the Czech Republic.

The cost-benefit analysis provides objective information for policy makers by presenting an overview of all relevant socio-economic effects in a structured manner. It has a normative foundation, based on aggregating individual/household preferences, but the choice for policy measures always remains a political choice that might be influenced by other factors than the socio-economic yield. However some policy recommendations are included:

– *treatment of eyesight problems.* The withdrawing of driving licences leads to large negative socio-economic effects. The countermeasures for eyesight problems will lead to a more positive socio-economic yield if they are based on treatment rather than driving restrictions. An additional advantage is that this will not prevent people from seeking medical treatment. What has to be kept in mind is that the threat of loosing one's driving license (due to driving restrictions) may lead to medical treatment

if medical treatment is possible. In order to meet the criteria for visual acuity, drivers will buy (better) glasses before they do the eyesight test.

- *research on UFOV testing.* Despite the substantial safety gain for UFOV testing, it leads to a negative net benefit in Norway and the Netherlands. This is mainly caused by the high costs related to loss of mobility in Norway and the Netherlands. As these costs are lower in Spain, the net benefit is positive for this country. A small change in the valuation of mobility loss will probably lead to a positive net benefit on UFOV testing in Norway and the Netherlands as well. This makes UFOV-testing promising. However, the quality of the input data is (partly) questionable. This leads to the conclusion that the UFOV test is not ready to play a decisive role in the provision of driving licences and more research is needed to determine prevalence, relative risk ratios, and effectiveness.

- *deregulation of license restrictions.* Based on this analysis it is clear that permanent withdrawal of driving licences leads to large negative socio-economic impacts. Especially when the initial relative risk ratio of the impairment is not so high and the drivers are relatively young (under 65 years old). Therefore it might be fruitful, based on socio-economic principles, to review existing regulations.

- *assessment of more countermeasures.* The number of possible countermeasures is infinite and although explicit criteria were used for the pre-selection, it is possible that more promising countermeasures will be 'invented' or even are already in place in a particular country.

- *stricter regulations for registration of accidents.* One of the largest difficulties in this study was the lack of accurate and detailed information. The European Commission might provide a framework for registering accident data and perhaps even medical information.

Contents

1. Introduction

1.1. Background

Large number of traffic accidents
There is a large number of traffic accidents on European roads each year. Statistics show that the number of accidents involving injuries is some 1.3 million accidents per year. These accidents lead to some 1.7 million injuries and 40,000 deaths per year. In general road safety can be improved by measures regarding the infrastructure, the vehicle, or the drivers behaviour. The behaviour of the driver is influenced by his capabilities and competences. These behavioural aspects can be influenced by impairments.

Research for impairments
In order to study such impairments and their influence on traffic safety, the European Commission has issued a research programme called IMMORTAL (Impaired Motorists, Methods Of Roadside Testing and Assessment for Licensing). IMMORTAL focuses on the accident risk associated with different forms of driver impairment and the identification of 'tolerance levels' applied to licensing assessment and roadside impairment testing (including drug screening). The aim of IMMORTAL is to provide evidence to propose intervention methods for driver impairment, and support the future development of European policy governing driver impairment legislation. The forms of intervention method considered will be licensing assessment for chronic impairment of driver fitness, and roadside impairment assessment for acute impairment of driver state.

Different forms of impairments
Driver impairment can be either 'chronic' or 'acute' depending on the duration and source of the impairment. The impairment from *chronic factors* is cumulative and persistent. Such factors may be associated with the natural decline of performance capability (i.e. driver fitness) related to ageing, or with the development of illness and disease. In all these cases the impairment effect may influence all aspects of life including driving.

The impairment from *acute factors* is immediate but transient. For example, alcohol is recognised to be a significant source of driver impairment. There is also evidence that drugs and medicines may impair driver functioning. In all these cases, the impairment effect results from the consumption (or deficit) of a substance that results in an altered level of functioning (i.e. driver state), which has a limited duration, but may be present while driving.

From the meta-analysis in Deliverable R1.1 of the IMMORTAL consortium (Vaa, 2003) it can be concluded that almost all kinds of impairment increase accident risk.

Policies and cost-benefit analysis
In order to decide on possible policies for impaired drivers it is necessary to have insight in the socio-economic effects of the policies. This way it can be clear what the benefits are and what the costs are of the different policies. A social cost-benefit analysis provides an unambiguous appraisal method, which takes into account all relevant social effects. This report describes the

different steps to such an analysis and presents the results for different policies, specified for four European countries.

The aim of the cost-benefit analyses in this case is to identify in a structured manner those policy options regarding control of impaired driving of which the benefits (in terms of socio-economic yield) are greater than their costs, regardless of who gets the benefits and who has to pay. By doing so it can help politicians to base their decisions on scientific knowledge and rational arguments as far as possible.

Objectives of this task (P2)
In the Technical Annex of the contract it is stated that this deliverable (P2) has to contain:

"… an inventory of promising measures against chronic and acute impairment factors covered in the research packages; estimations of costs, intended effects and side effects of these measures based on existing knowledge; assessment of monetary values of these effects, as far as possible given the state of knowledge; discussion of the other aspects that are relevant for decision makers (like the weights they assign to the various effects and the fairness of their distribution among road users); assessment of the social profitability of the measures (benefit/cost ratio's) and a ranking of measures."

The causes for driver impairment are numerous and the number of possible countermeasures is infinite. Besides this, the context for a specific policy option (existing legislation, number of impaired drivers, etc.) will differ greatly between countries. Given the limited resources and the time constraint (and the fact that input is required from work packages that are not finalized yet), it was impossible to rank all possible countermeasures on their benefit/cost ratio's for all EU-member states.

Instead a rough assessment was made, based on the relative accident risk of a particular impairment, its estimated prevalence, the expected effectiveness of the countermeasure, its feasibility, and its novelty for most member states[1]. This resulted in a list of 6 potential policy options (see *Paragraph 4.4.1* in *Chapter 4*). In consultation with civil servants from the European Commission in charge of driving licensing regulations, from this list three countermeasures were chosen to be included in the cost-benefit analysis. These policy options are:

− mandatory eye sight testing (on visual acuity, field of view, light adaptation and chronic eye diseases) after the age of 45, including a so called Useful Field Of View (UFOV) test after the age of 65, each time the driving licence has to be renewed;
− zero BAC limit for novice drivers (age < 25) in combination with increased random roadside breath testing;
− installation of alcohol locks for at least two years in cars of drivers that are caught with a BAC of 1.3 g/l or higher or the second time caught with a BAC between 0.5 g/l and 1.3 g/l.

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[1] A policy option that is already in place in most member states will add little to the improvement of road safety in the European Union.

The analysis has been performed for four European countries with a geographical different location in Europe and representation within the IMMORTAL programme. These countries are Norway (the north), Spain (the south), the Netherlands (the west) and the Czech Republic (the east). Because the cost-benefit analyses in this report are only carried out for the four mentioned countries, the results are not representative for Europe. In fact there is no 'European average' for a certain countermeasure. Even between neighbouring countries that have many political and cultural aspects in common, due to even minor differences between the two legal systems in those countries, the outcome of a cost-benefit analysis for a particular countermeasure may differ considerably. The four countries were chosen for practical reasons (all within the IMMORTAL-consortium and therefore fast access to data sources) and heterogeneity (different parts of Europe).

Context of the study
In other deliverables of the IMMORTAL programme, impairments and associated risk factors are determined for ageing, illness, diseases, alcohol, drugs, and medicines. The information from the different deliverables is used in the cost-benefit analysis. Since not all work packages had been finalized, some preliminary results had to be used. When data was missing, estimates and assumptions were made in order to perform the cost-benefit analysis.

The different parts of the study have different limitations. For instance the relative accident risks, which are determined in R1.1. of the IMMORTAL-project (Vaa, 2003), include limitations from the meta-analysis and limitations from epidemiological data. Besides the limitations of the different studies behind this cost-benefit analysis, there are also limitations to the use of cost-benefit analysis itself. These intrinsic limitations of cost-benefit analysis will be further discussed in *Chapter 3*.

A general weakness of most traffic safety related research is that there is, for most European countries, a lack of accurate data. In this study there was a lack of accurate data on the prevalence of certain impairments, the alcohol abuse, and estimates of the so-called second order effects. How do we know how drivers will react once their driving licence has been withdrawn?

Due to these limitations one can question the usefulness of cost-benefit analyses for politicians and policy makers. However the cost-benefit analysis does provide objective information and is transparent regarding assumptions. This provides insight in the availability of accurate data to base the policy decision upon. Therefore the assumptions are clearly mentioned in the report, including estimates about the weaknesses of the input and arguments for the assumptions. This implies that it is not sufficient for policy makers only to look at the results.

1.2. **Structure of the report**

In *Chapter 2* some basic principles of the cost-benefit analysis will be addressed and compared to another evaluation method, namely the cost-effectiveness analysis. In *Chapter 3* the different impairment factors are listed and some issues regarding epidemiological studies are addressed. At the end of this chapter attention is paid to how to quantify accident involvement. *Chapter 4* deals with the different types of policy options,

divided into options to control chronic impairments and acute impairments. The effect on traffic safety of these measures is also mentioned. In *Chapter 5* the cost-benefit analysis will be described in more detail, including the socio-economic effect that are included in the analysis. For the three selected countermeasures detailed cost-benefit analyses were performed for four selected countries. The analyses are described in the *Chapters 6-8*. In *Chapter 9* an overview of the results is presented. These results are discussed and some conclusions are drawn.

2.   Efficiency assesment in theory

There are several efficiency assessment tools. In this paragraph we will briefly discuss two that are used in the field of traffic safety, namely the *cost-benefit analysis* and the *cost-effectiveness analysis*. One common point of departure for both methods is the so-called 'project effects matrix' or the overview of effects. In this matrix the alternative expenditure possibilities (projects) are set against the various criteria by which these projects are to be assessed. The body of the matrix shows the scores for each project on each criterion.

2.1.   Cost-benefit analysis

Cost-benefit analysis (CBA) is an evaluation method that provides a quantified overview of the advantages and disadvantages of alternative projects or measures. These advantages and disadvantages are expressed in terms of costs and benefits and are wherever possible expressed in monetary terms. An example of a cost-benefit balance sheet (using headings rather than actual figures) is given in *Table 2.1*. This is taken from a study for the construction of a second national airport in the Netherlands, to supplement the existing national airport at Schiphol.

Costs	Benefits
- construction costs - modification of airspace structure - other costs (including road traffic infrastructure)	- operating revenue - net revenue from passengers and freight - indirect economic effects - noise nuisance at new airport - noise nuisance at Schiphol - planning assimilation - employment opportunity - other effects

Table 2.1. *Social cost-benefit balance sheet of a second Netherlands national airport.*

This balance sheet includes entries that affect those directly involved (as producer or consumer), such as the construction costs, operating revenue, and the net revenue from passengers and freight. It also shows the effects for those not directly involved, such as noise nuisance. In a financial/commercial CBA, the first category is of interest; in a socio-economic CBA, all effects must be taken into account, including the effects for those not directly involved. In the current case (analysis of countermeasures for impaired driving) a social CBA is obviously the most appropriate.

2.1.1.   *Equity*

Originally, cost-benefit analysis derived directly from the traditional theory of economic welfare, or mainstream (neo-classical) economic theory (Boardman et al., 2001; Brent, 1996; Mishan, 1988; Dasgupta & Pearce, 1975). In this theory, economic values are recognised as expressions of

individual/household preferences or willingness-to-pay. In practice however, some problems arise to which this theory offers no immediate solution.

The most significant example is how one can take into account effects on the distribution of income. Under the standard Pareto theory, the existing distribution of income is taken as a non-variable, whereby any shift as the result of a project is normally not included in the analysis. The assessment of the social effects of government measures is determined by individual preferences alone, and not according to the government's own objectives. This is closely related to the concept of 'optimality' in Pareto theory, based as it is on the principle of 'consumer sovereignty'. However, most governments wish to take into account the side effects of a project in terms of distribution of income; after all, they have implemented an income policy which aims to achieve a fair and just distribution of income.

In order to provide study results that are more useful to the policy-makers, it is sometimes recommended to perform, in addition to the CBA, a separate 'analysis of redistribution'; this should demonstrate to whom in society accrue the costs and benefits. In this analysis concerning countermeasures for impaired driving such an analysis of redistribution will not be performed. However, to a large extent the potential gains and losses identified in the performed analyses will also be attributable to specific identifiable groups.

2.1.2. *Project effects*

The effects of a project are determined in comparison to a reference situation. Frequently the 'zero situation' (also known as the one with 'unaltered policy' or 'business as usual') serves as the reference situation. This is based on the existing situation and its natural development if no new policy measures are implemented.

The effects include all changes (against the reference situation) as the result of a project. In first instance, these are the *intended effects*, i.e. changes which the project was consciously intended to bring about. In the case of controlling impaired driving, this is increased road safety. However, in addition to its intended effects, a project can also have *other effects*, the so-called 'side effects'. These may be positive or negative. For example, elimination of chronically impaired drivers may result in a social loss because of fewer trips or less comfortable trips. Or a substitution of drunk drivers by sober drivers may lead to more homogeneous and less polluting traffic.

2.1.3. *Time period*

Both costs and effects are spread over a period of time, effects usually over a longer period than the costs. In principle, they should both be calculated throughout the entire life cycle of the project. It is not generally acceptable to aggregate the future cost flow or to calculate average costs per year. Mostly because this takes no account of the moment at which the costs are incurred and the relevant value assessment in time. One possible solution is to apply a system of discounting (in the sense applied in accountancy), which entails relating the value of the investment stream in various years to the base value in one particular reference year. When the effects are assessed in economic terms, it becomes clear that discounting can take place in exactly

the same manner as costs. Because mostly the present year is chosen as reference, the system is also known as 'determining the present (discounted) value'. The application of discounting negates the factor of time, whereby direct comparison with other effects and costs of the project is facilitated.

2.1.4. *Socio-economic yield*

The objective of a social CBA is to assess one or more projects in terms of socio-economic yield – or socio-economic efficiency. Firstly it is necessary to establish the present (discounted) values of all costs and benefits. These values are then used to establish a certain investment criterion whereby the social profitability can be calculated.

One of these criteria is the *Benefit-Cost Ratio (BCR)*, i.e. the relationship between the aggregated present value of the benefits and the aggregated present value of the costs. Another frequently used criterion is the *Internal Rate of Return (IRR)*, which represents net returns expressed as an interest rate on the invested amount. A third measure of profitability is the *net present value (NPV)*, the difference between the aggregated present value of the benefits and of the costs.

When more than one project is being evaluated, they can be ranked in order of profitability using the BCR. The project with the greatest BCR will be considered for implementation first. When only one project is being analysed, as in the above example, it will become eligible for implementation if the socio-economic yield is greater than a set pre-established minimum values. In general, a project is seen to be of sufficient profitability if the BCR is greater than one. Where the Internal Rate of Return method is applied, the IRR must be greater than the market interest rate. This requirement is also applied to a project, selected on the basis of comparison with a number of other alternatives[2]. In this analysis concerning countermeasures of impaired driving, all effects are occurring annually and therefore the BCR will not be influenced by the time period used (but the NPV will be).

2.2. **Cost-effectiveness analysis**

Cost-effective analysis (CEA) is closely related to CBA and may be seen as a variant of it. The main difference is that in CEA, not all effects are included but only the 'intended one' and that only the costs to obtain effects are given in monetary terms. CEA is unable to take into account any aspects of distribution, such as the distribution of effects between various income groups. As with CBA, a distinction can be drawn between a

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[2] Actually, the proper way to determine if a project is desirable is to look at NPV. NPV always gives 'the right answer' in a choice among several mutually exclusive projects. The BCR may potentially be manipulated by changing classifications of costs and benefits, and thus alter the ranking of mutually exclusive projects. However, changes in the calculated BCR will *not* affect a decision about whether the proposed project is worthwhile. Another potential problem with the benefit-cost ratio is that the scale is lost – it doesn't show if the project (and net benefit) is big or small. The IRR shares all the limitations mentioned of the BCR and adds another more serious limitation: the IRR will identify correctly the "desirable projects" only if the net benefit stream is 'conventional', that is, if net benefits start negative and then turn positive and stay positive (Hanley et al., 1997). Focussing BCR (instead of NPV) may ease the presentation and comparison of results, and NPV will still be available from the CBAs.

financial/commercial analysis and a socio-economic or rather purely social analysis. In a social analysis all intended effects including those felt by third parties are included.

2.2.1. *Cost minimization versus effect maximization*

In this study the CEA can be described as an analysis by which the measure against impaired driving is identified that can be most efficiently implemented to reach a fixed amount of risk reduction (*cost minimization*). Alternatively, it may examine how fixed resources (an acceptable or maximum cost) can best be used to achieve a maximum reduction of risk (*effect maximization*).

In a *cost minimization* exercise, the effects of the alternatives are not explicitly considered because it is assumed that these will not demonstrate any great divergence. This will be the situation when alternative implementations of the same type of project are being examined (e.g. the runway of our airport example may be constructed in various ways).

In *effect maximization*, it is the alternatives of similar cost that are examined, or those that bear no major influence on the decision-making process. This will be the situation where there is a fixed budget within which alternative (combinations of) measures are to be financed.

In cost minimization not only the extent of the overall costs must be considered, but also the time at which these costs arise. If the distribution of the costs in time differs between the alternatives, discounting can be used to correct the differences. In effect maximization, the same applies to the effects' distribution over time (like in CBA). But, if the effects are not (entirely) expressed in monetary terms, which normally will be the case in social CEA analysis, discounting is not able to offer a complete solution. One could eventually attempt to express a sufficient proportion of the effects in monetary terms (which would bring the analysis very close to a CBA), so that the remaining effects become roughly comparable in terms of extent and distribution over time. Ranking could be performed according to the monetary value of the differences.

2.2.2. *Results of CEA*

In the case of effect maximization, the results will depend on whether all alternatives studied have been scored on a single intended effect, or on a combined set of various effects. If there is but one specific intended effect, and other effects do not play any significant role in the decision-making process (because, for example, they do not differ from each other greatly in terms of scope) then the costs-per-unit-effect can be calculated for each alternative. This is usually referred to as the cost-effectiveness ratio. In such case the alternatives can be ranked according to this ratio.

Where the alternatives have been scored according to various effects (intended and unintended, positive and/or negative, direct and/or indirect), the result will be a table or balance sheet in which the effects of all alternatives are systematically arranged (positive against negative). Apart from very special conditions, it won't be possible to establish a single ranking order.

Unlike CBA, the result of a CEA does not provide any information concerning the socio-economic profitability of the various alternatives. It merely provides a ranking order.

2.3. Comparison

Of the two evaluation methods described above, only the CBA enables determining the socio-economic profitability of various alternatives. If the objective is cost minimization based on a given set of alternatives, or if it is effect maximization based on a fixed budget, then CEA would be appropriate for ranking the various expenditure possibilities according to efficiency. However, where the alternatives have been scored on several aspects, it is not always possible to arrive at a clear-cut ranking order.

In applying CEA, it is not possible to take into account the effects on the distribution of income. In CBA this is normally not assessed either, but the monetarized effects (benefits) make it possible to assess distributional impacts. The available information must fulfil certain stringent requirements: quantitative information regarding the costs and all effects. In the case of a CBA, it must be possible to assess all effects (benefits) in monetary terms.

Other elements in decision-making
It should be realized that the final choice always falls to those who bear the political or administrative responsibility for the decision being taken. The use of evaluation methods will provide information that supports the making and justification of decisions. Considerations that are in themselves perfectly legitimate, but which are separate from the information provided by the evaluation study, may lead to decisions other than those suggested by the results of the study.

2.4. Principles of cost-benefit analysis

This report will focus on the CBA. As stated, a CBA is based on welfare economics, and can be described as resting on four main principles, namely:
1. consumer sovereignty;
2. willingness-to-pay;
3. maximizing efficiency;
4. distributional neutrality.

2.4.1. *Consumer sovereignty*

Consumer sovereignty refers to the right of consumers to choose how to spend their income. This serves as a starting point for analysis. Different consumers will make different choices; however within the framework of cost-benefit analysis, none of these choices is regarded as more correct than another. Individual preferences are respected, and the choices made on the basis of these preferences are simply taken as data. If someone values alcohol and tobacco so highly as to spend a major part of his or her income on these commodities, economists will not act as health advocates and advice the individual that this pattern of consumption is unwise in the long run. If someone drives his or her car even for a very short distance, economists will not assess this as silly and advice the individual that walking is healthier and friendlier to the environment.

In general, economic theory makes the assumption that consumers are perfectly rational utility maximizers. This means that each consumer chooses the most preferred pattern of consumption, given his or her budget constraint and the set of commodities available for consumption. This assumption of rational utility-maximizing consumer behaviour is closely connected to the normative status granted to consumer sovereignty. This connection actually has clear policy implications. Only if it can be shown that consumers do not act in their own best interest, a case can be made for what is usually referred to as paternalism. Paternalism means that consumers will be restricted in making their own choices; that these choices will be made by a more well-informed agent acting on their behalf.

However, the 'perfect information' assumption may be relaxed. Another element is that one consumer's sovereign consumption choice may clash with other consumers' choices. In other words, there may be negative (as well as positive) external effects, and economic theory is implicitly based on some institutional context that assures basic rights, freedom and property.

2.4.2. *Willingness to pay*

Individuals' preferences for goods and services, following from their utility maximization, are monetarized in their willingness-to-pay. In existing markets the consumers' willingness-to-pay show off in the demand and eventually in the market pricing (in association with the supply side). The allocation of goods and resources through individuals' behaviour in markets is often referred to as the act of an 'invisible hand'; the market resolves the rationing problem by balancing demand with supply through pricing, providing a social allocation from individuals' provision for their own needs. That the strength of preferences regarding the provision of goods is assessed in terms of the maximum amount individuals are willing to pay represents the second basic principle of CBA.

However, consumers who act in their own interest will not necessarily always promote social interests. *Market failure* includes cases in which a market does not exist at all, cases in which there are external effects of production or consumption, cases of markets that are permanently out of equilibrium, and monopolies. Thus, markets cannot solve all social problems, and CBA has actually been developed in order to help find solutions to problems in cases of market failure. To help find solutions to social problems that the market does not solve, economists study the demand for such solutions by investigating if it is possible to estimate individuals' willingness to pay for the provision of non-market goods.

2.4.3. *Maximising efficiency*

The objective of a CBA is to find the most efficient solution to the problem that is subject to analysis. Efficiency in welfare economics is a value term, closely related to consumer surplus. The consumer surplus is the welfare in monetary terms of consumption (of either market or non-market goods), given from aggregate demand in value terms ('the area under the demand curve') minus the cost of provision (price – if it exists). The CBA measures efficiency increases in economic terms, usually referred to as potential Pareto improvements (Deliverable P1). A potential Pareto improvement refers to a situation in which those who get the benefits of a change that is

made are able to compensate those who lose from the change, while retaining a net benefit. In practice, a potential Pareto improvement is regarded as attained whenever the benefits of an action are greater than the costs of the action. The objective of a CBA is thus to identify policy options that provide marginal benefits that are at least as great as the marginal costs of those options – increasing society's efficiency (socio-economic yield).

2.4.4. *Distributional neutrality*

In a CBA it is normally not relevant who gets the benefit and who pays the cost. Thus, an ordinary CBA is neutral with respect to distributive issues; it does not take a position concerning how best to distribute benefits and costs among various groups of the population. Fairness in income distribution is not the issue that CBA seeks to solve.

2.4.5. *Social constraints*

However, a social CBA cannot be removed from fundamental social constraints. The CBA becomes meaningless without institutions that are to promote the welfare of individuals. In short, social institutions and basic equity ('rule of law') represent prior premises of CBA. As Adam Smith pointed out, while individual benevolence in every act may be dismissed, justice is really a necessary condition for social welfare. One may bring this further and claim that CBA really gains its relevance in modern states with rule of law, democracy and transparent governance.

Opinions about the suitability of using CBA to illuminate options for solving social problems depend very much on how acceptable one considers the basic principles of CBA to be (Elvik, 2001a). In particular, a strict application of the principle of consumer sovereignty may be problematic. A case in point: to what extent is a severely cognitively impaired individual capable of making rational judgements regarding his or her fitness to drive a motor vehicle? Should not society intervene in the interest of public safety, by overruling any desire to drive a motor vehicle by an individual who is likely to represent an elevated hazard to both himself and others? These issues will be addressed further in this report (*Chapter 5*).

3.   Impairment factors

3.1.   **Review of epidemiological studies**

In another deliverable within the IMMORTAL programme, a review of relevant epidemiological studies has been made in order to evaluate the effects of various driver health impairments on driver accident rates (Deliverable R1.1). In the review evidence from the epidemiological studies has been summarized by means of meta-analysis. The analysis, included only evidence from the case-control or correlational studies. There are three general approaches to assess the relative risk factors:

1. *case-control studies*, in which drivers who have a certain impairment are compared with respect to accident involvement to drivers that do not have this impairment;
2. *correlational studies*, in which the statistical relationship between variables describing impairments and variables describing accident involvement is estimated;
3. *in depth studies* of accidents, in which an attempt is made to determine whether acute illness or other impairments may have contributed to causing an accident.

3.1.1.   *Case control studies*

In case-control studies, the effect of a medical condition on accident rate is usually assessed in terms of an accident rate ratio:

$$\text{Accident rate ratio} = \frac{\left(\dfrac{\text{Number of accidents involving drivers with condition X}}{\text{Kilometres of driving for drivers with condition X}}\right)}{\left(\dfrac{\text{Number of accidents involving drivers without condition X}}{\text{Kilometres of driving for drivers without condition X}}\right)}$$

If the value of the accident rate ratio is greater than one, the medical condition is associated with an increased risk of accident involvement. The higher the accident rate ratio is, the greater the contribution of a certain factor to the accident involvement of the drivers who are exposed to the factor. The term relative risk is sometimes used to denote an accident rate ratio. For an estimate of relative risk it is important that all other factors affecting accident involvement are as similar as possible in the groups of drivers that are compared with respect to a certain medical condition. Inadequate control for potential confounding factors is a major shortcoming of many studies that have evaluated the effect of medical impairments on driver accident rates.

3.1.2.   *Correlational studies*

Correlational or cross-section studies are usually applied to evaluate the effects of medical conditions that are best described as continuous variables. Static visual acuity is an example of such a condition. It can assume any value from perfect eyesight to complete blindness. The severity of very many diseases can also often be conceived of as a continuous

variable. Yet, in many epidemiological studies, the presence of disease is often represented simply as a binary variable: You have either got it, or you have not.

3.1.3. *In-depth studies*

In-depth studies of accidents usually try to estimate the proportion of accidents that were caused by the onset of acute illness. Results are stated in terms of the percentage of accidents that have been attributed to acute illness.

3.1.4. *Comparison of methods*

The results of studies employing these different approaches are not directly comparable. A correlation coefficient can, provided additional information is available, be converted to a slope coefficient that indicates the rate of increase in accident involvement as a function of the severity of the medical condition. Once the slope of a relationship between a medical condition and accident involvement is known, one can produce accident rate ratios for arbitrary cut-off points along the curve. In this way, the results of correlational studies can be stated in terms of accident rate ratios, comparable to those produced by case-control studies.

Estimates of relative risks do not by themselves show the proportion of accidents that have been 'caused' by the risk factor in question. The notion of 'cause' applied to accidents is controversial; some researchers argue that the concept of cause does not make sense as far as accidents are concerned (Haight, 1980). In in-depth studies of accidents, factors are listed as having contributed to an accident, and if these factors had not been present, the accident would not have happened. This means that a factor is regarded as having contributed to an accident if it forms part of a set of conditions that constituted a necessary condition for the accident to occur. The classification of factors as having contributed to accidents is obviously not an exact science, and the precise criteria used differ between studies.

3.1.5. *Attributable risk and prevalence*

In epidemiology, the relative importance of risk factors in contributing to accidents or disease can be assessed in terms of attributable risk (Kleinbaum, Kupper & Morgenstern, 1982). Attributable risk is simply the fraction of accidents or injuries that is attributable to a certain risk factor, or – to put it differently – the size of the reduction in the number of accidents that would be achieved by removing the risk factor.

Attributable risk is generally expressed as a fraction and can take on values in the range from 0 to 1. Suppose, as an example, that the *relative risk* associated with a certain medical condition is 5, i.e. those who have the condition have a 5 times higher accident involvement rate than those who do not have the condition. To bring down the accident involvement rate of those having this medical condition to the same level as for those who do not have it, it would have to be reduced from 5 to 1, that is by the fraction 4/5. This is the within-group *attributable risk*. The population-attributable risk for the medical condition depends on how prevalent it is among drivers. Population-

attributable risk is estimated according to this formula, in which PE denotes the *prevalence* of the medical condition in the population of drivers.

Population attributable risk (PAR) = $\dfrac{PE(RR-1)}{(PE(RR-1))+1}$

Let us assume that this is 10% (0.1 as a fraction). RR denotes relative risk associated with the medical condition, in this example 5. Hence, population-attributable risk in this case can be estimated to: (0.1 x 4)/[(0.1 x 4) + 1] = 0.286. This means that, in principle, the number of accidents could be reduced by 28.6 percent if the contribution of this risk factor to accidents was eliminated and overall driving exposure (the number of kilometres driven) remained the same.

3.2. Results of epidemiological studies

The studies included in the meta-analysis refer to a large number of medical conditions or diagnoses. Studies were initially grouped according to the main headings used in Council Directive 91/439/EEC regarding driving licences in the European Union. For each of these headings, the findings of relevant studies were summarized at the most detailed level possible. Results are stated in terms of estimates of *relative risks* associated with various medical conditions. *Table 3.1* summarizes the results. This table differs slightly from the results of the meta-analysis presented in *Table 6* of Deliverable R1.1 of the IMMORTAL-project (Vaa, 2003). Despite the fact that results presented here (*Table 3.1*) stem from a slightly older meta-analysis than the results presented in Deliverable R1.1, the table is more detailed. For choosing the most promising policy options a detailed table is required.

With the exception of treated sleep apnea, the table presents accident rate ratios that are based on at least two (non-contradictory) estimates. If there is a single study only available, there is no way of knowing the general validity of the finding of that study. With the exception of cardiovascular disease, study findings referring to imprecise diagnoses have also been omitted from the table.

As can be deduced from *Table 3.1*, most medical conditions and impairments appear to have only a small effect on the accident rate ratio. Estimates of the accident rate ratio associated with the conditions are in most cases in the range between 0.8 and 2.0. Values below 1.0 indicate that the condition is associated with a reduction of the accident rate i.e. an improvement in road safety. This could be caused by behavioural adaptation. If for instance a driver is aware of his eyesight deficiencies, he might avoid difficult circumstances such as driving in the night or at crowded city roads. However, in most cases, the conditions are associated with an increase of the accident rate.

The best estimate of the accident rate ratio associated with health impairments is in no case greater than about 6. Hence, the effects on accident involvement of health impairments tend to be smaller than the difference in accident rate normally found between an 18-year old driver and a middle-aged driver. Confidence intervals are in many cases quite small as well. Even the upper 95% confidence limits for the accident rate ratio of health impairments are in most cases smaller than 2.5. For 16-19 years

male drivers this rate is 7 times higher then for 45-54 years males (Vaa, 2003).

Medical conditions	Diagnoses	Cases	Comparison	Accident rate	95% limits		Number of estimates
					Lower	Upper	
Medical examination	For all diagnoses	Before exam	After exam	1.07	0.95	1.19	7
Sight	Static visual acuity	< 0.5 (approx)	> 0.5 (approx)	1.15	1.00	1.32	22
	Reduced field of view (UFOV)	> 0.4	< 0.4	4.74	2.67	8.41	15
	Failure on licensing screening test	Failed	Passed	1.25	1.01	1.55	6
	Retinal disorders	Patients	Normal	0.92	0.56	1.52	5
	Cataracts	Patients	Normal	0.97	0.86	1.10	3
	Glaucoma	Patients	Normal	0.90	0.64	1.27	3
	Glare sensitivity	Reduced	Normal	1.56	1.18	2.06	2
	Monocular vision	Patients	Normal	1.44	1.15	1.80	2
Hearing	All losses of hearing	Patients	Normal	1.19	1.02	1.40	5
Locomotion	Rheumatism	Patients	Normal	1.04	0.86	1.24	4
Cardiovascular disease	Hypertension	Patients	Normal	1.01	0.82	1.24	7
	Unspecified heart condition	Patients	Normal	1.25	1.04	1.51	10
Diabetes mellitus	All diagnoses of diabetes	Patients	Normal	1.38	1.14	1.66	11
Neurological diseases	Epilepsy	Patients	Normal	1.80	1.44	2.25	5
	Brain stroke	Patients	Normal	1.71	1.08	2.70	2
Mental disorders	Cognitive impairment/dementia	Impaired	Normal	1.53	1.12	2.10	11
	Alzheimer's disease	Patients	Normal	2.06	1.11	3.82	6
	Attention deficit hyperactivity disorder	Patients	Normal	1.93	0.84	4.43	3
	Depression	Patients	Normal	1.67	1.10	2.55	4
Alcohol	Self reported regular use	Users	Non-users	1.82	1.74	1.89	7
Drugs and medication	Use of amphetamine	Users	Non-users	4.23	3.14	5.70	3
	Use of barbiturates	Users	Non-users	1.39	0.95	2.04	2
	Use of benzodiazapines	Users	Non-users	1.28	0.94	1.75	7
	Use of cannabis	Users	Non-users	0.87	0.64	1.18	2
	Use of diazepam	Users	Non-users	6.14	1.51	24.97	3
	Use of marihuana	Users	Non-users	2.62	2.32	2.96	3
	Use of opiates	Users	Non-users	2.82	1.82	4.37	2
	Use of analgesics (pain killers)	Users	Non-users	1.21	1.08	1.36	4
	Use of antidepressiva	Users	Non-users	1.70	1.04	2.78	4
	Use of antihistamines	Users	Non-users	1.10	0.91	1.32	4
	Use of tranquillisers	Users	Non-users	1.79	1.16	2.75	2
Renal disorders	All renal disorders	Patients	Normal	0.87	0.54	1.39	3
Miscellaneous	Phases of the menstrual cycle	1/7 and 7/7	The others	1.57	1.09	2.27	4
	Illiteracy (oral driving licence test)	Oral test	Written test	1.22	1.19	1.24	3
	Untreated sleep apnea	Patients	Normal	2.08	1.89	2.29	5
	Treated sleep apnea	Patients	Normal	0.60	0.41	0.88	1

Table 3.1. *Estimates of the effects on accident involvement of various health impairments and medical conditions. Based on meta-analysis.*

Although most health impairments included in the table would seem to have a rather small effect on accident rate, one should be aware of the limitations of the evidence presented in the table. Most of the estimates presented in the table are based on very few studies. In most cases, fewer than 10 estimates were available. The conditions that have been most extensively studied are static visual acuity, field of view, diabetes, and cognitive impairments. Besides the limitations due to the small number of estimates, there are also intrinsic limitations to the use of epidemiological data. These limitations will be discussed in the following paragraph.

3.3.   Limitations to epidemiological evidence

The epidemiological evidence mentioned in the previous paragraph has a number of shortcomings. The most important of these are listed below. Each of these points will be commented more in detail and discussed by means of examples.

1. There are few studies available for some impairments.
2. The description of impairments is not sufficiently detailed in some cases.
3. The definition used of the accident rate is inadequate in many studies.
4. There is a sampling endogenicity problem in many case-control studies.
5. Factors that moderate the effects of impairments are in general not very well known.
6. The effects of combined exposure to several impairments are not well known.
7. Many studies do not control adequately for confounding factors that may influence driver accident rates.
8. The effects on health impairments according to accident severity are in general not very well known.
9. There is not enough evidence on the prevalence of various health impairments in the driver population.
10. The effects on accident rates of treatment programmes for various health impairments are not very well known.
11. There is a difference in type of study.

3.3.1.   *Few studies available*

For some types of health impairment, the effect on accident rate has been evaluated in just a few studies. In cases like this, it is impossible to know how representative the results are of the few studies that have been reported. In order to be able to assess the consistency of findings between studies, one would like to see at least a few estimates of the effect of a medical condition on driver accident rates. At least two studies yielding consistent results is needed to provide sufficient evidence of the effects of health impairments on accident rate. A number of impairments have not been included in the list, because only a single estimate is available, or because two or more estimates were contradictory.

3.3.2. *Poor description of medical conditions*

Studies vary greatly in the description given of the medical conditions that have been included. A study by Janke (1993), for example, uses the terms 'mental impairment' and 'physical impairment' to identify two of the categories studied. Both of these are very heterogeneous groups, each of them containing several hundred diagnoses, which may have greatly varying effects on driver accident rates. Only diagnoses that were judged to be sufficiently precise have been included.

3.3.3. *Inadequate measures of accident rate*

In general two definitions are used of driver accident rates in epidemiological studies. One of them is the number of accidents per driver per unit of time. This definition does not take annual driving distance into account. A higher rate of accidents per driver in one group than in another, could simply be the result of drivers in one group having a higher mean annual driving distance than drivers in the other group.

The other definition of driver accident rates used in epidemiological studies is the number of accidents per kilometre of driving. This seems to control adequately for driver exposure to traffic hazard. Unfortunately, not even kilometre based accident rates control adequately for the effect of exposure on the number of accidents. The accident rate per kilometre of driving is not independent of the number of kilometres driven, but tends to get lower at high annual driving distances. This could lead to statistical paradoxes, one of which is illustrated in the following example.
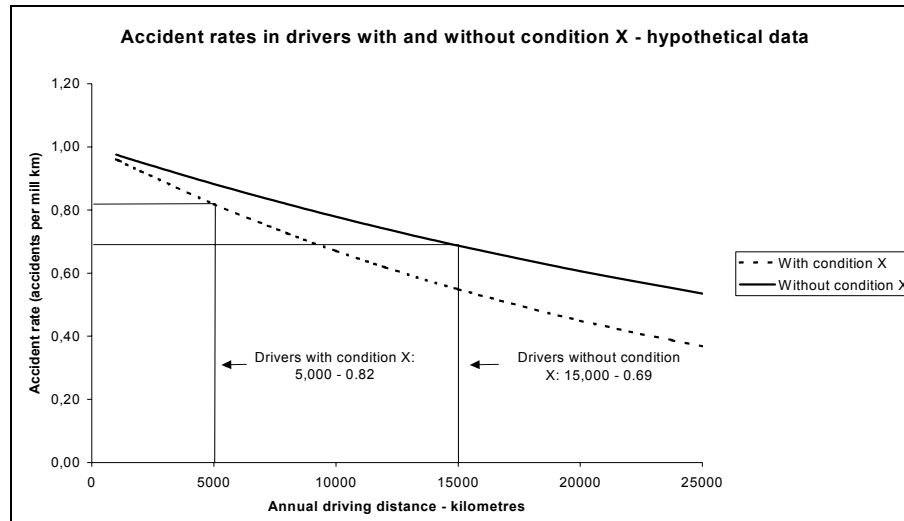
Figure 3.1. *The dependency of accident rates on kilometres driven (hypothetical data).*

In *Figure 3.1* drivers with condition X have been assumed to drive an average 5,000 kilometres per year. The accident rate at this annual driving distance is 0.82. Drivers without condition X have been assumed to drive on the average 15,000 kilometres per year. The accident rate at this annual driving distance is 0.69. If the contribution of condition X to accidents is assessed in terms of crude accident rates, an accident rate ratio of 0.82/0.69 = 1.19 is estimated, apparently showing that having condition X is

associated with an increased risk of accident involvement. This estimate is, however, misleading.

As shown in *Figure 3.1*, drivers with condition X have a lower accident rate than drivers without condition X at any annual driving distance. The accident rate at an annual driving distance of 5,000 kilometres for drivers without condition X is 0.88, leading to an accident rate ratio of 0.82/0.88 = 0.93, which does not indicate that having condition X is associated with more frequent involvement in accidents.

Suppose, for example, that in a case-control study designed to evaluate the effect of condition X on accident involvement rates, there were 500 driver who had the condition and 500 who did not. Such a sample size is not uncommon in case-control studies. Suppose further that the accident rates shown in *Figure 3.1* represent the number of injury accidents per million vehicle kilometres of driving. Then, the mean per driver per year accident rate would be 2.5 times higher for drivers without condition X than for drivers with condition X. The 500 case drivers (with X) would produce a total of 2.5 million km of driving in one year (500 x 5,000). The 500 control drivers (without X) would produce a total of 7.5 million km of driving in one year (500 x 15,000). Although these numbers may sound impressive, the expected number of accidents in each group is extremely low. It is about 2 accidents in total in the case group (2.5 x 0.82) and about 5 accidents in the control group (7.5 x 0.69).

This example, although based on hypothetical data, illustrates three very commonly found limitations in epidemiological studies of effect of impairments on road accidents:

–   Different *definitions* of accident involvement rates can produce very different estimates of the effect on accident rate of a certain condition. In the example given above, the three estimates that could be produced were:
    a.   crude km based accident rate ratio (with X/without X) = 1.19;
    b.   accident rate ratio adjusted for driving distance (with X/without X) = 0.93;
    c.   crude per driver based accident rate ratio (with X/without X) = 0.40.
–   Injury accidents, let alone fatal accidents, are very rare events, and *small accident samples* are likely to be a problem in studies that use records of medical diagnoses as sampling frame, rather than records of accident involvement.
–   There is often a difference in *driving exposure* between those who have a certain medical condition and those who do not have it. Simple kilometre based accident rates are then unlikely to give unbiased estimates of the accident rate ratio, because accident rates are not independent of the number of kilometres driven.

3.3.4.   *Sampling endogenicity*

Sampling endogenicity is likely to be a problem in many case-control studies, although it may not be recognised as a problem. Sampling endogenicity refers to the fact that the process of sampling is statistically dependent on the variable whose effects a study seeks to estimate (Heckman, 1979). To explain how this problem occurs, it is instructive to

consider how health regulations for drivers tend to be formulated. The following formulation is quite common:

"If a driving licence holder has reason to believe that he or she no longer fulfils the health requirements for having a license, the driver should contact a doctor for a medical examination. The doctor will then decide on the basis of the examination whether the driving licence should be withdrawn or can be retained."

It is fairly obvious that such a regulation does not encourage drivers who suspect that they might be medically unfit to drive to seek a doctor's opinion. If they contact a doctor, they risk losing their license. Hence, it is likely that there is a selective recruitment of drivers who seek medical consultation about their fitness to drive.

Many medical conditions that can result in a driver being ruled unfit to drive can remain undiagnosed for a long time. When a medical condition has reached the stage where treatment can no longer be postponed, the second stage of selective recruitment is reached. The doctor will have to decide whether a driver is unfit to drive. Drivers who are mildly impaired, having, for instance, slightly elevated blood pressure, mild cognitive impairments, or slight losses of vision, are likely to keep their driving licences. Only drivers who are severely impaired by their medical condition are likely to lose their driving licences.

Now suppose a case-control study is set up to assess the effects of various medical conditions on accident rate. Cases are sampled from medical records. Controls are sampled at random from the general population. Such a study is very likely to be affected by a sampling endogenicity problem, created by the voluntary nature of the process of seeking medical and by the fact that physicians are likely to rule drivers as unfit to drive only when it is perfectly obvious that they are unfit. The control group will contain some drivers who did not contact a doctor, and whose condition is undiagnosed. Underreporting of medical conditions relevant to driver licensing can be very severe (Vernon et al., 2002). This means that a comparison will be made between cases, whose condition was judged to be compatible with continuing to drive, and controls, some of which will have the same medical condition as the cases, however undiagnosed.

A strict evaluation of driver health regulations involves a paradox, resembling Catch 22. If the regulations are perfectly complied with, then no driver who is ruled medically unfit to drive will continue to do so. Therefore they are not exposed to the risk of accident (at least not as drivers); hence the risk associated with the medical condition that led to disqualification as a driver remains unknown. The only way this risk can be known, is by allowing drivers who have the condition to go on driving. This means that to evaluate whether it makes sense, for example, to disqualify drivers who have epilepsy, one must allow these drivers to go on driving, so that their accident rate can be observed and compared to that of drivers who do not have epilepsy.

Sampling endogenicity and underreporting of disqualifying medical conditions is likely to be a very severe problem in case-control studies that have used medical records of drivers who have sought treatment for

potentially disqualifying medical conditions to sample cases. The problem may be less severe, but perhaps not negligible, even in studies that have used crash records to sample cases.

3.3.5.   *No analysis of moderating factors*

Many medical conditions will not have the same effect on accident rate for all categories of drivers. For elderly drivers, for example, co-morbidity (the combination of several medical impairments) is often a problem and may moderate the effect of a condition that would otherwise not influence accident rate very much. Rather few studies have investigated factors that moderate the effect on accident rate of medical conditions. An example of a study that investigated age as a moderating factor, is a study of alternative vision screening criteria for older and younger drivers by Decina & Staplin (1993). *Figure 3.2* shows an example of a result of this study.

Accident rates for drivers who passed or failed a combined vision screening criterion applied by the state of Pennsylvania. Source: Decina and Staplin 1993, Fig 7 b
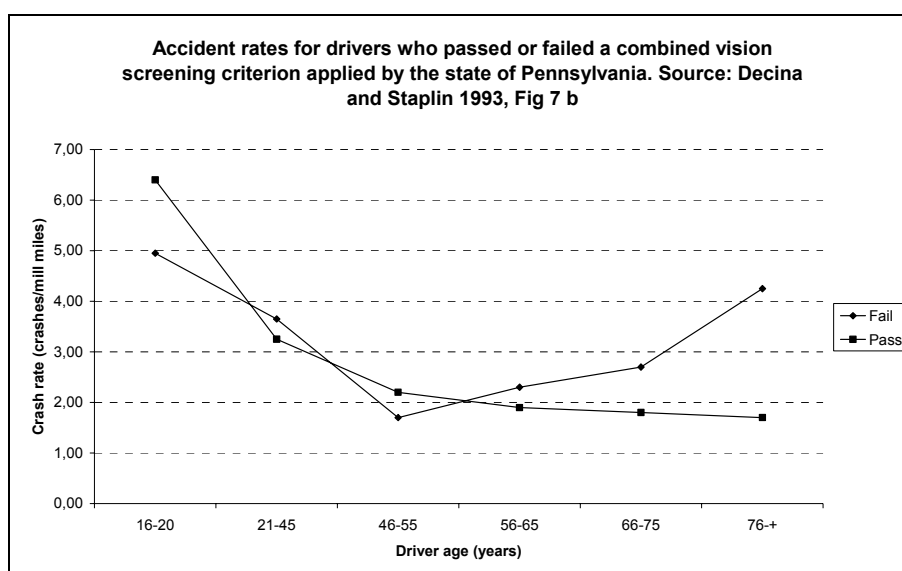
Figure 3.2. *Accident rates for drivers who pass or fail Pennsylvania's combined vision screening test. Based on Decina & Staplin (1993)*

Figure 3.2 shows that until the age of about 65, there are no clear differences in accident rate between those who passed the combined vision screening test and those who did not (the accident rates apply to the period immediately before the vision test was taken). After the age of about 65, those who failed the test have substantially higher accident rates than those who passed it. It is important to know that age is a moderating factor, because then use of the test can be restricted to drivers who are at least 65 years old. There does not seem to be much point in administering the test to drivers below the age of 65, since in drivers below this age those who fail the test seem to have almost the same accident rate as those who pass it.

3.3.6.   *Combined exposure to several impairments*

It is of great interest to know the prevalence of exposure to several medical impairments (co-morbidity). The practical implications of different patterns of

co-morbidity could be very different. If for instance 5% of drivers have a pattern of co-morbidity that makes them unfit to drive, one could deny driving privileges to these drivers without jeopardising the functioning of the transport system as such. The opposite extreme would be a population of drivers in which 50% have just one medical condition, that disqualifies them from driving. To disqualify all these drivers would have a major impact on the road transport system. Given the fact that western societies to an increasing extent rely on the individual use of automobiles, it would be difficult to implement rules for medical fitness so strictly as to disqualify a large proportion of drivers.

Co-morbidity could reinforce the effects of medical impairments. The effects of several risk factors on accident rate tend to combine multiplicatively. Hence, a driver who is exposed to factors A, B, and C, that entail relative risks of, respectively, 1.5, 1.2, and 2.0, would be expected to have a relative accident rate of 1.5 x 1.2 x 2.0 = 3.6 compared to a driver not exposed to any of the three risk factors. In principle, however, the combined effects on accident rate of several risk factors need not be multiplicative, but could exhibit any pattern of simple or higher-order interactions.

3.3.7. *Control for confounding factors*

Adequate control for potentially confounding factors when evaluating the effects of medical conditions on accident rate is one of the most important, but at the same time one of the most difficult, requirements for epidemiological studies of driver health. Since nearly all such studies will be non-experimental, perfect control for confounding factors cannot be achieved. Probably the best that can be done is to control statistically for as many potentially confounding factors as one can get reliable data on and sample size constraints will allow.

Some of the epidemiological studies used for the list have employed multivariate techniques of analysis, such as logistic regression. Most of these studies have, however, not employed appropriate multivariate techniques for analysing data. Based on experience from road safety evaluation studies (Elvik, 1999), one would expect poor control for confounding factors to lead to an overestimation of the effects of medical conditions on accident rate. On the other hand, sampling endogenicity, discussed in *Paragraph 3.3.4*, is likely to be associated with an underestimation of the effects of medical conditions on accident rate. The net effect of these counteracting sources of bias is unknown.

3.3.8. *Effect of accident severity gradients on accident rates*

In very many studies the word 'accident' is used without giving any information about accident severity. Depending on the system for accident reporting in the area where a study was conducted, the term 'accident' could refer to a mixture of injury accidents and property damage accidents, injury accidents only, or even just fatal and serious injury accidents. In studies that rely on self-reported accident data, the majority of the accidents reported are likely to be material-damage-only (MDO) accidents.

An advantage of using material-damage-only accidents is that they are far more numerous than injury accidents or fatal accidents. This means that the

statistical power to detect even relatively small effects on accident rates is increased. The drawback is that the chief purpose of regulating driver health is to prevent fatal and serious accidents, not damage to motor vehicles. It is thus more important to know how driver health influences the risk of fatal and severe accidents than it is to know how it influences the risk of material-damage-only accidents.

Is it reasonable to assume that there is an accident severity gradient in the effect of health impairments on accident rate, despite the fact that few studies give evidence of such a gradient? By and large, making the assumption that there is a severity gradient would be reasonable. The problem is to estimate it correctly. Suppose a medical condition increases the risk of a material-damage-only accident by a factor of 1.5. Would this medical condition then be expected to increase the rate of injury accidents by a factor of 2, and the rate of fatal accidents by a factor of 3? Or, would it rather be expected to increase injury accidents by a factor of 3 and fatal accidents by a factor of 6? In general, the answer to questions like these is unknown. There are two reasons why it nevertheless remains reasonable to assume an accident severity gradient for the effect of many medical conditions on the rate of accident involvement.

The first reason is that in-depth studies of factors contributing to accidents have found that acute illness contributes more often to fatal and severe accidents than to material-damage-only accidents. This is shown in *Figure 3.3*, which summarizes evidence from in-depth studies in terms of the percentage of accidents that were classified as having been precipitated by acute illness or a more chronic medical condition. It is seen that this proportion rises steeply as a function of accident severity.
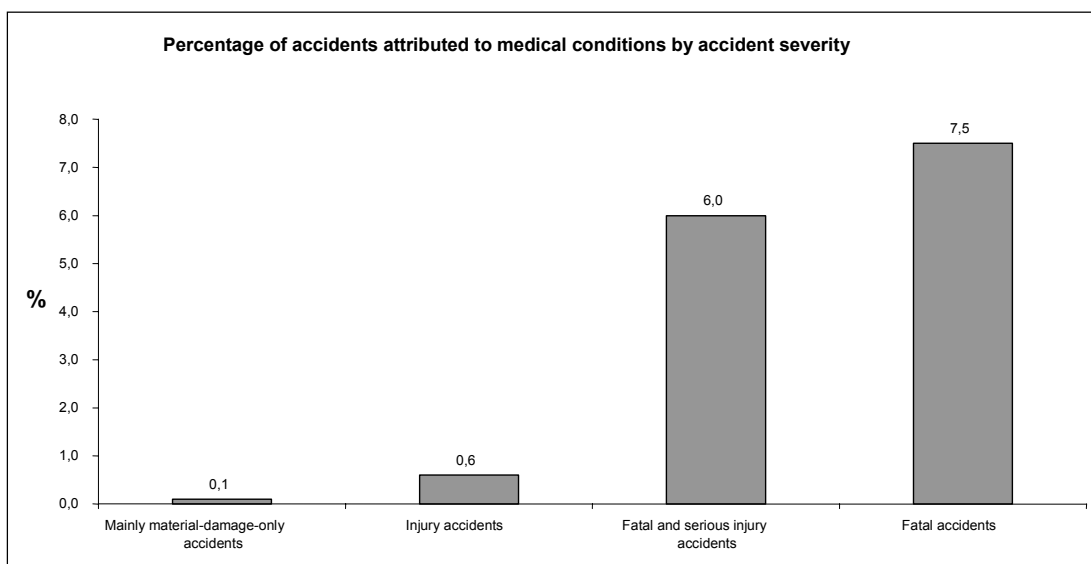
Figure 3.3. *Percentage of accidents attributed to medical conditions by accident severity. Based on in-depth studies of accidents.*

The second reason for believing in an accident severity gradient is the fact that some diseases very often occur so rapidly that the driver may not have enough time to react and take evasive action. The situation is then more

likely to result in a serious crash than if the driver has the time to slow down and perhaps pull over to the shoulder of the road. A heart attack, for example, can develop so quickly that the driver becomes unconscious in a matter of very few seconds. Other medical conditions are, on the other hand, more stable and are therefore less likely to have an accident severity gradient. Loss of hearing and rheumatism are examples of such more stable conditions.

3.3.9.   *Prevalence of health impairments in the driver population*

According to the World Health Organisation, health is a state of perfect physical, mental, and social well-being. By this definition, most people, including most drivers, have some kind of health impairment. The prevalence of health impairments that are subject to driver licensing regulation is rather poorly known. The incidence of some of these health impairments may be somewhat better known, but is often quite poorly known for acute health impairments like impairments caused by an excessive intake of alcohol or drugs.

Incidence denotes the number of *new cases* of impairment that occur in any year. Prevalence denotes the *total number of drivers* who are impaired at any given time. It is rather more important to know the prevalence of driver health impairments than to know their incidence. There are two reasons for this. In the first place, many medical conditions go *undiagnosed* for a long time after their onset, perhaps because drivers are not aware that they have these conditions, or perhaps because they hesitate to contact a doctor out of fear of losing their driving licence. Hence, there will at any time be a substantial number of undetected health-impaired drivers on the road.

In the second place, many medical conditions are *permanent*. For some of these conditions, a driver may be allowed to go on driving until the condition gets so bad that driving is no longer advisable. This applies to some forms of rheumatism and to cognitive impairment in elderly drivers. For medical conditions of this type, there will at any time be a number of drivers who have been identified by the medical system, but who are still allowed to go on driving.

The prevalence of health impairments in drivers is in general not sufficiently known. This means that the population risk attributable to these conditions is unknown and cannot be estimated accurately.

3.3.10.   *Effects of treatment programmes*

Drinking and driving is a serious road safety problem in many countries. But if a miracle drug was invented, that made it perfectly safe to drive while drunk, the road safety problem would be solved. It would of course still be the case that excessive drinking would impair health, at least in the long run. But as far as road safety is concerned, a problem has been solved once the additional risk associated with the problem has been eliminated.

A similar point of view applies to all driver health impairments. If treatment programmes are available that eliminate or greatly reduce the additional risk of accident involvement associated with these impairments, then the road safety problem has been solved and licensing regulations are no longer

needed. It is therefore important to know how treatment influences the relative risks associated with medical conditions. Unfortunately, this sort of knowledge is to a large extent lacking today. This means that cost-benefit analyses often have to be confined to the most drastic policy option, namely that of denying a driving licence to all drivers who have a certain medical condition, regardless of driver compliance with treatment programmes. This leads to large losses of welfare in the cost-benefit analysis.

3.3.11. *Difference between type of studies*

The risk ratios found in epidemiological studies are mostly not as high as the outcome of laboratory studies and studies in driving simulators. In laboratory experiments, the deteriorating effects of a certain impairment on the driving performance can be very obvious (e.g. slower reaction times, not noticing certain stimuli, etc.), whilst the accident ratio found in an epidemiological study is just slightly above one. An explanation for this is that in laboratory studies the *behavioural adaptation* of people is not taken into account. As an example, most elderly people know that their eyesight and reaction time are not as good as when they were young. Therefore they avoid driving in the dark as much as possible, take larger safety margins and/or avoid heavy traffic situations. By doing so they reduce the task demands to such an extend that they still can drive without putting themselves too much in jeopardy.

3.4. **How to use epidemiological evidence**

Someone who reads the discussion in the previous section might conclude that current epidemiological evidence of the effects of medical conditions on driver accident rates is so poor as to be useless, and provides no basis for making sensible choices with respect to assessment for licensing.

Such a point of view is self-defeating. Fairly detailed regulations of driver health already exist and have been in place for some time. Surely, the epidemiological evidence that served as the basis for drafting current driver health regulations must have been even more limited and riddled with errors than the evidence available today. In fact, most of the studies listed in *Table 3.1* have been reported after 1990. Current regulations were, however, mostly drafted before 1990.

Decisions cannot be postponed until perfect knowledge about their impacts is available. Perfect knowledge never becomes available. For all practical purposes, the only feasible approach is to make use of whatever knowledge there is at any time. This means that, for the purposes of doing cost-benefit analyses, the estimates of relative risks will be applied and will be assumed to reflect the true effect of the various medical conditions. Applying the estimates of relative risks in such a straightforward manner might seem to be inconsistent with the rather iconoclastic view of current epidemiological evidence. However, the practical implications of the limitations of current epidemiological evidence are far from obvious. There are three possibilities to deal with this problem.

Firstly, one could conclude that current knowledge of the road safety problems caused by driver health impairments is inadequate for the purpose of doing cost-benefit analyses. Such a conclusion has not been drawn in this

report. Although the quality of some of the epidemiological evidence clearly leaves much to be desired, it would be wrong to dismiss all of it as rubbish. For some health impairments, a number of studies of at least an acceptable quality have been made. One would be guilty of epistemological nihilism (that is a denial that sound knowledge could exist at all) by rejecting the evidence from these studies as not even indicating the effect of driver health impairments on accident rate. Besides, driver health regulations have already been drafted on the basis of poorer knowledge than what we have got today. It is sensible to try to reassess the merits of these regulations on the basis of better, though still far from perfect, knowledge.

Secondly, one could decide to take all results of epidemiological studies at face value and apply them uncritically. After all, decisions have to be made and cannot await perfect knowledge. An uncritical acceptance of all results is, however, not to be recommended. Some of these results are more uncertain than others – a few of them are so uncertain that it would not be very informative to make a cost-benefit analysis on the basis of them.

A third option, the one taken in this report, is to accept most of the evidence from epidemiological studies as providing a sufficient basis for doing cost-benefit analyses, but to reject evidence that is exceptionally weak. By exceptionally weak evidence is meant evidence from just one or a few studies that did not employ a rigorous study design. Therefore these studies are omitted from the meta-analysis and are not included in this report.

4.   Policy options to control impairment

4.1.   Background: a task-capability model

A driver has to perform certain tasks in order to reach his destination safely. The complexity of these tasks depends on the type of vehicle, the complexity of the traffic situation (other road users and road environment), and the (weather) conditions. To a certain extent, the driver determines how complex the task demands are. For instance if a driver decides to drive faster, the task demands become more complex. The reverse occurs with behavioural adaptation; the driver is aware of his incompetences due to, for instance, eyesight problems and lowers the task demands (no driving in the dark, no driving in crowded areas).

To what extent the driver is able to fulfil the task demands is determined by his capabilities and competences. A driver must have sufficient competences to be able to cope with all the task demands. If the competences are less than the task demands, errors and/or violations will occur, which might lead to accidents. Competences are determined by personal characteristics (i.e. age, aptitude, general mental and physical condition), education and training (e.g. driving lessons), and the experience gained as a driver. If a driver is chronically impaired his competences decline. The competences may be restored by medical treatment or be compensated by training and experience.

It is also possible that the competences are sufficient and still the task performance is inadequate. This is caused by inadequate capabilities, for instance due to acute impairments. Reasons for acute impairments are for instance the use of alcohol, fatigue, acute illness, etc. The task-capability model of the driving process is presented in *Figure 4.1.* The described processes are visualised in *Figure 4.1.* This presentation is deduced from the 'Task-Capability model of the driving process' by Fuller (2000).
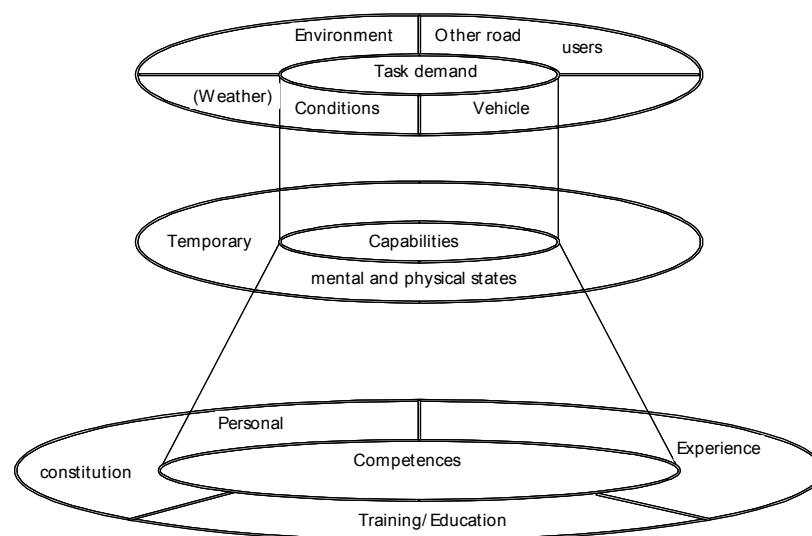
Figure 4.1. *Relation between task demands, capabilities and competences.*

4.2. **Description of policy options**

Based on the task-capability model, directions in policy options to control chronic and acute impairment can be distinguished. The different policy options can focus on the task demands, or on the capabilities and competences of impaired drivers. In this paragraph a list of examples of policy options will be presented. This shows that there are a lot of options to control impaired driving. In order to perform the cost-benefit analysis a specific policy option has to be precisely specified for a specific impairment. The selection of the measures to be assessed with the cost-benefit analysis is discussed in the next paragraph.

4.2.1. *Policy options to control chronic impairment*

1. Lowering the task demands:
   – adaptations in the vehicle;
   – simplifying the infrastructure (self explaining roads);
   – driving licence restrictions (not allowed to drive in the dark, not allowed to drive in dense traffic, etc.);
   – promote chronically impaired drivers only to drive under circumstances where the task demands are low by means of education and information.

2. Improvement of competences:
   – medical treatments and medicines that are aimed at recovery;
   – medical treatment and medicines that are aimed at minimizing the effect of the chronic impairments on the competences (e.g. use of anti-depressives for people with a depression);
   – training of driving skills in order to minimize the effect that impairment has on the competences.

3. Take drivers whose competences are too low out of traffic:
   – selection (withdrawal of the license) on the basis of results of (regular) medical tests;
   – selection on the basis of psychological assessment;
   – selection by means of (regular) driving tests;
   – promotion of self-selection by means of education and information.

4.2.2. *Policy options to control acute impairment*

4. Improvement of the task capabilities when driving:
   – deter drivers from impairing themselves (consumption of alcohol, illegal drugs abuse) before driving. This can be done by:
     - low BAC levels;
     - high sanctions;
     - raising police enforcement (e.g. random road side breath testing);
     - make driving while intoxicated impossible (e.g. by means of the use of alcohol locks);
   – warn drivers while driving that their task capabilities are too low (e.g. systems that can detect if a driver is fatigued or the use of rumble strips);
   – regulations on hours of driving and hours of rest, including the enforcement of these regulations;

– prohibition to drive if certain medicines are taken that impair the driving capabilities;
– education and information about the effects on the task capabilities of both legal and illegal drugs, alcohol, and fatigue.

As mentioned in *Paragraph 1.1*, IMMORTAL focuses on the accident risk associated with different forms of driver impairment and the identification of 'tolerance levels' *applied to licensing assessment and roadside impairment testing*. In the following only those policy options will be considered that deal with the issuing of licenses in relation to impairments and roadside impairment testing.

4.3. Criteria to select countermeasures

In the previous paragraph the directions in policy options are described. This shows that the number of possible policy options is almost infinitive. These directions however are not specific enough for cost-benefit analysis. Only concrete countermeasures for specified impairments and with clear norms are suitable for a CBA. Therefore a selection has to be made. We have based this selection on a quick scan estimation of the socio-economic yield of a countermeasure. To be concrete we have used four main criteria:
1. The specific chronic or acute impairment must lead to a substantial and certain *increase of accident risk*;
2. The *prevalence* (the number of kilometres driven by drivers with a specific impairment) must be substantial;
3. The specific countermeasure must be *effective*; this means it either leads to a substantial reduction of the accident rate ratio or to a substantial reduction of the exposure of impaired driving;
4. There must be sufficient political and/or public *support* for the countermeasure.

Impairments with increased accident risk
The relative accident risk (the risk of getting involved in an accident per distance driven for an impaired compared to the risk of a 'normal' driver) associated with a certain impairment, is one of the criteria that was considered. If a chronic or acute impairment has no negative effect on getting involved in an accident, it is pointless to take countermeasures against this impairment. This is based on the estimation of accident involvement mentioned in *Paragraph 3.2*.

If the lower level of the 95% confidence interval of the discovered accident rate ratio (the sixth column in *Table 3.1*) is 1 or less, the chance that there is no increased risk due to the impairment is 5% or more. It is not fruitful to have countermeasures for impairments of which the chance is high that the impairment has no impact on the accident risk. If the 95% confidence interval is wide and the lower limit is 1 or less, more and better studies are required before countermeasures should be taken.

Impairments with significant prevalence
The *prevalence* is also very important. This means that if the relative accident ratio is high, but the group of drivers suffering from that impairment is very limited, the total numbers of lives that can be saved will still be small. Because of the fact that accurate prevalence data is in most cases not available, the second criterion can only be used indicatively.

Effect on traffic safety
A third criterion is the *effectiveness* of the countermeasure. If the measure has no impact on either relative risk ratio or on exposure (the distance driven while impaired), there will be no effect. Countermeasures should either lead to a reduction of the *relative risk* or to a decline in *exposure*. An example of the reduction of the relative risk is the use of medicines to minimize the increased relative risk of an impairment. A decline in exposition can be reached by the exclusion of impaired drivers from the traffic system.

However there are some specific points that need to be taken into account. Treatment is in most cases only partly possible or can lead to negative side effects on the driving capability. The testing of impairments also has intrinsic limitations. The sensitivity (the ability to identify drivers that are really accident-prone) and the specificity (the ability not to identify good drivers as unsafe) of tests is never perfect. There will always be false positives and false negatives. For instance, from Deliverable 4.2 *Fatigue, sleepiness and reduced alertness as risk factors in driving* of the IMMORTAL-project (Sagberg et al., 2004) it can be concluded that fatigue increases the relative accident risk significantly and the prevalence of drowsy drivers is estimated to be high. It is possible to educate and inform private drivers on the dangers of fatigue and it is also possible to raise the alertness of drowsy drivers that tend to get off the road with the use of rumble strips. However at this moment there is no device that makes random roadside fatigue testing possible. And the sensitivity and specificity of in-car devices that warn drivers that they are drowsy are still too poor to rely on. As deterrence in the case of fatigue for private drivers is not possible, the effectiveness of countermeasures to combat fatigue in traffic is considered to be rather low.

More specific criteria are thus:
− the detection of impaired drivers must be high;
− if a screening method is used, the specificity (the chance that someone in the test is diagnosed as impaired is impaired in reality) and the sensitivity (the chance that someone is diagnosed in the test as not impaired in reality is not impaired) of the test must be high;
− in case of lowering the relative accident risk, the treatment (medical treatment, education, information, etc.) must be effective;
− in case of reducing the exposure (withdrawal of driving licence, restricted driving licence), compliance must be high.

The countermeasure must rely on political and public support
The fourth criterion (public support and political willingness) can only be used indicatively. In this project the long list of possible measures has been discussed with civil servants of the European Commission in order to choose the three most interesting measures. Besides this the results from the SARTRE study were used (see *Paragraph 4.4.2*).

4.4. Applying the criteria

4.4.1. *Criteria 1-3: accident risk, prevalence and effectiveness*

As mentioned in *Paragraph 4.3*, it is not fruitful to have countermeasures for impairments of which the lower level of the 95% confidence interval is 1 or less, even if the countermeasure is very effective and the percentage of

drivers with that impairment is very high. What the lower limits are on the basis of the meta-analysis can be seen in *Table 3.1*. The prevalence is known for some impairments, but for most impairments an estimate has to be used. The effectiveness of possible countermeasures for this pre-selection is also based on expert opinions rather than on existing data.

On the basis of these criteria, policy options regarding *vision* will have to include reduced field of view, glare sensitivity, and monocular vision. Although the effect of wearing proper glasses on the individual accident risks seems very small, if the prevalence is very high, testing on visual acuity at first glance might be worthwhile. Decline in useful field of view seems to have a strong impact on one's driving capabilities. This decline doesn't stem from atrophy of eye functions but rather from decay of cognitive functions and decay of attention capabilities after the age of around 65.

Diabetes mellitus is also a widely spread impairment and it has a substantial effect on the accident risk. With proper medication the effect on the driving capability can be minimized. As diabetes diminishes the quality of live in many respects, most patients will seek medical aid by themselves and the additional effect of the fear to lose one's driving licence in case of mandatory medical testing, will probably add little to this.

Neurological diseases like epilepsy and brain stroke have a substantial negative impact on the driving capabilities, but the prevalence among drivers is expected to be low. Besides this, some forms of epilepsy can be controlled with medication.

As the population in Europe is ageing, the amount of drivers with *cognitive impairments* and Alzheimer's disease will rise. As those diseases gradually and in the beginning almost unknowingly impair drivers, testing is possible and seems relevant.

Illiteracy has a relative strong impact on the accident risk of a driver and even in the industrialised world, illiteracy occurs more often than generally assumed. Therefore it seems relevant to test an aspirant driver on his or her ability to read in the language that is used on road signs.

Countermeasures against poor hearing, poor *locomotion* (arthritis, rheumatism), and *cardiovascular* problems do not seem to be useful. Apart from diazepam, *legal drugs* seem to have no strong impact on the accident risk (the lower 95% limit is one or less). Because valium is more and more replaced by newer medicines with fewer side effects, the prevalence of driving under the influence of diazepam nowadays is expected to be low.

In the category *miscellaneous* policy options on all impairments except for treated sleep apnea can be effective. However it seems not realistic that countermeasures will be taken against phases of the menstrual cycle. *Sleep apnea* leads to chronic fatigue. Due to breathing problems when sleeping, patients with sleep apnea get too little rest at night and usually have concentration problems and/or the tendency to fall asleep during daytime.

As can be concluded from *Table 3.1* this leads to a substantial increase of the accident risk ratio. It is estimated that about 4% of the middle-aged men and 2% of the middle-aged women have sleep apnea along with excessive

daytime sleepiness. As sleep apnea to a certain extent is treatable and the accident risk ratio and the prevalence given, it seems fruitful to develop countermeasures. However, diagnosis is difficult. Physicians, pneumonologists and neurologists have to cooperate and have to observe body functions during sleep. This makes testing on sleep apnea less suitable to be included in a mandatory medical driving licence test.

For acute impairments, countermeasures can be effective regarding *alcohol, some illicit drugs*, and most probably *fatigue*. But it is not clear from *Table 3.1* what the relative risks of the combination of drugs and alcohol are and what the relative risks of specific amounts of alcohol are. In *Table 4.1* the preliminary results are shown of a recent epidemiological study in the Netherlands (Mathijssen et al., 2004). This study is carried out within the framework of the IMMORTAL-project and will be presented in IMMORTAL Deliverable R4.2.

Psychoactive substances	Controls (n=3374)	Cases (n=110)	Accident rate ratio	Lower 95% limit	Upper 95% limit
No substance	89.0%	56.4%	1.0		
Cannabis-only	4.0%	0.9%	0.4	0.05	2.6
Amphetamine/XTC-only	0.4%	0.0%	--	--	--
Cocaine-only	0.3%	0.0%	--	--	--
Morphine/heroin-only	<0.1%	3.6%	211	22	2047
Codeine-only	0.5%	0.0%	--	--	--
Benzodiazapines-only	2.4%	2.7%	1.2	0.3	4.9
Tricyclic antidepressants-only	0.4%	0.0%	--	--	--
Drug/drug combinations	0.5%	10.9%	29	13	61
BAC 0.2-0.5 g/l	1.0%	0.9%	1.4	0.2	11
BAC 0.5-0.8 g/l	0.4%	1.8%	6.7	1.5	30
BAC 0.8-1.3 g/l	0.2%	1.8%	12	2.6	59
BAC > 1.3 g/l	0.3%	10.0%	60	24	151
BAC 0.2-0.8 g/l+drugs	0.3%	2.7%	16	4.3	62
BAC > 0.8 g/l+drugs	0.1%	8.2%	153	40	590

Table 4.1. *Relative risks of fatigue, drugs and BAC.*

From *Table 4.1* it can be deduced that considering the prevalence (the first column) and the relative accident risk ratio (the third column), it makes sense to develop effective countermeasures for drivers of all BAC > 0.5 g/l, drug-drug combinations, and alcohol-drug combinations. Drivers with a BAC level of 1.3 g/l are particularly interesting. They encompass only 0.3% of the driver population in the Netherlands (first column) but are responsible for 10% of all the cases (the injured drivers in the hospitals).

In this group however, recidivism is common and very often they remain using their vehicle when their driving licence is withdrawn. A more effective countermeasure than withdrawal of the driving licence for this group can be the installation of an alcohol lock in their car. With this device one can only

drive after a breath test and continue to drive after having done a second breath test while driving.

Although it seems that countermeasures on driving with a lower BAC than 0.5, will probably have little impact, for young inexperienced drivers the accident risks increases significantly with a BAC just above 0.2. Low BAC levels can also be very dangerous when the driver is under the influence of other substances.

Although some *illicit drugs* have a very negative impact on the driving capabilities, practical roadside testing on these substances is still difficult. As can be seen in *Table 4.1*, at least in the Netherlands, except for cannabis (which apparently has no substantial negative impact on the accident risk) the prevalence is low. However what is problematic is the combination of illicit drugs and alcohol. The presence of alcohol in blood or breath can easily be tested. Not all drivers take illicit drugs, mostly it is used by some subgroups in the young driver population. If the BAC limit for young drivers is zero and the enforcement of this limit is high (especially in the neighbourhood of places of entertainment for young people), enforcement on alcohol will often also be enforcement on illicit drug use.

In a literature review by the European Transport Safety Council (ETSC, 2001) it is estimated that in approximately 20% of commercial road transport crashes, fatigue was a contributing factor. For commercial drivers some countermeasures regarding *acute fatigue* are possible. The hours of work and the hours of rest can be regulated and, with the help of devices that register the hours of driving, these regulations can to some degree be enforced. This is not the case for private drivers. Only education and information seems to be possible. Relatively new are devices that warn drivers when their driving capabilities are beginning to get impaired because of fatigue. The problem of these devices is that their specificity and sensitivity still is inadequate.

Regarding the effect of a measure it is also relevant that the proposed countermeasure is new for most EU-member states. If the countermeasure is already in place in most countries, the effect on improvement of road safety will be small. Considering the first three criteria, the following specific measures seem to be promising enough for a cost-benefit analysis:

1. *eyesight testing* at the renewal of a driving licence. The norms and what is tested is stated in Directive 91/439/EEC. Due to the increased relative risk of people over 65 years a Useful Field Of View test will be included in the eye sight test after 65 years;
2. *testing on cognitive functions*; regular testing (every two years) on cognitive functions (especially Alzheimer's disease) for drivers over the age of 70. As long as the disease cannot be cured, the results of the test may lead to a restricted driving licence (not in complex traffic situations) or complete withdrawal of the driving licence;
3. *testing on alcohol*; random road side breath testing and a zero BAC limit for drivers younger than 25;
4. *prevent alcohol abuse*; installation of alcohol lock in cars for every driver that is caught with a BAC of 1.3 g/l or higher or for drivers caught twice with a BAC between 0.5 g/l and 1.3 g/l;

5. *prevent fatigue*; installation of fatigue warning devices in all vehicles (both private cars and commercial vehicles) when the technical requirements considering specificity and sensibility are fully met;
6. *prevent illiteracy*; incorporate literacy test in the theory test for the driving licence.

4.4.2. *Criterion 4: political and public support*

This list mentioned above is unquestionably not complete. Other effective countermeasures are possible and depending on the specific (legislative) situation in a country, the effects will differ from country to country. Due to time and budget constraints, a cost-benefit analysis could only be performed for three countermeasures. For this selection we have used the last criterion, namely political and public support.

An indication for public support for policy options regarding the control of chronic and acute impairment can be found in the latest SARTRE study (SARTRE consortium, 2004). This so called SARTRE 3 study conducted in 2002, is a large survey in 23 European countries. In total about 24000 drivers have filled in the questionnaire. From the Sartre 3 database the following results have been selected.
A question was: How important would *making drivers have a compulsory psycho-medical check-up every ten years* for improving road safety? Of all the drivers in all the countries, 58% think it very to fairly important and 42% think it is of not much importance to not important at all. There are substantial differences between countries: pro psycho-medical check-up ranges from 27% to 89% and against psycho-medical check-up ranges from 11% to 73%. The same question, but then only compulsory psycho-medical check-ups for drivers of sixty and older, shows about the same results. Overall 59% think this very to fairly important and 41% think it is of not much importance to not important at all. Again there are substantial differences between countries. In general more drivers have a positive attitude towards periodic (every ten years) compulsory psycho-medical check-ups than a negative attitude.

If there is public support for the third proposed policy option in *Paragraph 4.4.1* (*Testing on alcohol*; random road side breath testing and a zero BAC limit for drivers younger than 25) it can be deduced from the following two questions in the SARTRE 3 questionnaire: (1) How much would you be in favour of *not allowing new drivers to drink any alcohol before driving?* and (2) Would you be in favour of, or against, the Government devoting more effort in *having more enforcement of traffic laws?* Of all the drivers 82% are very to fairly in favour of a zero BAC limit for new drivers, and in each of the 24 European countries the majority of the drivers is in favour of this measure. About the same is true for more enforcement in general. Overall 76% is (strongly) in favour of more enforcement and in none of the countries less than 50% is (strongly) in favour. From the results of the answers of the two questions it can be deduced that there is strong public support for a zero BAC limit for novice drivers in combination with increased roadside breath testing.

If there is public support in Europe for the fifth policy option (installation of fatigue warning devices in vehicles) in *Paragraph 4.4.1* can be concluded from the following question in the SARTRE 3 questionnaire: Would you find

it useful to have a device on your car *that detects 'fatigue' and forces you to take a break?* Of all the drivers 66% thinks such a device is very to fairly useful and 34% it is not much useful to not at all useful. The opinion of the usefulness (very and fairly) of such a device varies from 39% to 85% between the countries. It can be concluded that there is reasonable support for fatigue warning devices.

To study the *political support* for a countermeasure, the road safety department of the European Commission was asked to select three countermeasures out of the above-mentioned countermeasures. This consultation and these research outcomes have lead to the following selection of countermeasures: mandatory eye sight testing, zero BAC limit for novice drivers combined with increased random roadside breath testing and alcohol lock programmes for problem drinkers.

In conclusion the partners in the IMMORTAL-project were asked their opinion regarding these selected countermeasures. Only one partner disagreed with the selection. In its comment it was stated that based on previous research the effect of mandatory testing on visual acuity is doubtful. As can be read in *Chapter 6*, this assessment appeared to be true.

The following measures are assessed in the CBA:
– *eyesight testing* at the renewal of a driving licence. The norms and what is tested is stated in Directive 91/439/EEC. Due to the increased relative risk of people over 65 years a Useful Field Of View test will be included in the eye sight test after 65 years;
– *testing on alcohol*; random road side breath testing and a zero BAC limit for drivers younger than 25;
– *prevent alcohol abuse*; installation of alcohol lock in cars for every driver that is caught with a BAC of 1.3 g/l or higher or for drivers caught twice with a BAC between 0.5 g/l and 1.3 g/l;

The measures are assessed separately. This means that the effect of a combined introduction of several measures is not assessed. A combined introduction of more than one measure usually does not lead to the additional sum in effects. It is possible that the effects strengthen or weaken each other. In advance it is very difficult to predict the effects of combined measures. In this research the results of such a combination of measures are not included.

4.5. Selection of countries

It is obviously desirable to perform analyses for all European countries. This however is very time consuming and requires a lot of detailed data that in most cases is not readily available. For this reason it was decided to do the CBA's for the selected countermeasures for four European countries only. It is impossible to speak of a representative sample. The result of a CBA is unique for each country. Even for neighbouring countries that have culturally and politically very much in common, due to slight differences in national legislation, the outcome of a particular CBA might differ substantially. For the researchers it was most practical to do the CBA's for their own country (Norway and the Netherlands) as access to data is the least troublesome. It was decided to choose two other countries from within the IMMORTAL-consortium. With the aid of their IMMORTAL-contacts it would be possible

for the researchers to have quick access to data in other countries than their own. The two other selected countries were Spain and the Czech Republic. Although it was the intention to have some heterogeneity in the selection of countries (one in the north, one in the south, one in the east and one in the west) to make the conclusions more robust, it was not the aim to have a representative sample, as in the case of CBA this is impossible to have.

5. Cost-benefit analysis in practice

5.1. Type of effects

In a cost-benefit analysis, all relevant impacts of a countermeasure must be identified and expressed in monetary terms. Converting impacts to monetary terms is complex and cannot be done with great precision. The following impacts of driver health regulations are included in the cost-benefit analyses:
1. changes in the number of road accidents;
2. changes in the amount and type of mobility;
3. changes in impacts on environment;
4. costs of measures to control impaired driving.

Changes in the number of road accidents can be valued monetarily by applying official estimates for road accident costs. Changes in the amount of driving, specifically the loss of benefits if a driver is ruled medically unfit to drive, have been valued in terms of the change in consumer surplus. Less driving will, however, not only lead to a loss of benefits to drivers, but also a reduction of external impacts of driving, in particular impacts on the environment. Below we will shortly describe these effects.

5.2. Traffic safety effect

5.2.1. *Quantification (1st order)*

The traffic safety effects are determined by using basic accidents rates and the relative accident risk of different impairments mentioned in *Chapter 3*. This way the *attributable accidents* for a specific impairment can be calculated. For the countermeasures it has to be determined to which extent they will decrease the number of attributable accidents. The attributable risk is defined as:

$$\text{Attributable risk} = \frac{PE(RR-1)}{(PE(RR-1)+1)}$$

Where PE is the share of exposure (e.g., person km, either as a share of km by car or km by all transport modes) and RR is the estimated risk difference. Thus, if the share of exposure is 15% and the estimated risk difference is 4.75 (higher than the basis) then the attributable risk will be approximately 36%. Thus, if this risk difference is eliminated accidents (and/or injuries and/or fatalities) can be estimated to decrease by 36%.

In the case of treatment we assume this treatment to be 100% successful. This means that if a driver with a reduced visual acuity (relative accident risk of 1,15) is treated by wearing glasses, we assume that his relative accident risk decreases to the normal level (namely accident risk of 1.0).

5.2.2.   *Valuation*

A rather difficult subject is the *valuation of safety effects*. It is known that in most countries the socio-economic costs of traffic accidents are rather significant. These socio-economic costs include for instance material damage, medical costs, loss of production, congestion costs, and immaterial costs related to traffic accidents. Since it is not practical to calculate all these effects for every accident, the total socio-economic costs of traffic accidents are divided by the annual number of traffic deaths.
This value for the socio-economic costs per traffic death is used to determine the benefits of a reduction of traffic deaths. Assuming a constant ratio between accident with deaths, injuries and material damage, thus the total socio-economic benefits of accident reduction is calculated.

This computation method has been introduced in 1997 by the European Commission in order to select cost-effective measures. Based on 1990 figures for all member states the total costs per fatality turned out to be one million ecu (Commission of the EC, 1997); therefore the method is known since as the One Million Euro Test .
This value per fatality naturally varies over the countries, since the share of fatal accidents and the total socio-economic costs of traffic accidents vary. Also countries differ on the issue of immaterial costs: some include them in the total socio-economic costs and others do not.
For the purpose of this CBA the four selected countries have determined their own socio-economic value for the reduction of traffic deaths. For the estimation of the safety benefits we will use the country specific valuation excluding immaterial costs (*Table 5.1*), since not all countries have estimates of immaterial costs.

Country	Immaterial costs excl.	Immaterial costs incl.
The Netherlands	4.8	7.4
The Czech Republic	1.1	-
Norway	5.9	11.9
Spain	0.8	-

Table 5.1*. Valuation of traffic fatalities (€ million per fatality).*

5.3.   **Mobility effect**

5.3.1.   *Quantification*

Some of the mentioned countermeasures include (partly) withdrawing someone's driving licence. This is the case for eyesight problems. The withdrawal of someone's driving licence leads to mobility effects, since the driver must decide whether he changes his driving pattern (e.g. no more driving in the dark), uses another means of transportation (e.g. public transport) or does not travel anymore. It is possible that some drivers of whom the driving licence has been withdrawn will continue to drive. This violation however will not be valued as a benefit to society (see *Paragraph 5.6*). Besides the private mobility effects, there are also commercial effects if the driving licence of an employee is withdrawn. Among other things, this

depends on the type of agreement between employer and employee, which of course may differ substantially in the member states.

In order to quantify, it is necessary to clarify the theory behind the consumer benefits. According to economic theory, the ultimate purpose of any economic activity is consumption. Goods and services are consumed for the benefits they provide. Some of these benefits are very basic - like food and shelter - others less so - like TV shows. In economics also the consumption of goods that are not (necessarily) traded in markets is considered. Thus, 'consumption' of forest recreation, cultural sites, and clean air, which may be free of charge, is comparable to consumption of priced goods. Car driving is sometimes performed for pure enjoyment; mostly, however, it is an 'intermediate good', which is purchased not because it is enjoyed intrinsically, but because it is a necessary input in order to enjoy other goods.

Each driver's demand for driving can be assessed in terms of a *demand function*, which relates the amount demanded to the price. The shape of the demand function is described in terms of its elasticity with respect to price. An individual demand function cannot be observed directly, and will usually be unknown. By studying how consumption depends on prices and other factors, it is possible to estimate market demand functions, which is the sum of individual demand functions.

For the purpose of quantifying the benefits of private car driving, one would seek to estimate market demand functions, and by this evaluate the demand function of 'a typical car driver'. Ideally speaking, one should know the demand functions for several categories of drivers, since it does not seem reasonable to believe that a single demand function will correctly describe the behaviour of all car drivers in response to changes in the costs of driving.
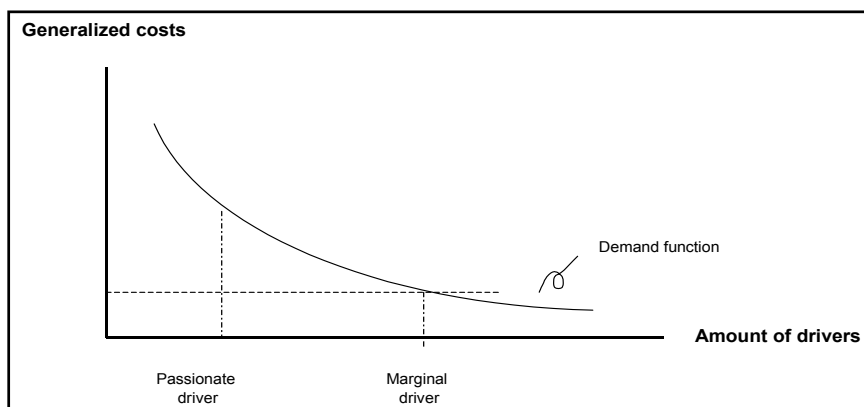
Figure 5.1. *Demand function.*

The benefits of car driving can be estimated according to the *consumer surplus* it generates. The *consumer surplus* is the difference between the demand function and the generalized costs. Each driver has his or her own consumer surplus of driving, since the demand function in principal differs for drivers. For marginal drivers – those who drive only a little and who get little pleasure out of it – the consumer surplus will be small. For passionate drivers – those who take to the road for the pure fun of it – the consumer surplus will be large. However, even passionate drivers cannot spend all

their time and income on driving, but face monetary and time constraints on their consumption of car driving.

Loss of mobility
Due to the withdrawal of the driving license people are forced to look for other options. It is possible that they will use another mode or that their mobility will decrease. This decrease in mobility might be due to the fact that the trip is not made anymore or to the fact that the distance of the trip changes. When a driving license is permanently taken away, we know form several travel surveys that the travel pattern might change. It is possible that in a somewhat longer period even origins and destinations might change. The extend to which the origins and destinations will change depends on the age group and country specific information. For instance in the Netherlands there is a high level of urbanisation and rather short travel distances. We expect that only a small percentage of the (elderly) people will change their origin or destination.

In the cost-benefit analysis we have to estimate which percentage of the trips will not be made anymore and by what transport mode the remaining trips will be made. Obviously this depends on the age of the driver. If a driving licence of a 70-year old man is withdrawn he will probably make less trips, while if a driving licence of a 30-year old man is withdrawn he is more likely to use another mode of transport (but still travel). Also a 30-year old man is more likely to use a bike or walk than a 70 year old man. We have estimated these effects for the different countries. This loss of distance travelled varies between the countries and the age groups (from 20% up to 50%).

For both the loss of trips and the shift of trips to other modes of transport, the loss of benefits are valued. Since the demand function is not available for all modes of transport and for all countries we have valued the mobility effects according to the difference in generalized costs. This is explained in the following figure.
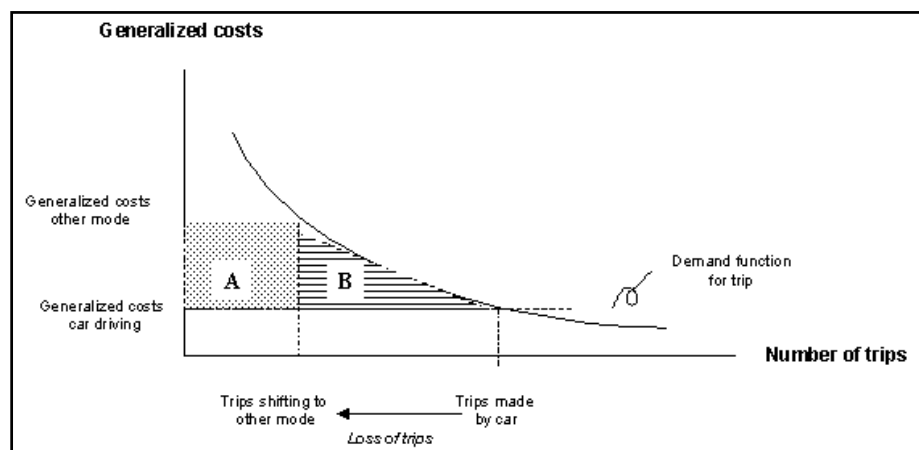
Figure 5.2. *Valuation mobility effects.*

Obviously, this 'generalized travel cost' approach is not the theoretical correct approach. It is questionable to assume a single demand function for 'travel', regardless of the transport mode. Also, within the choice of a person

for a mode, other elements besides time costs and vehicle costs are included, such as privacy and comfort. These elements are not taken into account in the generalized travel cost approach. However in order to use the theoretical correct approach (based on consumer surplus changes), data on willingness-to-pay and consumer surplus for different transport modes is needed.

5.3.2. *Valuation*

Thus the trips that are made by another mode of transport lead to a negative mobility effect defined by the increased generalized costs of transport (area A). The trips that are not made anymore, because the willingness-to-pay of the driver was not enough to pay the generalized costs of the other mode are valued by area B in the figure. The generalized costs consist of variable vehicle costs and time costs (average transport time per mode and value of time). These generalized costs vary over the countries and also between age groups (due to different value of time).

5.3.3. *Traffic safety effects (2nd order)*

Due to the shift of trips to other modes of transport, the number of accidents for this new mode of transport will increase. This effect is called the 2nd order safety effect. Thus the decrease of accidents involving impaired car drivers must be corrected for the increase in accidents on other mode. Some modes of transport (such as driving a moped) have a higher accident risk than car driving, perhaps even for an impaired car driver. The withdrawal of the driving licence might than lead to higher 2nd order safety effects than 1st order safety effects. This is included in the cost-benefit analysis.

In theory the impaired driver also has an increased accident risk on some other modes of transport compared to unimpaired persons (for instance a moped or bike). Within the IMMORTAL programme there has been extensive research to the additional risk of impaired car drivers. However this information is not available for other modes of transport and is therefore not taken into account.

5.4. **Environmental effect**

5.4.1. *Quantification*

Changes in the amount of car driving (mobility of the means of transportation) will also lead to changes in environmental effects such as emissions, noise, and barrier effects. The reduction in environmental effects due to the decrease in the amount of car driving has to be corrected for the increase in other modes, such as public transport or mopeds.

The valuation of environmental effects is rather difficult since the effects are felt outside the market. Such effects have traditionally been handled as *imponderabilia*, shown as an open entry of the cost-benefit balance sheet. The fundamental problem of leaving out (actually setting to zero) effects that lack market prices is that the BCR value will provide an incomplete indication of the yield of a project. A definite ranking of alternatives by potential economic yield would then be virtually impossible, and the social CBA would really not provide much more than a financial CBA.

Much has been published on solving the problem of imponderabilia in economic analysis, especially in connection with the assessment of so-called non-market goods (public goods) or external effects. In such cases, we see an 'un-priced scarcity', i.e., it is not possible to rely on market prices to establish the value placed on these benefits by the consumer. Nevertheless, methods have been developed to make this possible. Freeman (1993) presents a number of methods that can be used to value aspects such as clean air. On the one hand, the value assessment can be derived from the costs that people are prepared to incur in taking measures to *compensate* for the pollution, e.g. the purchase of a tumble drier to avoid having to hang clothes outside, or air filters for the windows. On the other, it is possible to examine the *financial losses* incurred, for example as the result of falling property prices. Finally, it is possible to quantify local residents' value assessment on the basis of their *behaviour pattern* with regard to clean air, such as the costs incurred in travelling to areas in which it is more readily available. Using these methods, the external costs become at least partially quantifiable in monetary terms.

5.4.2. *Valuation*

The last years a lot of effort has been put into determining valuations for external effects such as emissions to air. Even in EU funded projects this has been a main issue; for instance the ExternE project, the TREMOVE database and applied studies such as the UNITE project[3]. These studies have provided valuations for external effects that will be used in the cost-benefit analyses.

5.5. **Cost of measures**

The costs of the measure include all related costs during the *introduction* period and the *operational* period, regardless of who is paying the costs. This means that for instance enforcement costs, exploitation costs, maintenance costs, and replacements costs are included. These costs are determined for the different countermeasures in the following chapters.

5.6. **Implications for CBA impairment countermeasures**

5.6.1. *Commercial versus private driving*

In the previous paragraph it is described how the mobility effects are determined. But suppose, for example, that a bus driver from a medical point of view is ruled unfit to drive. Most likely another driver will replace the unfit driver. Commercial transport of commodities is regarded as an intermediate economic good; the costs of this transport make up a certain proportion of the prices we pay for groceries, clothes, and other goods and services we buy. The proportion of the price of a commodity that is attributable to transport costs will vary substantially, and may not even be very precisely known. How, then, should the costs to society of medical regulations for commercial drivers be assessed? In particular, what are the costs to society of denying a driver's licence to a commercial driver? Assuming that all

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[3] ExternE; External costs of Energy and Transport UNITE; UNIfication of accounts and marginal costs for Transport Efficiency.

commercial drivers are employees, the costs of ruling a commercial driver medically unfit to drive would be the sum of the following items:

1. The cost to the employer of *hiring and training* a new driver. These costs are often referred to as 'friction costs' in labour market economics, and refer to the costs of replacing an employee. Friction costs will consist of the costs of advertising a job, processing applications for it, interviewing applicants, signing a contract of employment, and providing training to do the job.
2. The *loss of welfare* for the driver who is ruled medically unfit to drive.

The latter item should principally be included because it is generally assumed in economic theory that individuals choose their most preferred job. Those who have chosen to become a driver will then have to choose a less preferred type of work if they are ruled unfit to be a driver, or may, depending on the medical condition that lead to disqualification as a driver, have to stop working altogether. In either case, the driver is likely to suffer some loss of welfare. Quantifying this loss is, however, not an easy thing to do. Besides this, the vacancy will be filled by another person (perhaps previously unemployed), who will gain welfare. The net loss of welfare to society will thus be rather limited. Therefore the latter effect is not included in the cost-benefit analysis.

One may argue that especially the effect on commercial driving should be limited to the immediate effect, since transport operators will adapt to the new regime and take this into account when hiring new personnel. Also for private driving, one may consider some adaptation to a new regime of stricter vision requirement for those below the relevant age (not adapting their eyes but, e.g., their choice of residence). However, in the calculations the first year result is presented, and these long-term effects will not be considered in the calculations.

5.6.2. *Younger versus older drivers*

The countermeasure regarding mandatory eyesight testing will be used for people older than 45 years and a UFOV test will be included for people older than 65 years. Of course the effect of withdrawing a driving licence from a 45-year old person are different than withdrawing the driving licence of a 65-year old person. In the CBA, future costs and benefits are discounted to present value by applying a discount rate. For a 45-year old driver, the future stream of costs and benefits affected by a licensing decision will extend for up to perhaps 35 years. For an older driver, the future stream of costs and benefits affected by a licensing decision may extend for as little as fifteen years or less (depending on remaining life expectancy and medical prognosis).

5.6.3. *Time dimension*

There is little information regarding the autonomous effects on prevalence of impairments, the development of impairments during test intervals, the introduction of regulations and the development of impacts over time. In the CBAs presented in this report, the time dimension of licensing decisions has been simplified by estimating costs and benefits for one year of driving only. Hence, the issue of the length of the time for which a driver loses the license

does not arise. If, for one year of driving, the loss of benefits is greater than the savings to society in terms of less accidents and gains to the environment, it is concluded that denying a licence results in a net loss of welfare to society.

It is, for the sake of simplicity, assumed that if there is a net loss of benefit in the first year, then there will be a net loss of benefit in all future years as well. This may not be a too heroic assumption, since both the benefits and adverse impacts of driving (accidents and environmental impacts) may occur at reasonably stable rates per year. However, the benefit loss due to impeded driving may decrease in real value since the long-term adaptation to new constraints is generally more flexible than in the short-term (the range of potential substitutes extends).

5.6.4.   *Consumer sovereignty versus rationality*

The normative status granted to the principle of consumer sovereignty in welfare economics is closely tied up with the assumption made that consumers make rational choices about their patterns of consumption. This implies that at the outset there cannot be made a case for paternalism, i.e., that a governmental body as such can overrun individuals' free right to choose. A case for paternalism can me made only if the individual's consumption affect other individuals welfare (external effects, or merely criminal behaviour) or if the individual can be deemed 'not rational' (not knowing his own best will).

The theoretically most correct measure of the cost to society of denying someone a driving licence is the loss of the benefits of driving that this leads to. When you are banned from consuming car driving, you lose the welfare it has provided. If, however, an individual is judged to be incapable of having rational preferences for driving, the benefits that the individual gets out of driving may be omitted from the benefits to society in a CBA. This means that for instance unlawful driving by underage individuals is omitted from a calculation of benefits to society, despite the fact that teenagers who 'borrow' their father's car may have lots of fun doing it. The issue of whether benefits obtained by means of traffic law violations should count as losses in CBAs of traffic police enforcement has been discussed by Elvik (2001b). There it is also concluded that benefits gained by means of *unlawful behaviour* should not be treated as a benefit to society in CBA of police enforcement.

For the present purpose, the issue is whether there is a sufficient element of rationality in the behaviour of individuals who are impaired by addictions or medical conditions to treat their preferences for automobile driving as a legitimate source of benefits to society. In explaining human behaviour, making an assumption of rationality is sometimes referred to as the 'principle of charity'. It is more charitable to assume that individuals make the best use of their senses than to assume that they are out of their minds. This assumption is probably not true for a small group of addicted drivers.

The main implication for the present analysis is that a decision to withdraw the driving licence will sometimes have to be made without the consent of the licence holder. It is at this stage that paternalism enters. However, paternalism in the sense that a driving licence has to be forcibly taken away from drivers who are unwilling to give it up, does not imply that these drivers

get no benefit out of driving, nor that the benefit of driving should be disregarded. Therefore we do include loss of benefit for impaired drivers who lose their driving licence, but we do not include benefits from unlawful activities, such as continue to drive without a license.

5.6.5. *Uncertainty*

The foregoing assumes that it is possible to quantify all benefits and to express them in terms of money. In practise this poses many problems. For several reasons quantification of effects is surrounded with much uncertainty. These uncertainties can be included in studies behind the cost-benefit analysis (such as the estimation of relative accident risk or the prevalence of impairments), but can also be intrinsic (such as the valuation of traffic deaths). It is recommendable to test the solidity of the figures with a sensitivity-analysis. In this way the risks of a project become evident. In the cost-benefit analyses we provide insight in assumptions that influence the results to large extent.

6. CBA eyesight testing

6.1. Description of the measure

The countermeasure consists of mandatory eyesight testing every license holder (category A and B), after the age of 45 every time the licence has to be renewed. The criteria that have to be met by the licence holder are:

- visual acuity ≥ 0.5 (with glasses or contact lenses);
- field of view over at least 120 degrees;
- 'normal' adaptation to the light circumstances (no extreme glare sensitivity);
- no chronic progressive eye disease (cataract, glaucoma, etc.) that although the above- mentioned criteria are still met, will, if untreated or impossible to treat, cause the mentioned criteria not to be met within the period the renewed driving licence is valid.

After the age of 65, a 'Useful Field Of View' (UFOV) test will be included in the standard eyesight test. The criterion for this test is that the reduction of useful or attended field of view should not exceed 40%.

6.2. General aspects CBA eyesight testing

Definition of countermeasure
The (project) costs of mandatory eyesight testing include costs for testing and for treatment. The costs will principally vary with the frequencies of these tests. Nowadays the frequency of testing varies between the four countries. With this countermeasure there will be decennial tests from 45 to 65 and tests every five years above the age of 65 (as proposed by the European Commission in 2003).

The eyesight testing involves three sub-countermeasures:
- testing visual acuity;
- standard eyesight testing (field of view, glare sensitivity, cataract/glaucoma);
- UFOV testing.

In the CBA the tests are assessed in combinations, thus only visual acuity, standard eyesight testing (including visual acuity) and standard eyesight testing including UFOV testing. The first two are applied to people between 45 and 65, and UFOV is applied to those above 75; for people between 65 and 75 all three tests are relevant.

General assumptions
For the cost benefit-analyses on eyesight testing it was necessary to assume some general simplifications that are not all entirely based on scientific research, namely:

- *safety effects in stable situation.* Although there is some development of reduced visual acuity between the tests it is assumed that there will be a full safety effect in all age groups. The time between two tests is at the

most ten years, but it is assumed that there will be no decline of visual acuity in between and the calculated safety effects are those in a stable situation (after ten years of testing).

– *same effect on severity of accident.* It is assumed that assessed risk differences for accidents will be the same for the effect on injuries and fatalities. In other words the same percentage change (for vision deficiency) will be applied to accidents with material damage, injuries, and fatalities (per age group).

– *treatment is 100% successful and 80% possible.* 80% of the drivers that fail the visual acuity test the first time are able to meet the criterion with the aid of glasses/lenses or better glasses/lenses and for 20% is treatment not sufficient. For the 80% that is treated, treatment is expected to be 100% successful; the relative accident risk drops to 1.0 after treatment;

– *no illegal driving.* It is assumed that when the driving licence is withdrawn, the excluded drivers will comply with this withdrawal and will not drive illegally. An Australian literature review on illegal driving (Bobevski, 2004) indicates that some 36% of the people whose driving licence are withdrawn will continue to drive illegally. This study included drivers whose driving licence was withdrawn temporarily because too many penalty points were received or they were caught with alcohol. Drivers that are exempted from driving a car on the basis of a medical test will probably be more willing to comply with the rules then drivers that lose their driving licence (temporarily) as a punishment. However since it is decided that welfare gains acquired through illegal activities are not included in the CBA, this group of people will not be taken into account and the loss of welfare will be determined for everybody whose driving licence is withdrawn. We thus assume that all people will comply with the withdrawal and not drive illegally.

– *modal shift estimated by modal split.* Once the driving licence is withdrawn, it is assumed that, depending on age, a certain percentage of the trips will not be replaced and the remaining percentage will be redistributed in accordance with the travel trends within that particular age group.

There are elements that are not assessed in the CBA. For instance in the case of cataract/glaucoma (as with most other diseases) it is favourable for the individual to have the impairment detected at the very earliest stage. Thus, an intensified eye testing may result in earlier detection and treatment of cataract and glaucoma for some individuals – potentially leading to considerable welfare gains. However, this and other possible indirect effects will not be included in the calculations.

Limitations to practical use of eyesight tests
It is the intention of this countermeasure to screen drivers on their eyesight in relation to their driving capabilities. However no test is perfect, due to lack of *sensitivity* (the proportion of drivers that rightfully is diagnosed as incapable to drive is not 100%) and *specificity* (the proportion of drivers that is rightfully diagnosed as capable to drive is not 100%). If the results of the eyesight tests are used to determine the permission to drive, the sensitivity and specificity of the vision tests should be high.

In a study in the Netherlands (Coeckelbergh, 2002) the scores of a standard vision test were compared with the results of a driving test with an examiner

of the Dutch driving licence authority (CBR). In a sample of 100 drivers with visual view defects, the standard eyesight test indicated 67 drivers as incapable to drive. Out of these 67 drivers 23 were able to pass the driving test. On the other hand, out of the 33 subjects that in accordance with the results of the standard eyesight test were capable to drive, 12 failed on the practical driving test. This results in a sensitivity of 79% and a specificity of 48%. The implication is that if drivers are screened on their visual impairments using the standard European criteria, out of the population that on the basis of their visual capacities is tested as fit to drive, 21% in reality is not capable to drive. From the drivers, using the standard test (not including a UFOV-test), that are screened as incapable to drive, 52% in reality is capable to drive.

When a kind of UFOV-test was included in the standard eyesight test, the sensitivity and specificity respectively were 80% and 64%. This implies that with the inclusion of a kind of UFOV-test out of the drivers that were identified as capable to drive 20% was not able to pass the practical driving test and out of the drivers that were indicated as incapable to drive on the basis of the test results 36% passed the driving test. It should be noted that the sensitivity and specificity values are based on a rather small sample of drivers with visual view impairments and that the validity and reliability of the driving test are not taken into account.

Although the sensitivity and specificity values cannot be transferred to the general population, their rather low values even when a UFOV-test is included, makes withdrawal of the driving licence on the basis of eye sight test results only, a blunt measure. There will be many drivers that are not capable to drive who are allowed to continue to drive and there will be many drivers that are forbidden to drive that are actually able to drive. The sensitivity and specificity can substantially be improved with the inclusion of a practical driving test. However if all drivers from the age of 45 on, when renewing there driving licence, also have to do a test drive, the costs will rise considerably.

As the accident rate ratios are based on epidemiological studies, for calculating the first order safety effects of a particular measure, there is no need to take lack of sensitivity and specificity into account. This lack is implicitly allowed for in the accident rate ratios. However policy makers should be aware of the fact that due to imperfectness of tests a certain percentage of the drivers that are excluded from driving on the basis of medical test results solely, are wrongfully excluded.

In strict terms, a UFOV-test is not an eyesight test since it tests the spread of attention in a stationary visual field and deals probably more with attention and cognitive capabilities (information processing) than with visual capabilities. An Attended Field Of View (AFOV) also tests the spread of attention but then in a non-stationary field of view and thus resembles the driving task more than la UFOV test. Although UFOV- or AFOV-tests are not specific eyesight tests, they predict the chance to get involved in a future accident very well and therefore it seems worthwhile to include them in a mandatory eyesight test for drivers. Since the reduction in useful field of view is strongly related to age, it is not fruitful to perform a UFOV test at younger ages. The limit for the UFOV test is set on 65 years of age.

To estimate the road safety effects, the prevalence of the test results on UFOV-test among the driver population must be known. This data is not available for the different countries. They are all based on the following *Figure 6.1* showing the results of a study on this subject in the United States (Rubin et al., 1999).
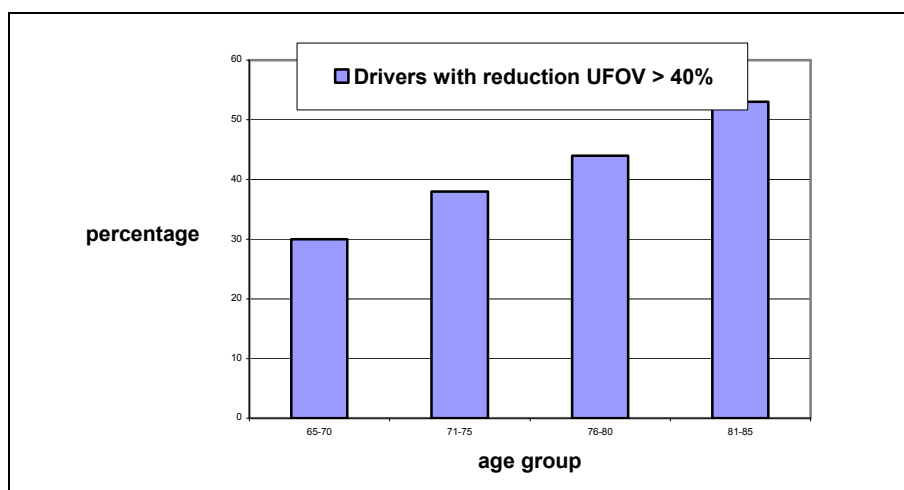
Figure 6.1. *Prevalence of Useful Field of View Impairment. Source: Rubin et al (1999). The association of vision, cognition, and attention with crashes in an older American population.*

6.3.   **The Netherlands**

6.3.1.   *Current regulations*

In the Netherlands a person has to pass the driving test, and must have the mental and physical capabilities to drive in order to acquire a valid driving licence. The first step (only for licenses for private cars (category B) and motorcycles (category A)) is that the applicant driver has to fill in a report about his constitution. He does so by answering ten questions about his mental and physical condition. One of these questions is about vision limitations. If an applicant driver (for licence A or B) confirms on the form that he has visual limitations, he has to consult a physician (not being his own general practitioner). This physician has to diagnose the severity of the (in this case) visual limitations and write a report about it. This report is attached to the questionnaire and sent to the medical advisor of the driving licence authority. This medical advisor will judge if the aspirant driver can obtain his driving licence or not. When in doubt this medical advisor can require the applicant driver to consult a specialist (in this case an ophthalmologist).

In case an applicant bus- or lorry driver applies for the first time for driving licence C or D he always has to send a medical report from a physician to the medical advisor of the driving licence authority, even if the answers on all the questions of the questionnaire are negative.

The official criteria are:
−   The visual acuity (with glasses or contact lenses) has to be ≥ 0.5 for the driving licence for private cars and motorcycles and visual acuity has to be ≥ 0.8 for the driving licence for lorries and buses.

- If the driver has only one eye the visual acuity of that eye (with glasses or a contact lens) has to be ≥ 0.6 for the driving licence for private cars and motorcycles. For the driving licence for lorries and buses the aspirant driver needs to posses two active eyes of which the visual acuity of the worst eye is at least 0.5.
- For lorry drivers and bus drivers, if they wear glasses, the strength may vary between plus or minus 8 dioptres. There are no limitations for the strength of contact lenses. For private car drivers and motorcyclists there are no limitations about the strength of the glasses nor for contact lenses;
- The field of view for all license types must be at least an angle of 140 degrees;
- Colour blindness is no ground for not obtaining one's driving licence;
- Adaptation of the eyes to darker circumstances has to be 'normal'. When in doubt a test with an adaptometer is required. The deviation may not exceed one log-unit;
- If the driver has a chronic progressive eye disease that can not be treated (cataract, glaucoma, etc.), but at the moment of testing all criteria are met, the period of the validity (normally ten years and five years after the age of seventy) of the driving licence can be shortened for the licenses A and B. For licenses C and D a chronic progressive eye disease that cannot be treated, will mean the loss of the license.

If after consulting the ophthalmologist, the medical advisor of the driving licence authority still has doubts about the driving capabilities, he may require a driving test. This is not an ordinary driving test but a test to verify if the driver is able to compensate in real driving conditions, (e.g. adapted scanning behaviour) for his visual shortcomings.

After having acquired a driving licence, it remains valid for the next ten years until the age of seventy. For renewal of the driving licence no driving test or medical examination is required. When renewing the driving licence, it is the responsibility of the driver to inform the driving licence authority if he is impaired. If a driver does so, the same criteria and test will be used as mentioned above. However this self reporting on a voluntary basis will no longer be possible in the near future for the licences C (lorries) and D (buses). From October 2004, drivers with licence C or D have to be medically examined (including a visual acuity test) every time they renew their licence.

After seventy, the renewed driving licence remains valid for five years and every time the driving licence has to be renewed, the driver has to fill in a report about his physical and mental constitution. This is the same form as is used for aspirant drivers when acquiring the driving licence for the first time. The difference is that even when the answers on all the questions about the physical and mental constitution are negative, a medical report from a general practitioner has to be attached to the form. The test that the general practitioner performs includes a static visual acuity test. The form and the report are sent to the medical advisor of the driving licence authority. This advisor can judge if the licence will be renewed or not, or if an additional test of an ophthalmologist and in some circumstances a driving capability test is required.

6.3.2. *Prevalence of low visual acuity in the Netherlands*

There are no data available regarding the eyesight of drivers. The national organization for statistics (CBS), conducts a large survey on the mental and physical constitution of the population every year. This test includes two questions about visual capabilities:

– Are you able (with your glasses or contact lenses) to read the articles in lower-case letters in newspapers? The ability to read the articles in newspapers is about the same as having a visual acuity of ≥ 0.5.
– Are you able (with your glasses or contact lenses) to recognize a face at the distance of four metres?

If the answer on at least one of the two questions is 'no' or 'with great difficulties', the respondent is qualified as having 'low visual acuity'. In *Table 6.1* the results of this survey over the year 2002 are presented.

Categories/age	Percentage of the total population with low visual acuity
Total population aged 12 and older	3.9
Men (aged 12 and older)	3.1
Women (aged 12 and older)	4.6
12-17	0.3
18-24	0.3
25-34	0.5
35-44	1.9
45-54	6.4
55-64	6.1
65-74	7.0
75 and older	13.4

Table 6.1*. Percentage of the Dutch population with low visual acuity in 2002. Source: Statistics Netherlands (CBS).*

The figures in *Table 6.1* are based on self-assessment and represent the total population. In reality the percentages may be higher as most people have the tendency to overestimate their capabilities.

For the purpose of this cost-benefit analysis it is assumed that the prevalence of low visual acuity among drivers between the age of 45 and 70 is the same as in the total population. After the age of 70 drivers are already regularly tested in the Netherlands, so there will be no impact of the countermeasure on drivers older than 70 years.

The age groups in *Table 6.1* are different from the one's being used in the statistics for driving licence holders. In *Table 6.2* the figures of *Table 6.1* are transformed to the required categories. This is done by first plotting the data and then adding the best fitting trend curve.

Age group	Estimated percentage of license B holders with a visual acuity < 0.5
45-49	3.7
50-54	4.8
55-59	5.8
60-64	7.3
65-69	8.7

Table 6.2. *Estimated percentage of drivers with driving licence B with a visual acuity < 0.5 in the Netherlands.*

6.3.3.   *Traffic safety effects*

6.3.3.1.   First order safety effect of mandatory testing on visual acuity after age 45

The introduction of the measure will have no impact on drivers above the age of 70, because they are already regularly tested in the Netherlands. For drivers with licenses C (lorries) and D (buses), mandatory testing will be introduced in October 2004. Motorcyclists between the age of 45 and 70 with licence A that don't have a licence B are very rare. This implies that the road safety effects are only estimated for drivers with licence B between the age of 45 and 70. All data that are used are derived from the national road accident database and mobility figures from Statistics Netherlands (CBS).

In *Table 6.3* the demographic figures about drivers, the accident risk and number of casualties are presented. The number of people killed or admitted to hospital in a specific age group might be the driver in the age group, his or her passenger(s) of any age and the collision partner(s) of any age. This implies that the total number of accidents is higher than in reality. If for example a car driver in the age group 45-49 has a crash with another car driver in the age group 50-54 and the driver in the later age group dies, the accident will both be counted in the 45-49 and the 50-54 age group. The accident risk (fourth column) and number of casualties in the fifth and the sixth column are based on the averages over the years 2000-2002.

Age group	Number of license B holders in 2002	Total number of kilometres driven x 10^6	Number of accidents per billion kilometres driven that caused at least one fatality or one person seriously injured and at least one person involved is of the age group	Number of people killed in road accidents of which at least one of the drivers is of the age group	Number of hospitalized people due to road accidents of which at least one of drivers is of the age group
45-49	1,028,068	10,090	252	51	707
50-54	977,723	9,963	228	41	627
55-59	893,008	6,990	261	38	443
60-64	618,246	4,214	276	24	307
65-69	454,905	2,589	342	25	253
70-74	314,529	1,629	463	27	217
75-79	213,740	881	628	26	155
80+	130,552	354	1,270	25	130

Table 6.3. *Demographic figures and accident figures.*

According to *Table 3.1* the accident risk of drivers with a low visual acuity is 15 percent higher than that of drivers that meet the criterion for visual acuity. The first order safety effect of the measure can be estimated using the general assumptions (*Paragraph 6.2*).

The reduction in fatalities and hospitalized people is calculated by adding the effect of treatment (80% of the impaired drivers can raise their visual acuity above 0.5 with the aid of better glasses) and the effect of exclusion of the drivers that cannot be treated. The results are shown in *Table 6.4*.

Age group	Reduction of the annual fatalities	Reduction of the annual hospitalized persons
45-49	0.6	8.1
50-54	0.6	9.6
55-59	0.7	8.2
60-64	0.6	7.2
65-69	0.7	7.0

Table 6.4. *First order safety effects of visual acuity testing of drivers over 45.*

If all drivers in the Netherlands that possess driving licence B and are older than 45 years, are tested on visual acuity each time they have to renew their driving licence, it is estimated that this will lead to an annual reduction of around 3 fatalities and 40 hospitalized persons.

This is the first order safety effect of the countermeasures, assuming that the car kilometres of the excluded drivers are not replaced. Most drivers that have lost their driving licence, will use other modes of transport instead. As these other modes also have an accident risk, that in some cases in higher than that of cars, this modal shift will have an adverse effect. These second order safety effects are estimated in *Paragraph 6.4.5*.

6.3.3.2. Safety effect of mandatory standard eye sight testing after the age of 45

Beside the visual acuity test, the standard eyesight test for elderly drivers also includes a simple field of view test (this is not a UFOV or AVOF test) and sometimes a test on glare sensitivity. It is also diagnosed if the driver has progressive eye disease like cataract or glaucoma.

There is no data available on the prevalence of limited field of view, glare sensitivity and chronic progressive eye diseases among drivers between 45 and 70 years of age. Probably the other eye disorders that are tested in the standard eyesight test for drivers in the Netherlands are progressive with age, but their prevalence will be smaller than reduced visual acuity. If the assumption is made that the total size in each age group of all the other disorders that are superficially tested is half as much as the size of the drivers with a low visual acuity, then the percentage in each age group that will fail the standard eyesight test can be estimated. It must be stressed that these estimates are not very accurate.

According to *Table 3.1* the accident risk of drivers that fail to pass a standard eyesight test is 25 percent higher than that of drivers that meet all the criteria. Using the general assumptions (*Paragraph 6.2*) the first order safety effect of the introduction of a mandatory standard eyesight test for drivers over 45 each time they have to renew their driving licence, can be estimated. These estimates are shown in *Table 6.5*.

Age group	Estimated percentage that will fail the standard eye sight test	Estimated Reduction in fatalities	Estimated reduction in hospitalized persons
45-49	5.6	1.5	21.6
50-54	7.2	1.6	23.6
55-59	8.7	1.8	20.9
60-64	11	1.4	18.5
65-69	15.3	2.2	23.7

Table 6.5. *First order safety effects of the introduction of a standard eyesight test for drivers over 45.*

If a mandatory standard eyesight test is introduced in the Netherlands for all drivers after 45 when renewing their driving licence, this will lead to an annual reduction of around 9 fatalities and 109 hospitalized persons.

This is the first order safety effect, assuming that the kilometres driven by car are not replaced. In reality people will start to use other modes of transport. Since less people can be treated for a standard eyesight test in comparison to a visual acuity test, the effects of the shift to other modes of transport will be larger in the case of mandatory eyesight testing.

6.3.4.   *Safety effect UFOV test in mandatory eyesight test for drivers over 65 years*

Due to the fact that drivers are (to large extent) able to compensate for their (visual) impairments, sub-optimal visual acuity and other moderate forms of eye impairment only lead to a relative small increase of the accident risk ratio. It is not surprising that the results in the previous paragraphs show that testing on visual acuity and standard eyesight testing only leads to relative small road safety benefits. However from *Table 3.1* it can be concluded that there is one 'vision' factor that has a strong relationship with accident risk. This is the 'vision' factor Useful Field Of View (UFOV).

There are reasons to believe that prevalence in reduction of useful field of view among elderly drivers in the Netherlands is not as high as in the United States (see *Figure 6.1*). In the Netherlands trip distances are shorter, public transport is better, and due to many bicycle paths, cycling is relatively safe. As elderly people in the Netherlands are less depending on their cars for mobility needs, there will be more self selection (voluntarily giving up driving) than in the United States. A rough estimate is that it is about 30 percent lower. This leads to the following numbers.

Age group	Number of accidents per billion kilometres that caused at least one fatality or one person seriously injured and at least one person involved is of the age group	Number of fatalities due to road accidents of which at least one of the drivers is from the age group	Number of hospitalized persons due to of road accidents of which at least one of drivers is from the age group
65-69	342	25	253
70-74	463	27	217
75-79	628	26	155
80+	1,270	25	130

Table 6.6. *The accident risk, people killed or admitted to hospital. The persons killed or admitted to hospital can be the driver in the age group, his or her passenger(s) of any age and the collision partner(s) of any age (averages over the years 2000-2002).*

In *Table 3.1* it is estimated that the number of accidents per kilometre driven is 4.75 times higher for a driver with reduced UFOV of more than 40% than of drivers with a UFOV-reduction less then 40%. Using this information, the results shown in *Figure 6.1*, the data in *Table 6.6* and the general assumptions, the first order safety effect can be estimated.

Age group	Estimated percentage with reduced UFOV > 40%	Annual reduction in fatalities	Annual reduction in hospitalized persons
65-69	21	5	53
70-74	27	8	59
75-79	31	8	48
80+	37	9	48

Table 6.7. *Safety effects of including UFOV-test in standard eyesight test after the age of 65.*

If a UFOV is included in the mandatory standard eyesight test in the Netherlands after the age of 65, an annual reduction of around 30 fatalities and 208 hospitalized persons will occur. In reality it will be less due to the fact that people will use other modes of transport when their driving licence is withdrawn. However in this age group (65 years and older), the percentage of trips that will not be made anymore will be significant and the percentage of trips that will be made with unsafe modes of transport will be less.

6.3.4.1.   Overview of the first order safety effects

In the following table the first order safety effects are determined. The second order safety effect, including a shift to other modes of transport is estimated in *Paragraph 6.4.5*.

	Mandatory testing on visual acuity after 45 years	Mandatory standard eye testing after 45 years	Mandatory testing including UFOV after 65 years
Reduction traffic fatalities	3	9	30
Reduction hospitalisation	40	109	208

Table 6.8. *First order traffic safety effects (not including the effects of modal shift).*

The table shows mandatory testing on visual acuity of standard eyesight testing does not contribute very much to the increase of traffic safety. Mandatory standard eyesight testing after 45 years, including a UFOV test after 65 years will lead to a substantial decrease of traffic fatalities.

6.3.5.   *Costs*

The eyesight testing will take place at renewal of the driving licence. In the Netherlands the driving licence is renewed every ten years until the age of seventy and after that every five years. This means that each year 397,195 tests are performed on people until the age of seventy years and 65,882 tests on people older than seventy years. This will lead to costs due to the testing and due to treatment.

The costs of a visual acuity test and a standard eye test are estimated at respectively € 20 and € 40 per test. According to a Dutch medical professor (prof. Kooijman) a UFOV-test cannot be performed by a general practitioner. A test performed by an ophthalmologist will take about 30 minutes and will cost around € 100. We have assumed that 80% of the persons who fail the visual acuity test can be treated by wearing glasses. The costs of these glasses are estimated at € 100 per glasses. The total costs of the countermeasures are presented in the following table.

Test	Visual acuity after 45 years	Standard eyesight testing after 45 years	Standard eye testing after 45 years incl. UFOV test after 65 years
Costs eyesight testing	7.9	17.9	38.1
Costs treatment	22.2	22.2	22.2

Table 6.9. *Costs (€ million per year).*

Since only those who fail the test due to low visual acuity can be treated, the costs for treatment are the same for all countermeasures, namely the costs of treatment for 20% of those who initially fail the visual acuity test.

6.3.6.   *Mobility effects*

In order to establish the mobility effects it is necessary to determine the number of people from whom the driving licence will be withdrawn. These

numbers can be calculated from the percentages that fail the test (see *Tables 6.2, 6.5* and *6.7*) and the number of license holders. For the testing on visual acuity 80% of those who fail the test will be treated (wear glasses), therefore only of 20% of those who fail the test the driving licence is withdrawn. This means that the following number of driving licences is withdrawn per year.

Test	Total
Testing on visual acuity after 45 years	44,295
Standard eye testing after 45 years	166,090
Standard eye testing after 45 years including UFOV test after 65 years	461,105

Table 6.10. *Annual number of withdrawn driving licences.*

It is also important to determine the number of persons that need their driving licence for *commercial* purposes (such as couriers or delivery personnel). These people might lose their job as a result of the withdrawal of their driving licence and their employers are forced to look for a replacement. In a large biennial survey (about 10,000 respondents) in the Netherlands (Feenstra et al., 2002), Dutch road users are asked about their road traffic behaviour and their motives. From the most recent survey it can be deduced that 12% of the car drivers predominantly use their car for their job, 70% for personal purposes and 18% to travel to and from the workplace. It is most likely however that not all 12% of the commercial drivers will be fired due to their withdrawal of the driving licence. Some of them will be able to use the public transport or travel as a car passenger instead. We assume that 6% of all drivers under 65 years old from whom the driving licence is withdrawn will loose their job, leading to commercial effects. We also assume that the kilometres related to these drivers will still be made by car, only by a different driver.

6.3.6.1. Private driving

After withdrawal of the driving licence, people will use other modes of transport (public transport or taxi) or will decide not to make the trip. In order to determine this modal shift we use the current modal split. We have assumed that 20% of the trips of people between 45 years and 65 years will not be made anymore. For the people older than 65 years we have assumed that this is 40%. The kilometres made with the car will shift to other modes in the following order.

Reaction	Percentage (45 to 65 years)	Percentage (older than 65 years)	Additional pass. km (mln km)		
			Visual acuity	Standard eye test	Standard eye test incl. UFOV
Use car (passenger)	16%	12%	41	155	375
Use moped	1%	1%	2	9	21
Use bike	34%	25%	88	328	793
Go walking	24%	18%	62	231	558
Use train	2%	1%	5	18	43
Use bus, tram or metro	2%	2%	6	22	54
Use other (incl. taxi)	2%	1%	5	18	43
Do not travel	20%	40%	52	195	933

Table 6.11. *Modal shift effect of withdrawing driving licences (CBS, Statline, 2003).*

The socio economic effects will be determined by the cost-difference method, as discussed in *Chapter 5*. This includes the difference in generalized costs (time and variable vehicle costs) between the modes of transport. The time costs are monetarized by using the value of time. The value of time is depending on the motive with which people travel. For people between 45 and 65 years the value of time is € 7.97 per hour in the Netherlands and for people older than 65 years this is € 5.40 per hour, since this group has a larger recreational motive (which has a lower value of time). These values of travel time are based on the study *Value of Dutch Travel Time Savings* (HCG, 1998). In the following table the generalized costs for each mode are presented.

Reaction	Variable vehicle costs (€ per pass. km)	Time costs per km (€ per pass. km)	Loss of welfare per km (€ per pass. km)
Car (driver)	0.08	0.20	-
Car (passenger)	0.00	0.20	0,00
Moped	0.02	0.40	0.14
Bike	0.01	0.53	0.26
Walking	0.00	1.33	1.05
Train	0.07	0.27	0.06
Bus, tram, or metro	0.08	0.27	0.07
Other (incl. taxi)	0.15	0.20	0.08
Do not travel	-	-	0.17

Table 6.12. *Calculation of loss of welfare per passenger kilometre for different modal shift reactions (time costs presented for people between 45 and 65 years old).*

The total socio-economic mobility effects are determined by combining the amount of shifting passenger kilometres (*Table 6.11*) and the utility loss per shifting passenger kilometre (*Table 6.12*). This leads to an overall socio-

economic loss of 213 million euro per year for the visual acuity test, 800 million for the standard eye test and 1,164 million for the eye test including a UFOV test.

These socio-economic mobility effects seem rather large. The table presented above shows that the time costs per kilometre are larger than the variable vehicle costs per kilometre for all modes. The withdrawing of the driving licence will lead to a modal shift of passenger kilometres. A large part of these shifting kilometres will be made by bike (34%) or on foot (24%). These shifts have a large loss of welfare per kilometre due to the large difference in time costs. Also the loss of welfare when the trip is not made anymore is rather substantial. Especially for people older than 65 years who are excluded due to the UFOV test, a large part of the trips will not be made anymore (40%), leading to a large loss of welfare.

6.3.6.2. Commercial driving

Besides the loss of welfare due to the private mobility effect, the withdrawal of a driving licence can lead to commercial mobility effects if the driver is also a commercial driver (courier, delivery personnel etc). We have already assumed that 6% of the drivers under 65 years old from whom the driving licence is withdrawn are commercial drivers who will loose their job.

In this analysis we assume that commercial drivers are employees and not self-employed. The commercial costs thus consist of the cost of the employer of hiring and training a new driver and the loss of welfare for the driver. Obviously the driver who is fired suffers some utility loss. However in a cost-benefit analysis the socio-economic effects are determined on a macro level. Depending on the market situation the driver is able to find another job and a previously unemployed person might fulfil his previous job. The net macro economic effects are thus small in this situation. Therefore an additional socio-economic loss is not included. An estimate of the costs is presented in *Table 6.13*.

Cost elements	Estimate (euro)
Advertising vacant position	1,500
Processing of applications	203
Interviewing applicants	76
Signing contract	101
Training new driver	2,535
Loss of welfare disqualified driver	-
Total	4,415

Table 6.13. *Calculation of loss of welfare per commercial driver.*

The additional effect of a UFOV test over 65 years to a standard eye test for people older than 45 years does not lead to commercial effects, since all drivers are over 65 years and thus generally retired. The total commercial costs amount to € 4,415 per withdrawn driving licence with commercial

effect. The total amount of welfare loss is thus respectively € 12, € 44, and € 44 million per year.

6.3.6.3. Safety effects due to mobility effects

The modal shift from car to other modes has a negative impact on the number of accidents especially when the accident risk of the new mode is higher than that of a car. In *Table 6.11* the modal shift is presented, leading to additional passenger kilometres on other modes. Using the accident risk for these modes (in traffic fatalities per passenger kilometre) it is possible to determine the so-called '2nd order' safety effect. In *Table 6.14* the first order safety effect related to the withdrawal of the driving licence is presented. The second order safety effect is related to the increase in passenger kilometres on other modes due to the modal shift of the drivers.

Reaction	Visual acuity	Standard eye test	Standard eye test incl. UFOV >65 years
Safety – 1st order	- 3	- 9	- 30
Safety – 2nd order	+1	+ 5	+ 5
Total effect	- 2	- 4	- 25

Table 6.14. *Safety effects (annual traffic deaths; - reduction and + increase).*

The table shows that the total safety effect is positive for all tests (reduction in fatalities). The second order safety effect due to the modal shift is smaller than the first order safety effect due to the decrease of car kilometres and/or treatment. The reduction in fatalities is however very small for testing on visual acuity and standard eye testing.

6.3.7. *Environmental effects*

The modal shift leads to environmental effects such as air pollution and noise. For instance a kilometre that was driven by car and now by moped, leads to an increase in air pollution and noise. A shift form car to train however leads to a reduction in air pollution and noise. These changes in environmental effects can be monetarized by using the marginal transport costs. As mentioned in *Chapter 5* these marginal costs have been studied in a large number of (EU-funded) research projects, such as ExternE and UNITE. The results of these studies have been used to estimate the following results. For the matter, there are no environmental effects related to commercial transport since the kilometres will still be driven, only by different drivers.

The combination of shift in passenger kilometres (see *Table 6.12*) and the marginal external costs leads to the socio-economic effect that is presented in *Table 6.15*.

Reaction	Air pollution	Noise
Car	0.011	0.003
Moped	0.036	0.034
Bike	0.00	0.00
Walking	0.00	0.00
Train	0.002	0.005
Bus, tram or metro	0.023	0.005
Other (incl. taxi)	0.011	0.003
Do not travel	0.00	0.00

Table 6.15. *Marginal external costs (euro per passenger kilometre).*

Table 6.16 shows that the external effects of the withdrawn driving licences are positive. The effects on emissions and noise are positive due to the large number of people that go by bike or go walking.

Reaction	Visual acuity	Standard eye test	Standard eye test incl. UFOV >65 years
Emissions	5	18	35
Noise	1	4	9
Total	6	22	44

Table 6.16. *Socio-economic effect (€ million per year).*

6.3.8. *Overview and results*

In *Table 6.17* a summary of the results for the Netherlands is presented.

Effect	Mandatory testing on visual acuity after 45 years	Mandatory standard eye testing after 45 years	Mandatory UFOV test after 65 years
Safety benefits - 1st order	15	41	142
Safety benefits - 2nd order	-6	-24	-25
Environmental benefits	6	22	44
Mobility benefits - private	-213	-800	-1164
Mobility benefits - commercial	-12	-44	-44
Project costs	-30	-40	-60
SUM (annual net benefit)	-240	-845	-1,107
Benefit/cost ratio	-7	-20	-17

Table 6.17. *Summary of annual welfare effects (€ million).*

The reduction in traffic deaths is valued at 4.8 million euro per traffic death, using the Dutch value for the One Million Euro Test of the European Commission (see *Chapter 5*). This value includes medical costs, losses of

production, material costs, and transaction costs. The value also includes accidents with only injured people or material costs, so these costs do not have to be estimated separately. The value however does not include immaterial costs (value of statistical life) to ensure that the results are comparable with the results for the other countries.

In the cost-benefit analysis all socio-economic effects are included for the time period they exist. Since the effects mentioned above are all annual effects, the cost-benefit analysis will include all effects for each year. The benefit/cost-ratio (BCR) will not be influenced by the time period for which the effects are included.

The annual net benefits are negative for all three countermeasures and the BCR is less than one, it is even negative since the project costs lead to negative net benefits. Therefore the conclusion is that none of these countermeasures is cost-effective for the Netherlands. This is mainly due to the mobility effects once the driving licence is withdrawn. A large part of these mobility effects is related to the modal shift towards bike and/or walking and to the trips that are not made anymore. Stimulating people to use the public transport if their driving licence is withdrawn can reduce these negative mobility costs. However in many countries the last years this has proven to be very difficult. If for instance the use of public transport is subsidized, the mobility effects will be reduced rather significantly. However the negative mobility effects will probably remain larger than the positive safety and environmental effects.

6.4.   **The Czech Republic**

6.4.1.   *Current regulations*

All driving licence applicants have to pass a basic eyesight test in order to acquire a driving licence for the first time. If the general practitioner, who carries out this test, has doubts about the eyesight qualities of the candidate driver this applicant has to be tested by an ophthalmologist. Since 1978 no directives have been issued on how medical tests for obtaining a driving licence have to be carried out. Except for all diabetics, there are no further mandatory eyesight tests after the initial test at the beginning of one's driver career. If however the general practitioner of a driver gets doubts about the ability of his patient to drive safely because his eyesight is worsening, this physician can send his patient to an ophthalmologist. If that ophthalmologist thinks the eyesight of the driver is too poor, the license can be withdrawn.

6.4.2.   *Prevalence of low visual acuity in the Czech Republic*

There is no data available regarding visual acuity (with glasses or contact lenses) among drivers in the Czech Republic. However there are no reasons to assume that there are large differences in the prevalence of low visual acuity between the countries. One might argue that the number of people who need treatment (glasses) and cannot afford it might differ between countries. However we assume that all people in the European countries who have their driving licence will be able to acquire treatment (glasses) if treatment is possible. It is estimated that from all car drivers in the Czech Republic above the age of 44, 7% have a visual acuity of 0.5 or lower.

6.4.3.   *First order traffic safety effects of the visual acuity test*

There are 5.6 million driving licences issued in the Czech Republic, but we haven't received any division to driver's age. If it is assumed that 90% of these licenses are for normal car driving (category B) and 35% of the Czech car drivers are 45 or older, then there are around 1.7 million car drivers of 45 and older. From these drivers 7% have low visual acuity, being 125,000 drivers.

On average in each car about 9.800 km is annually driven and there are some 3,7 million cars registered in the Czech Republic (2004). If 35% of all the cars are driven by drivers older than 45 years, the total kilometrage of Czech car drivers older than 45 years is around $1.27*10^{10}$ km. Assuming drivers with a low visual acuity drive the same distances as the average driver, the total distance travelled by drivers with a low visual acuity is some $9*10^8$ km.

About 34,000 of the registered (severe) accidents in the Czech Republic are caused by drivers of 45 and older (19% of all registered accidents). In 2003 there were 1,319 road fatalities. If in about 1,100 of these fatalities a car was involved, then the 34.000 accidents in which a driver of 45 and older was involved have lead to approximately 228 fatalities.

If the same general assumptions are made as mentioned in *Paragraph 6.2*, mandatory testing on visual acuity each time the driving licence has to be renewed after the age of 45 (assuming this will be every ten years), will lead to an annual decrease annually of around six fatalities. Because of all the estimates and all the assumptions that had to be made due to missing data, the mentioned results are highly speculative.

6.4.4.   *Costs of visual acuity*

We have assumed that of 1.7 million car drivers older than 45 years, 125,000 car drivers have a visual acuity below 0.5. This assumption is based on the Dutch figures on the prevalence of poor visual acuity. The testing will be performed every ten years, which means that annually 170,000 tests will be performed and 12,500 car drivers will not pass this test. Of these 12,500 car drivers, 10,000 drivers will be treated with glasses and 2,500 driving licences will be withdrawn. The cost estimates of the visual acuity are five euro per test (based on the Dutch value, corrected for differences in wages) and of the glasses are 25 euro (also based on the Dutch value, corrected for differences in wages)[4] .

The annual costs are thus 0.8 million euro for visual acuity tests and 0.3 million euro for treatment of low visual acuity (glasses), leading to a total annual cost of 1.1 million euro.

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[4] Source: World Development Indicators: PPP Czech Republic is 54,6% of Dutch value and International Labour Organisation earnings per month Czech Republic are 24,7% of Dutch earnings.

6.4.5. *Mobility effects of visual acuity*

6.4.5.1. Private effects

We have assumed that 2,500 driving licences are withdrawn per year, leading to a reduction of 24.5 million kilometres by car, of which 94% has private mobility effects and 6% has commercial mobility effects. It is not realistic that the people in the Czech Republic who have their driving licence withdrawn will make the same modal shift, since for instance the bike is less commonly used (modal split of bike is even unknown in the Czech Republic). input shows that busses is 9% of modal split and .

The modal split percentage of the car usage in the Czech Republic is 63%, showing that the car is by far the most dominant transport mode. We therefore assume that for all drivers 40% of the trips will not be made anymore once the driving licence is withdrawn. We have furthermore assumed that the value of time is 2.15 euro (based on the Dutch value, corrected for differences in wages). We have no detailed information regarding variable costs. The following input has been used.

Reaction	Modal shift		Variable vehicle costs (euro per pass. km)	Time costs per km (euro per pass. km)	Loss of welfare per km (euro per pass. km)
	(%)	(km)			
Car (driver)	-	-	0.010	0.04	-
Car (passenger)	15%	3,454,500	-	0.04	-0.01
Moped	5%	1,151,500	0.010	0.11	0.06
Bike	5%	1,151,500	0.005	0.14	0.09
Walking	15%	3,454,500	0.000	0.43	0.38
Public transport	15%	3,454,500	0.020	0.07	0.04
Other (incl. taxi)	5%	1,151,500	0.050	0.04	0.04
Do not travel	40%	9,212,000	-	0	0.05

Table 6.18. *Modal shift to determine mobility effects.*

This leads to a total estimated mobility effect of 2.1 million euro per year. However this calculation is largely based on the Dutch situation due to the lack of detailed data from the Czech Republic.

6.4.5.2. Commercial effects

We have assumed that – by lack of specific information based on the Netherlands - 6% of the 2,500 persons who lose their driving licence, will also lose their job over this. The expenses of replacing and requalification in the professional driving business are estimated at 1,300 to 3,000 euro, depending on the availability of qualified personnel. We assume however that there will be qualified replacements available, thus the replacement costs (with qualification costs) are estimated on 1,800 euro, leading to a total effect of 0.3 million euro

6.4.5.3. Second order safety effect of visual acuity

In *Table 6.18* the modal shift effect is presented of the people whose driving licence are withdrawn. The increased use of the other modes may lead to an increase of the traffic accidents on that new mode. Since we have no detailed data available, we will use the Dutch values, although it is obvious that those will differ form the Czech Republic. However, the 2nd order safety effect is so low (estimate based on Dutch values is an increase of 0.05 traffic fatalities), that we will ignore this effect.

6.4.5.4. Environmental effects

The modal shift in passenger kilometres will lead to external effects. For the determination of these effects, the Dutch values will be used. These effects are also very small (less than 0.1 million euro per year).

6.4.5.5. Overview of effects

In the table presented below an overview of effects of testing on visual acuity is presented. The socio-economic value of a reduction in traffic deaths in the Czech Republic is 1.1 million euro per traffic fatality (according to the methodology of the 1 million euro test of the European Commission).

Reaction	Effect
Safety - 1st order	6.8
Safety - 2nd order	None
Costs	- 1.1
Mobility - private	- 2.1
Mobility - commercial	- 0.3
Environment	None
SUM (annual net benefit)	3.3
Benefit/cost ratio	4.0

Table 6.19*. Summary of annual effects of mandatory testing of visual acuity after the age of 45 years (€ million; - costs and + benefits).*

The table shows that the costs lead to positive net benefits. The annual benefits are about three times higher than the annual costs. The socio-economic effect of testing on visual acuity thus is positive, since the positive safety effect outweighs the negative mobility effects. This is caused due to the fact that the Czech Republic has a rather poor road safety record. Because of this even a small decline in risk (as is the case with testing on visual acuity) leads to a substantial road safety gain. And because the costs are low the benefits outweigh the costs quite easily.

6.4.6. *Mandatory eyesight testing (including la UFOV-test after the age of 65)*

Too much data is missing to make a reliable estimate of these two measures. However if all the above assumptions are made again, and it is assumed that the prevalence of eyesight impairments is the same as assumed in the Netherlands and the age distribution and the accident

distribution with age is also the same, then very roughly the safety effects will be proportionally the same. This implies that with the modal shift taken into account, annually 3 lives will be saved when mandatory eyesight testing is implemented after the age of 45 and about 35 if after the age of 65 a UFOV-test is included in the test-battery. Again these results are highly speculative.

6.5. Norway

6.5.1. *Current requirements for vision and test frequency*

In Norway the applicants for a driving licence in classes A or B provide information regarding vision on a personal statement of health. For driving licence classes C or D a medical certificate is demanded.

Regarding visual requirements the official criteria for driving licences of class B (and A) are:
– The visual acuity, eventually with glasses or contact lenses, has to be ≥ 0.5 for both eyes, or if < 0.5 for one eye it has to be ≥ 0.6 for the other.
– The field of view should be 'normal' for at least one eye.

The official vision criteria for driving licences of class C are:
– The visual acuity, eventually with glasses or contact lenses, has to be ≥0.8 for one eye and ≥0.5 for the other.
– If visual acuity is < 0.5 without optical correction the required visual acuity must be obtained with glasses with a strength that should not exceed 8 dioptres.
– The field of view should be 'normal' for both eyes.
– No diplopia.

Other visual deficiencies and vision-cognitive deficiencies (reduced UFOV) are not particularly described in the specifications for the right to obtain/retain a driving licence. However, it is quite possible that a much-developed glaucoma (and even cataract) or glare sensitivity could disqualify for a driving licence within the existing regime.

Eye testing frequency is a vital part for the assessment of the eyesight projects. After having acquired a driving licence in Norway, it remains, as a point of departure, valid until the driver is 100 years old. However, reaching the age of 70 every driving licence holder is summoned for an examination of vision. After 75 the eyesight is controlled annually. The proposed intensification of testing frequency, from the age of 45, will enable detection of more drivers with visual deficiencies (and cognitive deficiencies – from the age of 65).

6.5.2. *Prevalence of vision deficiencies*

There is a lack of data on all types of visual deficiencies in Norway. There are no recent data neither on drivers' visual acuity, other eyesight impairments (limited field of view, glare sensitivity and chronic progressive eye diseases), nor UFOV. The national organization for statistics, Statistics Norway (SSB, www.ssb.no), reports fairly crude results from a national health survey in 1995. This provides rounded off percentages with self-

assessed visual impairment for five age groups above 16. This is displayed in *Table 6.20*.

Age / categories	Percentage of population with visual impairment (predominantly low visual acuity)
16-24	1%
25-44	1%
45-66	2%
67-79	5%
80 and older	15%
Total population aged 16 and older	2%
Men (aged 16 and older)	2%
Women (aged 16 and older)	3%

Table 6.20*. Percentage of the Norwegian population with self-assessed visual impairment in 1995 (Source: Statistics Norway (SSB).*

Like the Dutch case, since the figures in *Table 6.20* are based on self-assessment it is reasonable to suspect that these percentages underestimate the true extent of visual handicap. The SSB also refers to a newer survey with focus on the age groups above 60: 5% of them stated problems with reading a newspaper, even with glasses, and 7% stated problems with performing daily tasks due to visual impairment.

The results in *Table 6.20* are consistent with a study conducted by Stensholt et al. (1992). They found that 3% of the Norwegian drivers did not satisfy visual requirements, but they also assessed that most of these drivers would be able to rectify their vision by lenses or glasses. Thus, we will apply the figures in *Table 6.20* as a measure of reduced visual acuity (only), i.e., below 0.5. For other eyesight impairment and for UFOV we will apply estimations based on the Dutch figures.

6.5.3.   *Prevalence of low visual acuity*

The age groups in *Table 6.20* are different from the ones being used in the statistics for driving licence holders, exposure (km driven) and injuries/fatalities. In *Table 6.21* the crude figures are adapted to the required age categories by simple averaging.

Age group	Estimated percentage of license B holders with a visual acuity < 0.5
45-49	2.0%
50-54	2.0%
55-59	2.0%
60-64	2.0%
65-69	3.8%

Table 6.21*. Estimated percentage of drivers with driving licence B with a visual acuity < 0.5 in Norway.*

6.5.4. *Prevalence of other visual deficiencies*

Beside the visual acuity test, the mandatory standard eyesight test for elderly drivers also includes a simple field of view test. It is also diagnosed if the driver has progressive eye disease like cataract or glaucoma. If the assumption is made that the total size in each age group of all the other disorders that are superficially tested is half as much as the size of the drivers with too low visual acuity (following the Dutch approach), then the percentage in each age group that will fail the standard eye sight test can be estimated. It must be stressed that these estimates, displayed in *Table 6.22* are very crude.

Age group	Estimated percentage of license B holders with severe eyesight deficiency
45-49	1.0%
50-54	1.0%
55-59	1.0%
60-64	1.0%
65-69	1.9%
Note: The percentages refer to eyesight deficiencies other than low visual acuity, e.g., limited field of view, glare sensitivity or chronic progressive eye disease like cataract or glaucoma.	

Table 6.22*. Estimated percentage of drivers with eyesight deficiencies too severe for driving in Norway.*

6.5.5. *Prevalence of UFOV reduction (above 40%)*

The prevalence of useful field of view (UFOV) reduction in the Norwegian driver population is not known. As indicated in *Paragraph 6.2*, this is actually more of a cognitive deficiency than a specific vision deficiency. Estimates have been made with the figures from the US (*Figure 6.1*) as a point of departure. However, the US figures seem indeed very high, if compared to assessment of old age among Norwegian drivers – estimated to approximately 15% in the group of drivers above 80 (Brækhus, 1998). Taking the 15% as an approximation to the maximum in the group above 80, the prevalence of UFOV reduction above 40% will be set as much as 70% lower for those having a driving licence in Norway compared to the US estimates. The estimated prevalence for different age groups above 65 is displayed in *Table 6.23*.

Age group	Estimated percentage of license B holders with severe eyesight deficiency
65-69	9%
70-74	11%
75-79	13%
80+	16%

Table 6.23*. Estimated percentage of UFOV reduction above 40% in Norway.*

6.5.6. *Costs*

The eye testing will take place at renewal of the driving licence. In Norway the driving licence is in general not renewed until the age of 70 and after 75 annually. It is assumed that the tests are to be performed decennially until the age of 65, quinquennially from 65 to 75, and then annually.

It can be estimated that approximately 120,000 will be tested each year for visual acuity or standard eyesight. Since testing is more frequent for the older age groups, the overall annual testing will apply to nearly 160,000 for UFOV.

For Norway we will apply the cost figures for the Netherlands as point of departure, but increase them by 25%, i.e., € 25, € 50 and € 125 per visual acuity test, standard eye test, and a UFOV test, respectively. As indicated in *6.2*, we disregard scale economies due to combined tests. Glasses to correct visual acuity are also assumed to have an average cost 25% higher in Norway, i.e. € 125. Total test numbers and costs are presented in the following table.

	Visual acuity after 45 years		Standard eye testing after 45 years		Standard eye testing after 45 years incl. UFOV test after 65 years	
Age group	No.	€ x 1000	No.	€ x 1000	No.	€ x 1000
45-49	27,856	696	27,856	1,393		
50-54	26,637	666	26,637	1,332		
55-59	24,876	622	24,876	1,244		
60-64	17,469	437	17,469	873		
65-69	24,615	615	24,615	1,231	24,615	3,077
70-74					20,874	2,609
75-79					61,852	7,732
80+					50,661	6,333
Glasses (SUM)	19,235	2,404				
SUM	121,453	5,441	121,453	6,073	158,002	19,750

Table 6.24. *Estimated percentage of drivers with driving licence B with a visual acuity < 0.5 in Norway.*

These are the project costs, and these can be treated as annual costs for any chosen project period.

6.5.7. *Base line figures for car driving*

In *Table 6.25* the demographic figures about driving licences, driving distances, and risks of accidents, injuries, and fatalities are presented. This relevant background data on licenses, exposure and risk is derived from 'Statistics Norway' (SSB), the Norwegian Travel Survey 2001 (Denstadli & Hjorthol, 2002) and Norwegian risk studies (Bjørnskau, 2000; 2003).

Age group	Number of driving licence B holders (01.01.04)	Estimated No of km driven annually x 10^6	Risk of car being involved in injury accident	Car driver injury risk	Car driver fatality risk	Estimated risk of car being involved in fatal accident
45-49	278,556	3,413	0.23	0.11	0.0017	0.005
50-54	266,369	3,265	0.23	0.11	0.0019	0.005
55-59	248,762	2,414	0.24	0.12	0.0021	0.006
60-64	174,689	1,693	0.24	0.12	0.0035	0.006
65-69	123,075	806	0.31	0.15	0.0089	0.009
70-74	104,371	682	0.31	0.15	0.0031	0.009
75-79	61,852	291	0.95	0.54	0.0102	0.053
80+	90,182	238	0.95	0.54	0.0454	0.053

Note: The car driver risk estimates (per mill. km) for accidents and injuries are based on a 2001 risk assessment by Bjørnskau (2003), while fatality risks are adapted from the same source comparing fatality and injury reports from 2001 and 2002 (from Statistics Norway).

Table 6.25. *Demographic figures and accident figures.*

Assessing the effects with respect to risk changes for car injury risk and car fatality risk will underestimate the effects, since the car drivers are involved in more accidents with injury than the number of injured car drivers. However these numbers are not readily available. As a first approximation the risk estimates for accidents resulting in injury and the subsequent estimate of fatalities (the third and last columns of *Table 6.25*) will be applied.

6.5.8. *Primary traffic safety effects*

6.5.8.1. Primary safety effect of mandatory visual acuity testing after the age of 45 for licence B

The introduction of the measure will be assumed to have (full) effect on drivers with driving licence B between 45 and 70. According to *Table 4.1* the accident risk per kilometre driven of drivers with a visual acuity lower than the limit is 15 percent higher than that of drivers that meet the criterion for visual acuity (RR=1.15). The effect of the measure on road safety will be estimated, using the general assumptions.

The reduction in fatalities and injuries is calculated in the following way:
– For the 80% of the impaired drivers that can raise their visual acuity above 0.5 with the aid of better glasses, the reduction is calculated using population-attributable risk – applying the 15% risk difference between drivers with visual acuity lower than the limit and those with visual acuity above the limit, given by age group. For this group this represents the total safety effect, since they will continue to drive as before – only slightly safer – not changing their use of other transport modes.
– For those 20% excluded from driving the reduction is also calculated using population-attributable risk, but in this case first getting only the primary effect from car driving exclusion (not the secondary effect from using other substitute transport modes). In this case the primary effect attributable risk can be estimated as (PE(RR-0))/(PE(RR-0)+1), compared to the formulae in *Paragraph 4.4.5*. Applying a multiplication of

their risk – 15% higher than the averages in the mid and rightmost column of *Table 6.26* – by their exposure would yield similar results.

Age group	Reduction of the annual number of fatalities due to treatment/retention of drivers with visual acuity problems			Reduction of the annual number of injuries due to treatment/retention of drivers with visual acuity problems		
	80% treated	20% excluded	SUM primary effect	80% treated	20% excluded	SUM primary effect
45-49	0.04	0.08	0.12	1.9	3.5	5.4
50-54	0.04	0.07	0.11	1.8	3.4	5.2
55-59	0.03	0.07	0.10	1.4	2.6	4.0
60-64	0.02	0.05	0.07	1.0	1.8	2.8
65-69	0.03	0.06	0.09	1.1	2.1	3.2
SUM	0.17	0.32	0.49	7.2	13.4	20.6

Note: For the 20% excluded the effect on fatalities and injuries is only a primary effect from not driving anymore (not taking into account the opposite secondary effect from increased use of substitute transport modes). For the 80% treated the estimated effect is the total safety effect.

Table 6.26. *Primary safety effect mandatory testing on visual acuity after age 45 for license B.*

If in Norway all drivers that possess a driving licence are tested after the age of 45 on visual acuity, it is estimated that this will lead to a primary effect of an annual reduction of '1 half' fatality and less than 21 road injuries. This relative low reduction will only occur under the assumptions made, and not taking into account the opposite secondary safety effect from the 20% excluded from driving increasing their use of alternative modes, which is treated below. Again, this disregards the possibility that some disability will develop between the decennial tests (which of course is likely). Further, some drivers that have their driving licence withdrawn may continue to drive.

6.5.8.2. Primary safety effect of mandatory standard eye sight testing after the age of 45 for licence B

The introduction of the measure will be assumed to have (full) effect on drivers with driving licence B between 45 and 70. According to *Table 3.1* the accident risk per kilometre driven by drivers who fail to pass a standard eyesight test is 25 percent higher than that of drivers that meet all the criteria (RR=1.25). The effect on road safety of the measure will be estimated, using the general assumptions. With these assumptions the effect of the introduction of mandatory standard eyesight test for drivers over 45 each time they have to renew their driving licence (every ten years from 45 to 70) can be estimated.

The reduction in fatalities and injuries is calculated using population-attributable risk, getting only the primary effect from car driving exclusion (not the secondary effect from using other substitute transport modes). The attributable risk can be estimated as (PE(RR-0))/(PE(RR-0)+1), compared to the formulae in *Paragraph 4.4.5*. (Applying a multiplication of their risk – 25% higher than the averages in the third and last column of *Table 6.26* – by their exposure would yield similar results.) These estimates are shown in *Table 6.27*.

Age group	Reduction of the annual number of fatalities due to retention of drivers with eyesight deficiencies	Reduction of the annual number of injuries due to retention of drivers with eyesight deficiencies
45-49	0.2	9.7
50-54	0.2	9.3
55-59	0.2	7.2
60-64	0.1	5.0
65-69	0.2	5.8
SUM	0.9	36.9

Table 6.27. *Primary safety effect of mandatory testing on standard eyesight after age 45 for license B.*

If a mandatory standard eyesight test is introduced for all drivers after 45 when renewing their driving licence, and if all those failing to pass the criterion have their driving licence withdrawn, annually nearly one life will be saved and approximately 37 will not be injured. Again this will only be so if no one develops the eyesight problem between the decennial tests (which is highly unlikely) and if no one continues to drive illegally. The secondary safety effect, due to replacement of some kilometres driven by car with other transport modes, will be handled below.

6.5.8.3. Primary safety effect of mandatory UFOV testing after the age of 65 for licence B

The introduction of the measure will be assumed to have (full) effect on drivers with driving licence B above the age of 65. According to *Table 3.1* the accident risk per kilometre driven is estimated to be as much as 4.75 times higher for a driver with reduced UFOV of more than 40% than for drivers with a reduced UFOV les than 40% (RR=4.75). The effect of the measure on road safety will be estimated, using the general assumptions.

With these assumptions the effect of the introduction of mandatory UFOV test for drivers above 65 each time they have to renew their driving licence (every five years from 65 to 75, and then annually) can be estimated. The reduction in fatalities and injuries is calculated using population-attributable risk, getting only the primary effect from car driving exclusion (not the secondary effect from using other substitute transport modes). The attributable risk can be estimated as (PE(RR-0))/(PE(RR-0)+1), compared to the formulae in *Paragraph 4.4.5*. These estimates are shown in *Table 6.28*.

Age Group	Reduction of the annual number of fatalities due to retention of drivers with UFOV reduction > 40%	Reduction of the annual number of injuries due to retention of drivers with UFOV reduction > 40%
65-69	2.2	75
70-74	2.2	74
75-79	5.9	105
80+	5.4	96
SUM	15.6	350

Table 6.28. *Primary safety effect mandatory testing on UFOV after age 65 for licence B.*

If a mandatory UFOV test is introduced for all drivers after 65 when renewing their driving licence, and if all those failing to pass the criterion have their driving licence withdrawn, annually nearly as much as 16 lives can be saved and 350 injuries prevented. Again this will only be so if no one develops the UFOV reduction between the tests (which is somewhat unlikely) and if no one continues to drive illegally. The secondary safety effect, due to replacement of some kilometres driven by car with other transport modes, will be handled below.

6.5.9. *Mobility effects*

6.5.9.1. Reduction in driving licences class B and person kilometres by car

In order to establish the mobility effects it is necessary first to determine the number of people from whom the driving licence will be withdrawn. These numbers can be calculated from the number of licence holders with the specific visual problem, and the percentage that will fail the test. For the testing on visual acuity only 20% of those who fail the test have their driving licence withdrawn. For the standard eye test and the UFOV test all those who fail the test have their driving licence withdrawn.

The number of persons having their driving licence B withdrawn, as a share of all drivers with licence B, can be combined with estimated number of kilometres driven by car annually. This yields the person kilometres by car lost by these drivers. It is estimated that 4.14% of these person kilometres, the percentage of commercial drivers, will still be driven with other drivers. The welfare effect on commercial driving is handled below. The net after subtracting 4.14% yields the kilometres reduction in car driving. This is relevant for the environmental effects that are assessed below.

The number of withdrawn licences of class B and the person km by car that these ill drivers loose is displayed in *Table 6.29*.

Age group	Visual acuity test		Standard eye test		UFOV test	
	Withdrawn licenses	Lost car km by the ill (x1000)	Withdrawn licenses	Lost car km by the ill (x1000)	Withdrawn licenses	Lost car km by the ill (x1000)
45-49	1,115	5,246	2,785	13,116		
50-54	1,065	5,017	2,665	12,541		
55-59	995	4,685	2,490	11,713		
60-64	700	3,290	1,745	8,225		
65-69	935	4,404	2,340	11,010	11,075	52,155
70-74					11,900	56,023
75-79					7,980	37,569
80+					14,070	66,241
SUM	4,810	22,643	12,020	56,606	45,020	211,988

Table 6.29. *Annual number of withdrawn driving licences and lost person km by car by the ill.*

The principal welfare effect from the lost car kilometres can be calculated by multiplying by some estimated value of average consumer surplus from driving. The relevant kilometres for commercial driving and for environmental effects can also be calculated from the lost car kilometres by those with eye illnesses or deficiencies. Part of these kilometres will be retained in transport by others transport modes.

The mobility effects will also be determined by a cost-difference method, as discussed in *Chapter 5*. This is based on adding the differences in generalized costs (time and variable vehicle costs) between the replaced kilometres from car to other modes of transport.

6.5.9.2. Alternative transport modes

After withdrawal of the driving licence, people will have to apply other modes of transport or will decide not to make the trip. To estimate the modal shift we should principally know the substitution relationship between the modes. Without such knowledge a simplified procedure may be applied. One approach is to use the current modal split for those who actually do not have a driving licence (Denstadli & Hjorthol, 2002), for the part of the car kilometres that are assumed replaced. However, those being forced to hand in their driving licence may not have the same preference for other transport modes as those that (more or less) voluntarily did not obtain a driving licence. It is fairly obvious that some kilometres driven by car will not be replaced by other transport modes. Some trip behaviour by car simply cannot be replaced by slower modes (cycling, walking) or modes with fixed routes (public transport). It is assumed (as a point of departure) that 30% of the trip length (by car) for people between 45 years and 65 years will not be made anymore. For the people older than 65 years it is assumed a reduction of 50%. (i.e., slightly higher than the percentages applied for the Dutch case.)

How the kilometres travelled by car are assumed to shift to other modes, for each of the three vision measures, is shown in the following tables.

Age group	Car passengers	Bicycling	Pedestrian	Moped	Public transport	Other (e.g., taxi)	No transport
45-49	986	211	1,443	35	810	35	1,509
50-54	943	202	1,380	34	774	34	1,443
55-59	880	189	1,289	31	723	31	1,347
60-64	618	132	905	22	508	22	946
65-69	617	132	903	22	506	22	2,202
SUM	4,043	866	5,921	144	3,321	144	7,447

Table 6.30. *Modal shift effect of withdrawing driving licences for persons with severely reduced visual acuity – in 20% of cases (x1000 km per year).*

Age group	Car passengers	Bicycling	Pedestrian	Moped	Public transport	Other (e.g., taxi)	No transport
45-49	2,464	528	3,609	88	2,024	88	3,772
50-54	2,357	505	3,451	84	1,936	84	3,607
55-59	2,201	472	3,223	79	1,808	79	3,369
60-64	1,545	331	2,263	55	1,269	55	2,366
65-69	1,541	330	2,257	55	1,266	55	5,505
SUM	10,109	2,166	14,802	361	8,304	361	18,618

Table 6.31. *Modal shift effect of withdrawing driving licences for persons with severe eyesight deficiencies (x1000 km per year).*

Age group	Car passengers	Bicycling	Pedestrian	Moped	Public transport	Other (e.g., taxi)	No transport
65-69	7,302	1,565	10,692	261	5,998	261	26,077
70-74	7,843	1,681	11,485	280	6,443	280	28,012
75-79	5,260	1,127	7,702	188	4,320	188	18,784
80+	9,274	1,987	13,579	331	7,618	331	33,120
SUM	29,678	6,360	43,457	1,060	24,379	1,060	105,994

Table 6.32. *Modal shift effect of withdrawing driving licences for persons with severely reduced UFOV (x1000 km per year).*

These person kilometre estimates with other transport modes will be applied for the calculation of secondary safety effects and secondary environmental effects.

6.5.9.3. Secondary safety effects due to substitution of car by other transport modes

The modal shift from car to other modes has a secondary negative impact on the number of injuries and fatalities. For some transport modes this secondary effect is somewhat higher per kilometre than the primary effect from annulled car kilometres, since some of these alternative modes imply higher risk than travel by car - even when the driver has a severely reduced UFOV. Thus, even if fewer kilometres are driven by the alternative transport modes, the secondary negative safety effect is substantial. The secondary effects for all three proposed vision tests are presented in the following table.

Age group	Visual acuity test		Standard eye test		UFOV test	
	Increase in the annual no of fatalities	Increase in the annual no of injuries	Increase in the annual no of fatalities	Increase in the annual no of injuries	Increase in the annual no of fatalities	Increase in the annual no of injuries
45-49	0.04	0.9	0.09	2.1		
50-54	0.04	0.8	0.09	2.0		
55-59	0.04	0.8	0.09	1.9		
60-64	0.03	0.5	0.07	1.3		
65-69	0.04	0.6	0.09	1.5	0.4	7
70-74					0.5	10
75-79					2.1	20
80+					3.2	35
SUM	0.2	4	0.4	9	6.2	72

Table 6.33. *Secondary safety effects from increased use of alternative transport modes due to the three proposed vision testings for licence B.*

6.5.10. *Net effect on safety and its welfare effects*

Now the net effect on safety can be calculated, and its welfare effect can be estimated applying monetary values of preventing a fatality and an injury. The net safety effects are given in the following tables.

	Visual acuity test	Standard eye test	UFOV test
Safety – primary effect	-0.5	-0.9	-15.6
Safety – secondary effect	0.2	0.4	6.2
Net effect	-0.3	-0.5	- 9.4

Table 6.34. *Net safety effects on fatalities.*

	Visual acuity test	Standard eye test	UFOV test
Safety – primary effect	-21	-37	-350
Safety – secondary effect	4	9	72
Net effect	-17	-28	-278

Table 6.35. *Net safety effects on injuries.*

The relevant monetary safety values for Norway (based on standard behavioural approach and individual willingness-to-pay) are € 3,016,000 per fatality and € 84,720 per injury (a weighted average of 0.9 times € 41,420 for slight injury and 0.1 times € 474,405 for serious injury – following the approximate distribution in accident data) based on Elvik (2004). The net welfare effect from the safety gain (both reduced fatalities and reduced injuries) is given in the following table.

	Visual acuity test	Standard eye test	UFOV test
Net safety gain	2,4	3,7	51,9

Table 6.36. *Net welfare effect from safety gain (€ milion) – fatalities and injuries valued separately.*

For the visual acuity test and the standard eye test the monetarized safety gains are relatively meagre; they are actually less than the estimated project costs (testing and treatment). However, we will also apply an estimated Norwegian value for the One Million Euro Test , similar to the Dutch and Czech approach. This is estimated from a total estimated annual accident costs at approximately € 3,500 million (using a NOK/€ exchange rate of 8). With an annual average of 295 fatalities (in 2002 and 2003) this yields a value per prevented fatality at slightly less than € 11.9 million (including immaterial costs). The value excluding immaterial costs is € 5,9 million. For the purpose of comparability (see *Chapter 5*) only the latest figure will be used. This fatality indicator" value embraces the values/costs of injury accidents and property damage accidents, but not the immaterial costs. The net welfare effect from the safety gain using the Norwegian value of the One Million Euro Test is given in the following table.

	Visual acuity test	Standard eye test	UFOV test
Net safety gain	1.8	2.7	55.5

Table 6.37. *Net welfare effect from safety gain (€ million) – One Million Euro Test .*

6.5.11. *Welfare effects of license withdrawal*

As indicated, two approaches to mobility effect valuation are applied for Norway. Firstly, the primary effect of lost consumer surplus from car driving (total car kilometre loss) is estimated. Secondly, the mobility effect is calculated by generalized travel cost differences, between car driving and substitute alternatives, as done for the Netherlands, the Czech Republic and for Spain.

Elvik (2002) estimated the average annual consumer surplus per car in Norway to approximately € 7,500. The estimated annual kilometres driven by an average car in Norway is approximately 13,000 km. Then consumer surplus can be estimated to approximately € 0.58 per kilometre. (In this case value per person km is equal to value per vehicle km.) As a corollary, if the generalised cost of travel is € 0.27 in average, then average willingness-to-pay (WTP) per km driving is € 0.85.

We apply this estimated consumer surplus per kilometre (i.e., estimated willingness to pay per kilometre by car minus estimated generalised transport cost) to calculate the welfare loss from driving licence withdrawal. This is displayed in the following table.

	Visual acuity test	Standard eye test	UFOV test
Mobility effect	13.1	32.7	122.3

Table 6.38. *Primary consumer surplus loss from driving impedance (€ million).*

The negative benefits due to withdrawal of driving licence are substantial – far higher than the project costs, and even higher than the estimated safety gains. However, this is the estimated primary effect. Some of the driving will be replaced by transport by other modes. Thus, the primary loss of welfare should principally be corrected (reduced) by a secondary effect mirroring the consumer surplus from the alternative modes. However, due to the lack of knowledge and data this has been discarded. It should only be noted that, given correct measurements, this represents an overestimation of true welfare loss from altered mobility.

To calculate monetary mobility effects from cost differences (implicitly assuming a common demand function for 'travel') we apply the following estimated generalised travel costs:

	Vehicle operation	Time	Difference (alternative v. car)
Car (driver)	0.13	0.14	0
Walking	0	1.99	1.72
Bike	0.02	0.61	0.35
Public transport (bus)	0.27	0.11	0.11
Other (incl. taxi)	0.26	0.40	0.39
Car (passenger)	0	0.14	-0.13
Moped	0.03	0.14	-0.10
Note: The estimates for car driving are based on Elvik et al. (2004), Eriksen (2000), and Denstadli & Hjorthol (2002). For time values an average value of time (VOT) per person hour of € 6.12 for car driving was adapted to other transport modes applying the Dutch figures (assuming identical relationship in the Norwegian case). These per hour values were then transformed to per person km values by the average speed. Also the vehicle operation values were adapted to the other modes than car driving by applying the Dutch figures.			

Table 6.39. *Estimated generalised travel cost differences between car driving and alternatives (€ per person km).*

As can be seen immediately from the table this approach gives the counterintuitive indication that the car driver at the outset (before having the driving licence withdrawn) made a 'silly choice' of not fully exploiting the possibility of, e.g., carry out more travel (kilometres) as passenger instead of as driver, since this presumably would reduce costs, and, assuming a common demand function for all transport modes, increase consumer surplus. If we, in addition, wrongfully assumed that the impeded car driver would replace all (or large part of) the lost car driving kilometres by car passenger kilometres, the unlucky would actually end up with a mobility-welfare gain from losing the driving licence.

The monetized mobility effect based on cost differences can be calculated by multiplying the cost differences by the estimated increases in alternative transport modes (in *Tables 6.30-6.32*). The lost car kilometres that are not replaced are multiplied by the generalized travel cost of car driving (summing the vehicle cost and time cost in the upper row in *Table 6.39*), assumed to represent an indication of (net) willingness to pay (consumer surplus) from car driving. The aggregates are given in the following table:

	Visual acuity test	Standard eye test	UFOV test
Mobility effect	12.4	30.9	104.8

Table 6.40. *Cost loss and cost increase from driving impedance (€ million).*

Interestingly, the estimates from the cost difference approach (assumed to cover both primary and secondary mobility effects) are fairly close to the estimates in *Table 6.39* based on only the primary consumer surplus loss. This may be taken as an indication that this approximation with available cost data (lacking estimates of willingness to pay and consumer surplus) can provide fairly reasonable estimates of the welfare loss from the mobility alteration. However, it may still overestimate the total mobility effect, giving too little weight to the secondary gain.

6.5.12. *Welfare effects of environmental improvements*

It has been presumed that the modal shift would lead to overall positive environmental effects – reduction of air pollution and noise, although there is both a primary positive effect from the reduction in car kilometres and a secondary negative effect from increased use of alternative modes. Only moped use has substantially higher external environmental costs, especially for noise, compared to car driving per person kilometre. Some transport is also annulled due to the modal shifts. The external costs in the Norwegian case of air pollution (local and global) and noise for each transport mode is presented in the following table.

Transport mode	Air pollution	Noise	Difference relative to car driving
Car (driver)	0.025	0.011	0
Walking	0	0	-0.036
Bike	0	0	-0.036
Public transport (bus)	0.035	0.016	0.015
Other (incl. taxi)	0.025	0.011	0.000
Car (passenger)	0	0	-0.036
Moped	0.079	0.125	0.168
Do not travel	0	0	-0.036

Table 6.41. *Marginal external costs (€ per passenger kilometre).*

The combination of shift in passenger kilometres (see *Tables 6.30-6.32*) and the marginal external costs leads to the effects that are presented in *Table 6.42*.

	Visual acuity test		Standard eye test		UFOV test	
	Altered transport (x1000 km)	Environmental value (€ mln.)	Altered transport (x1000 km)	Environmental value (€ mln)	Altered transport (x1000 km)	Environmental value (€ mln)
Primary effect (reduced car driving)	-21,888	0.8	-54,721	2.0	-211,988	7,7
Secondary effect (increase in alternative modes)	14,441	-0.4	36,102	-0.9	105,994	-2,6
Net effect	-7,447	0.4	-18,618	1,1	-105,994	5,1

Table 6.42. *Net environmental effects from altered transport behaviour.*

The monetarized environmental benefits from the measures are substantial but less than the positive safety benefits and far less than the negative mobility benefits. Both the reduced overall transport and the increased walking/biking drive these environmental results.

6.5.13. *Commercial driving and its monetary effects*

Besides the loss of welfare due to the private mobility effect, the withdrawal of a driving licence may also lead to some (immediate) commercial mobility effects since some of the drivers diagnosed may be commercial drivers. Based on data from Statistics Norway, it has been estimated that 4.14% of each diagnosed cohorts (between 45 and 65) are commercial drivers that must be replaced due to eye testing and subsequent license withdrawal. The sudden and hastened replacement cost could be presumed to be higher for the relatively young than for the relatively old. However, it can't be concluded with certainty that the increase in replacement will equal the number of commercial drivers affected. But, in any case there is an advance of costs for firms (at least until they can adapt to a stricter regime for driving with eye diseases or other deficiencies). As a simplified approach a unique cost per hiring/training similar to the Dutch case will be applied i.e., € 4,500 per diagnosed commercial driver. And, as a simplification, it will be assumed that the increase in replacement will equal the number of commercial drivers affected. Further, any positive benefit for the firm that a risky driver is removed from their ranks will also be omitted. It has also been omitted that there may be an extra welfare loss for those who lose their job, in addition to the lost possibility of choosing to go by car (personal mobility effect).

Age group	Visual acuity test		Standard eye test		UFOV test	
	No. of drivers	Negative benefits (firm costs, € mln)	No. of drivers	Negative benefits (firm costs, € mln)	No. of drivers	Negative benefits (firm costs, € mln)
45-49	46	0.2	115	0.5		
50-54	44	0.2	110	0.5		
55-59	41	0.2	103	0.5		
60-64	29	0.1	72	0.3		
SUM	160	0.7	400	1.8	0	0

Table 6.43. *Negative benefit for firms due to hastened replacement of commercial drivers.*

As calculated these negative commercial effects are within the order of magnitude as the positive environmental benefits. The UFOV test will have no negative commercial effects since it is intended to only apply to persons above 65 years old.

6.5.14. *Summary of welfare effects from vision testing and license withdrawal*

The following table provides a summary of the economic results for Norway.

Effect	Mandatory testing on visual acuity after 45 years	Mandatory standard eye testing after 45 years	Mandatory UFOV test after 65 years
Safety benefits	2.4	3.7	51.9
Environmental benefits	0.4	1.1	5.1
Mobility benefits	-12.4	-31.0	-104.8
Commercial benefits	-0.7	-1.8	0
Project costs	-5.4	-6.1	-19.8
SUM (annual net benefit)	-15.7	-34.0	-67.6
Note: The safety benefits are based on separated fatality and injury values. The estimates of the negative mobility benefits are based on the "cost difference approach" (not the consumer surplus loss) to make the results comparable with the Dutch, Czech, and Spanish results.			

Table 6.44. *Summary of annual welfare effects (€ million) – separated fatality and injury values.*

As can be seen, all three separate projects yield negative results, primarily driven by the huge negative mobility benefits. It can be assumed, as a simplification, that the estimates in *Table 6.44* are annual effects that remain the same over the project period (which has not been chosen). Given that the effects mentioned above are fixed annual figures, an assessment of benefits versus costs (including the BC-ratio) will not be effected by the chosen time period.

However, since the benefits are negative the BC-ratios are not defined. For the two first measures the estimated safety effects are just too limited to justify project costs and negative mobility effects. For the UFOV-testing the safety benefits are very substantial – the relative risk is much higher (4.75) and a larger part of the driver population above 65 is expected to be diagnosed with such a deficiency – but again the mobility effects knock down the positive welfare effects. The net benefits are also estimated based on the use of the One Million Euro Test with a fatality indicator value of approximately € 5.9 million.

Effect	Mandatory testing on visual acuity after 45 years	Mandatory standard eye testing after 45 years	Mandatory UFOV test after 65 years
Safety benefits	1.8	2.7	55.5
Environmental benefits	0.4	1.1	5.1
Mobility benefits	-12.4	-31.0	-104.8
Commercial benefits	-0.7	-1.8	0
Project costs	-5.4	-6.1	-19.8
SUM (annual net benefit)	-16.3	-33.0	-64.0
BC ratio	-2.0	-4.8	-2.2
Note: The safety benefits are based on a fatality value indicator of the One Million Euro Test. The estimates of the negative mobility benefits are based on the 'cost difference approach' (not the consumer surplus loss) to make the results comparable with the Dutch, Czech, and Spanish results.			

Table 6.45. *Summary of annual welfare effects (€ million) – fatality indicator for One Million Euro Test .*

Also in this case the net benefits and the BCR are negative.

6.6. Spain

6.6.1. *Current requirements for vision and test frequency*

The requirements regarding vision are similar in Spain as those prevalent in the Netherlands and Norway. However, medical check is also required for driving licences class B. Another most important main difference in the Spanish case is the periodical renovation of the driving licence – including assessment of health. A driving licence is valid for only ten years until the age of 45, then it has to be renewed quinquennially until the age of 70, and then biannually.

Thus, a project of testing visual acuity and/or standard eyesight from the age of 45 on seems somewhat superfluous. The measure is already in place. In the Spanish case only the UFOV-testing will be assessed in the following.

6.6.2. *Prevalence of UFOV reduction (above 40%)*

Data on the prevalence of useful field of view (UFOV) reduction among the Spanish driver population is not known either. As a first approximation a similar percentage as in the Norwegian case will be applied. Those above 65 are not split into separate age groups, and a common percentage of 15% will be applied (slightly above the estimated weighted average of 12.4% for Norway).

6.6.3. *Costs*

It is presumed that the UFOV testing will take place within the existing regime of renewal of the driving licence. Thus, it will be performed

quinquennially from 65 to 70, and then biannually. As a simplification it will be assumed that ⅓ of the age group above 65 is tested every year. Based on this it can be estimated that 552,441 will be tested each year for UFOV reduction. For Spain we will apply the same cost figures as for the Netherlands, i.e., € 100 per UFOV test. The estimated annual project costs equal € 552,441.

6.6.4.   *Base line figures for car driving*

The demographic figures about drivers, driving distances, and risks of injury accidents and fatalities are presented in the following table.

Age group	Number of drivers (X1000) (2002)	Estimated No of km driven annually x 10^6	Risk of car being involved in accident w/injury	Car driver fatality risk
45-64	5,886			
65+	1,657	28,681	0.70	0.03
Note: The estimated number of kilometres driven is based on data only about vehicle km in non-urban areas.				

Table 6.46*. Demographic figures and accident figures.*

The average number of drivers above 65 involved in injury accidents, in 2002-2003, was 19,666. The average number of road user fatalities was 821. These figures serve as a base line to assess the extra risk of driving with UFOV reduction above 40% and how many fatalities and injuries that can be expected to be avoided annually.

6.6.5.   *Primary traffic safety effects of mandatory UFOV testing after the age of 65*

The introduction of the measure will be assumed to have (full) effect on drivers with driving licence B above the age of 65. According to *Table 4.1* the accident risk per kilometre driven it is estimated to be as much as 4.75 times higher for a driver with reduced UFOV of more than 40% than for other drivers (RR=4.75). The effect on road safety of the measure will be estimated using the general assumptions

With these assumptions the effect of the introduction of mandatory UFOV test for drivers above 65 each time they have to renew their driving licence (every five years from 65 to 70, and then biannually) can be estimated. The reduction in fatalities and injuries is calculated using population-attributable risk (41.61%), getting only the primary effect from car driving exclusion (not the secondary effect from using other substitute transport modes). The attributable risk is estimated as (PE(RR-0))/(PE(RR-0)+1), compared to the formulae in *Paragraph 4.4.5*. The resulting estimates are shown in the following table.

Age group	Reduction of the annual number of fatalities due to retention of drivers with UFOV reduction > 40%	Reduction of the annual number of injuries due to retention of drivers with UFOV reduction > 40%
65+	341	8,112

Table 6.47*. Primary safety effect mandatory testing on UFOV after age 65.*

If a mandatory UFOV test is introduced for all drivers after 65 when renewing their driving licence, and if all those failing to pass the criterion have their driving licence withdrawn, annually as much as 341 lives can be saved and more than 8,000 injuries prevented. Again this will only be so if no one develops the UFOV reduction between the tests and if no one continues to drive illegally. The secondary safety effect, due to replacement of some kilometres driven by car with other transport modes, will be handled below.

6.6.6. *Mobility effects*

6.6.6.1. Reduction in driving by car

In order to establish the mobility effects it is necessary first to determine the number of people from whom the driving licence will be withdrawn. These numbers can be calculated from the number of license holders with the diagnosed UFOV problem (those that fail the test and subsequently lose their driving licence). With an estimated average of 15% having a UFOV reduction above 40%, the annual number of drivers above 65 losing their license due to this problem is 82,868.

The number of persons having their driving licence withdrawn, as a share of all drivers with a licence in the age group, can be combined with estimated number of kilometres driven by car annually. This yields the kilometres by car lost by these drivers: 2,519 million kilometres per year.

The environmental effect can be calculated from these kilometres reduction in car driving and the half of these applied for other substitute transport modes after having the driving licence withdrawn (50% of the car kilometres are not replaced): 1,260 million kilometres per year.

With an estimated consumer surplus from car driving the principal welfare effect from the lost car kilometres can be calculated. But, also for Spain the mobility effects will be determined by a 'generalized travel cost-difference approach', as discussed in *Chapter 5*.

6.6.6.2. Alternative transport modes

After withdrawal of the driving licence, people will have to apply other modes of transport or will decide not to make the trip (in an estimated 50% of the previous kilometres by car). To estimate the modal shift we should know the substitution relationship between the modes. Without such knowledge and without data on existing modal choice (for short trips) in Spain, we will apply the following simplified approximation: We assume that the distribution (of half the initially lost car driving kilometres) among alternative modes is similar to that of the Norwegian case. The estimates are given below.

6.6.6.3. Secondary safety effects due to substitution of car by other transport modes

If half of the lost car kilometres are apportioned on alternative modes as in the Norwegian case, and if we further assume that the risk difference between car driving (without UFOV reduction) and alternative modes also is the same as that in the Norwegian case, we can estimate the secondary safety effect from the increased use of alternative modes. This is displayed in the following table.

Age group	Increase in the annual no of fatalities	Increase in the annual no of injuries
65+	263	3,921

Table 6.48. *Secondary safety effect mandatory testing on UFOV after age 65.*

6.6.7.   *Net effect on safety and its welfare effects*

Now the net effect on safety can be calculated, and its welfare effect can be estimated applying monetary values of avoiding a fatality (*the value of a statistical life*) and an injury.

The available monetary safety values for Spain (though not based on standard behavioural approach and individual willingness-to-pay) are € 202,118 per fatality and € 26,680 per injury. (This is based on information about former PTA values provided by Pere Riera, Autonomous University of Barcelona, as well as Sælensminde 2003). The net safety effects and net welfare gains are given in the following tables.

	Fatalities	Injuries
Safety – primary effect	-341	-8,182
Safety – secondary effect	263	3,921
Net effect	-78	-4,261
Net monetary effect (€ mln)	114	16
Net safety gain	129	

Table 6.49. *Net safety effects and net welfare gain (€ million).*

With the relatively low values for a statistical life and an avoided injury, the annual sum of monetized safety gains is close to € 130 million.

However, we will also apply an estimated Spanish value for the One Million Euro Test. This is estimated from applying the ratio between the Norwegian One Million Euro Test and fatality value to the Spanish fatality value. This yields an estimated Spanish value of the One Million Euro Test of approximately € 800,000. This 'fatality indicator' estimate is assumed to embrace the values/costs of injury accidents and property damage accidents. The net welfare effect from the safety gain using this Spanish estimate of the One Million Euro Test is given in the following table. This approach yields higher safety benefit estimates.

Net safety gain	925

Table 6.50. *Net welfare effect from safety gain (€ million) – One Million Euro Test .*

6.6.8.   *Welfare effects of license withdrawal*

Also in the Spanish case we calculate monetary mobility effects from cost differences (implicitly assuming a common demand function for 'travel') we apply the following estimated generalized travel costs:

	Vehicle operation	Time	Difference (alternative vs. car)
Car (driver)	0.094	0.059	0
Walking	1.343	0	1.19
Bike	0.448	0.008	0.30
Public transport (bus)	0.228	0.064	0.14
Other (incl. taxi)	0.134	0.118	0.10
Car (passenger)	0.133	0	-0.02
Moped	0.338	0.016	0.20
Note: The estimates for car driving are based on Nellthorp et al. (2001), Betancor & Nombela (2002), and Eriksen (2000). For time values an average VOT per person hour of € 4.05 for car driving was adapted to other transport modes applying the Dutch figures (assuming identical relationship in the Spanish case). Also the vehicle operation values were adapted to the other modes than car driving by applying the Dutch figures.			

Table 6.51. *Estimated generalized travel cost differences between car driving and alternatives (€ per person km).*

Additionally an alternative better-founded approach based on consumer surplus loss, as done for Norway, was also estimated in the Spanish case. The average consumer surplus per km driving was approximated from differences in generalised travel costs. Thus, an estimate of € 0.32 was found for Spain.

Results from both the 'generalized travel cost difference' approach and the consumer-surplus loss approach (including only the principal effect from impeded driving) are presented in the following table.

	Generalized travel cost differences	Primary consumer surplus loss
Mobility effect	867	817

Table 6.52. *Cost loss and cost increase from driving impedance, and primary consumer surplus loss from driving impedance (€ million).*

As in the Spanish case, the two alternative mobility effect estimates are fairly close, but, interestingly, the estimated primary consumer surplus loss is lower than the estimate based on travel cost differences (that was assumed to include both the negative primary effect and the positive secondary effect). Although the estimates represent approximations, the applied consumer surplus value per car kilometre can be considered so high as adding to the indication that the 'generalized travel cost difference' approach yields too high estimates of lost welfare due to impeded driving.

6.6.9. *Welfare effects of environmental improvements*

Betancor & Nombela (2002) provide estimates of external costs of transport in Spain, applying cost figures based on Nellthorp et al. (2001). Overall per vehicle estimates for all transport have been apportioned between transport modes using the Norwegian proportions given in Eriksen (2000). Using the same assumptions above about transport mode choices, this gives a possibility of estimating monetary values of the environmental effects.

The estimated external costs in the Spanish case of air pollution (local and global) and noise for each transport mode is presented in the following table.

Transport mode	Air pollution	Noise	Difference relative to car driving
Car (driver)	0.006	0.005	0
Walking	0	0	-0.011
Bike	0	0	-0.011
Public transport (bus)	0.007	0.007	0.003
Other (incl. taxi)	0.009	0.023	0.021
Car (passenger)	0	0	-0.011
Moped	0.016	0.041	0.046
Do not travel	0	0	-0.011

Table 6.53. *Marginal external costs (€ per passenger kilometre).*

The combination of shift in passenger kilometres (see *Tables 6.30-6.32*) and the marginal external costs leads to the effects that are presented in *Table 6.41.*

	Altered transport (mln. km)	Environmental value (€ mln)
Primary effect (reduced car driving)	-2,519	27,8
Secondary effect (increase in alternative modes)	1,260	-5,1
Net effect	-1,260	22,7

Table 6.54. *Net environmental effects from altered transport behaviour.*

The monetized environmental benefits from the measures are substantial but less than the positive safety benefits and far less than the negative mobility benefits.

6.6.10. *Summary of welfare effects from UFOV testing and license withdrawal*

The following table provides a summary of the economic results for Spain.

Effect	Gen. tr. cost diff.	CS (primary only)
Safety benefits	129,4	129,4
Environmental benefits	22,7	22,7
Mobility benefits	-867,3	-817,4
Project costs	-55,2	-55,2
SUM (annual net benefit)	-770,4	-720,5

Table 6.55. *Summary of annual welfare effects (€ million).*

BC ratios are not defined since (gross) benefits are negative. Similarly to the results for the Netherlands and for Norway, the large negative benefits from impeding people from driving outweigh the positive benefits from safety gains and environmental improvements. The net benefits are also estimated based on the use of the One Million Euro Test with a fatality indicator value of approximately € 800,000.

Effect	Gen. tr. cost diff.	CS (primary only)
Safety benefits	925,3	925,3
Environmental benefits	22,7	22,7
Mobility benefits	-867,3	-817,4
Project costs	-55,2	-55,2
SUM (annual net benefit)	25,5	75,4
BC ratio	1.5	2.4

Table 6.56. *Summary of annual welfare effects (€ million) – fatality indicator for the One Million Euro Test .*

The use of safety values based on the One Million Euro Test provides far higher estimates of safety benefits. In this case the UFOV test is indicated to be an efficient measure. The BC ratio is approximately 1.5 applying the generalised travel cost difference approach to the mobility effects.

6.7. Overview of results of the selected countries

In *Table 6.57* an overview of the benefits, the costs and benefits/costs ratio is presented.

	Netherlands			Norway			Czech Republic			Spain		
	B	C	B/C	B	C	B/C	B	C	B/C	B	C	B/C
Visual acuity test	-210	-30	-7	-10	-5	-2,0	4	-1.1	4,0	-	-	-
Standard eye test	-805	-40	-20	-29	-6	-4,8	n.p.	n.p.	n.p.	-	-	-
Standard eye test incl. UFOV	-1.047	-60	-17	-44	-20	-2,2	n.p.	n.p.	n.p.	81	-55	1,5

Note: (-) means not relevant, (n.p.) means not performed due to lack of data. As in Spain mandatory eyesight testing (including visual acuity testing, but not UFOV-testing) is already in place, there will be only an effect of the introduction of the UFOV-test.

Table 6.57. *Results eyesight measures for different countries (million euro, annual effects).*

Discussion

In general the safety effects regarding eyesight testing seem rather limited. The reason for this is that the first order safety effect is rather small. The relative risk ratios of the eyesight impairments are not high. Probably this is due to the fact that most drivers will compensate for their poor eyesight (increasing their headway distance or lowering speed). The first order safety effect due to the decrease impaired car driving is partly undone by the second order safety effect due to the modal shift to other (sometimes more riskier) modes of transport.

For Norway and the Netherlands, visual acuity testing leads to negative net benefits, but for the Czech Republic the result is positive. The reason for this is that as the Czech Republic has relatively many road fatalities. Even a moderate decline of the relative accident risk ratio leads to relatively many lives saved. This does not imply that visual acuity testing in the Czech Republic is the most effective measure to take. Other countermeasures not considered here may have a much higher B/C ratio than visual acuity testing. As is the case with visual acuity testing, standard eyesight testing leads to negative net benefits for Norway and the Netherlands. A CBA on standard eyesight testing was not conducted for the Czech Republic (because of lack of data) and Spain (because such a test is already in place). For testing on reduced useful field of view, out of the three countries (due to lack of data a CBA could not be conducted for the Czech Republic), for one country (Spain) the benefits are higher than the costs. Although UFOV-testing leads to a substantial road safety gain both in the Netherlands and Norway, these benefits are outweighed by mainly the mobility costs. As these costs are much lower for Spain, the net benefits are positive. With these positive results for Spain, one has to keep in mind that the quality of the input data on prevalence on reduced useful field of view is too poor to recommend compulsory UFOV-testing in Europe.

Sensitivity analysis

We have made some assumptions in the calculations, besides the general assumptions presented in *Chapters 2, 5* and *6.* Since the mobility effects are most decisive, the assumptions made in order to calculate this effect are important.

For instance, we have assumed that part of the trips made by people between 45 and 65 will not be made anymore and an even larger part of the trips of people older than 65 years. The percentage of trips not made anymore varies over the countries. Norway and Spain are estimated to have the highest percentage of trips not made anymore (up till 50%). If a smaller part of trips will not be made anymore, the safety and environmental effects will be less positive and the mobility effects will be less negative. We have also estimated the shift to other modes. This is based on the existing modal split between modes.

The assumption with the most influence on the final result for the Netherlands is the average speed of walking. This is used to determine the time costs of walking, which are very high. For the Netherlands the average speed of walking is set at 6 kilometres per hour, since only short distances will be walked. If the average speed of walking is for instance set to 4 kilometres per hour, the mobility effects of testing on visual acuity will be – 311 million euro instead of -213 million euro.

Other, less decisive assumptions are made in order to determine the safety effects, such as the *prevalence* of eyesight impairments. The prevalence of the reduced field of view is based on data from a study in the United States. As for instance in the Netherlands distances are shorter and elderly are less depending on a car for their mobility needs, there are reasons to believe that the reduction in useful field of view in the Netherlands is not as high as in the United States. We have assumed that the prevalence is 30% lower in the Netherlands. If the prevalence is actually higher, both the safety effects will increase, but also the mobility effects. The results will remain negative, although the environmental effects will slightly increase.

Another assumption is that we expect that 80% of the people who do not pass the visual acuity test the first time can be *treated* by wearing proper glasses. Only 20% of those who fail the test will have their driving licence withdrawn. If this percentage is set at, for instance 40%, the safety effects will increase, the treatment costs will be lower, but the mobility effects will also be larger. Again the results will remain negative, despite the increase in environmental effects.

7. CBA zero BAC for young drivers and increase roadside testing

7.1. Description of the measure

The measure includes random roadside breath testing and a zero BAC limit for young drivers until the age of 25. This measure will aim at substantially and permanently increasing the level of enforcement in the area of drunk driving. There have already been several studies undertaken on the effectiveness of various methods of law enforcement that prevent driving over a certain BAC limit. The results have been reviewed in recent projects (Gadget, ESCAPE, and an ETSC Working Party). These studies concluded that random breath testing is a very effective instrument to deter drivers from drunk driving, hence improving road safety.

In this study the type and amount of sanctions inflicted on offenders will not be taken into account. In general, it is known that punishment is a necessary condition for deterrence, but the type and severity of sanctions add little to the general deterrence effect of enforcement. Besides this, sanctions are merely a redistribution effect in the cost-benefit analysis, leading to additional benefits of the government and additional costs to the car driver.

General assumptions
We have used some general assumptions to perform the cost-benefit analysis:
− *no effect on mobility*; the countermeasures regarding alcohol do not influence the mobility, since the breath testing aims to prevent people from drinking more than the permitted amount of alcohol before driving. If the aim is achieved, the mobility will not be affected. However some people will feel forced to drink elsewhere or to choose another transport mode, leading to minor welfare losses. These losses will be ignored in the CBA since they are acquired illegally and should not be considered as social losses. Therefore there are no mobility effects and no environmental effects estimated. For Norway however an estimation of this effect has been made.
− *traffic safety determined by meta-analysis*; in an ESCAPE working paper (Elvik, 2001) a meta-analysis of 26 evaluation studies on drink-driving law enforcement is carried out. Also the declining marginal effects of successive increase in enforcement are taken into account, leading to the conclusion that an increase of road side breath testing by a factor of 2 would yield 20% of the theoretically possible maximum potential benefit (this is a complete elimination of drink-driving). An increase of the breath testing by a factor 3 would yield 30%, a factor 6 would yield 45%, and a factor 10 would yield 60%. These results will be used to determine the safety effects for the different countries.
− *no separate enforcement on zero BAC limit*; we assume that the general increase in random road side breath tests also includes the enforcement of the lowering of the BAC level for drivers under 25. This will thus not lead to additional costs, other than the general increase in random roadside breath tests.

7.2. **The Netherlands**

7.2.1. *Current situation*

In the Netherlands the current BAC limit is 0.5 g/l. There is already an intensive breath testing policy; some 1.5 million roadside breath tests were performed in 2003 (this estimation is based upon the number of mouthpieces that were used). This means that in general one in seven car drivers is tested each year. However, depending on their lifestyle some drivers have a higher chance to get stopped and tested than others. Drunk drivers have a higher risk of getting tested, since they drive relatively more at night (when most random road side tests take place), are relatively more involved in traffic accidents (leading to breath testing in the Netherlands), and have a conspicuous driving pattern.

The percentage of drivers with a BAC higher than 0.5 g/l is estimated to be some 1.5% (ETSC, 2003), leading to a total amount of 143,000 drunk drivers each year. These drivers are responsible for 30% of the traffic accidents in the Netherlands (ETSC, 2003). From all traffic related fatalities, 15% is related to alcohol and 13% is related to the combination of alcohol and drugs. This means that in total some 325 traffic deaths in the Netherlands are related to alcohol (Mathijssen, 2004).

There are around 788,000 people with a driving licence under the age of 25 years in the Netherlands (Statistics Netherlands, CBS). In 21% of all accidents a driver under the age of 25 years is involved (national Dutch accident database). From all drivers that underwent random road side breath testing on (during) weekend nights under the age of 25, 3,5% had a BAC level between 0.2 and 0.5 g/l (Mathijssen, 1999), being some 27,500 drivers. On young novice drivers, alcohol has a more devastating effect than on older more experienced drivers. Young novice drivers with a BAC level between 0.2 and 0.5 g/l have, compared with complete sober young novice drivers, a relative accident risk of 1.5. Older and more experienced drivers with a BAC between 0.2 and 0.5 g/l have an accident risk ratio of 1.2 (Mathijssen, 1999).

7.2.2. *Costs*

Currently there are some 1.5 million random roadside tests performed ach year. The countermeasure to increase this number of roadside tests, leads to different costs, such as costs related to personnel, material, publicity, and administrative costs. A policeman is estimated to perform 16,200 breath tests per year (ETSC, 2003). The personnel costs of a policeman are estimated on € 70,000 per year (Statistics Netherlands, CBS). The material costs for the breath test equipment and the mouthpieces are estimated to be € 750 per tester per year and € 0.25 per mouthpiece (ETSC, 2003).

Publicity has proven to be an essential element of roadside breath testing (Elvik, 2001). Part of the publicity will be free; articles and police communications in newspapers about forthcoming roadblocks and results from performed actions. Another part will be commercial publicity campaigns. These costs are estimated at € 2 million (ETSC, 2003). The

administrative costs are related to the captured offenders. These offenders will be prosecuted and sentenced. These administrative and justice costs are estimated at € 1,000 per offender (ETSC, 2003).

7.2.3. *Traffic safety effects*

As mentioned above the total amount of offenders (drivers with more than 0.5 g/l BAC) in the Netherlands is some 143,000. These offenders cause 325 traffic deaths. The Netherlands already have a rather intensive random breath-testing programme, thus we assume a maximum increase of a factor 2. This means that 20% of the maximum possible benefits will be achieved, leading to a reduction of 65 traffic deaths per year (20% of 325 traffic deaths).

The number of drivers younger than 25 years and with a BAC level between 0.2 and 0.5, g/l is some 27,500 drivers per year. The traffic safety effect that can be realised for this group of drivers is 12.9 traffic deaths per year (Mathijsen et al., 2002).

7.2.4. *Overview and results*

In the following table a summary of the results for the Netherlands is presented. The reduction in traffic accidents is valued at € 4.8 million per traffic death, using the Dutch value for the One Million Euro Test of the European Commission.

Reaction	Increased random road side breath testing	Increased random road side breath testing including zero BAC limit for drivers under the age of 25
Safety	314	376
Costs - annual	-40	-40
Costs - incidental	-2	-2
Mobility	n.a.	n.a.
Environment	n.a.	n.a.
SUM (net annual benefit)	272	334
B/C-ratio	7.5	9

Table 7.1. *Summary of results (€ million).*

In the cost-benefit analysis the costs and safety effects are included for the time period they exist. The enforcement costs and traffic safety effects are annual effects and will be included each year. The benefit/cost-ratio (BCR), even if it is based on the lower value of a traffic death being larger than 7, will not be influenced by the time period for which the effects are included. Besides the enforcement costs there will also be costs to amend the law. These costs will only occur once at the start of the cost-benefit analysis and are included in the calculations. They will however not influence the results of the calculations; the benefits of random roadside breath testing will remain larger than the costs. The results show that increased random roadside breath testing and a zero BAC limit for young drivers is highly cost effective.

7.3. The Czech Republic

7.3.1. *The current situation*

In the Czech Republic some 5,662,550 people have a driving licence. There are around 195,851 accidents per year, leading to 1319 traffic deaths in 2003 of which 111 (8.4%) are related to alcohol (input CDV, 2004). The BAC limit is 0.0 g/l for all drivers. The zero BAC limit for young drivers will thus have no impact in the Czech Republic, other than an effect of the increased enforcement. Breath testing in the Czech Republic is nowadays used at routine police checks. The number of random roadside breath tests is currently estimated upon 900,000 tests per year (input CDV, 2004). In this analysis we assume that the number of random roadside testing will be doubled or tripled.

7.3.2. *Costs*

The costs related to random roadside breath testing in the Czech Republic are partly based upon Dutch costs (adjusted for the difference in wages between the two countries) (International Labour Organization) and are partly based upon estimates of CDV. This leads to the following cost elements. The personnel costs (including overhead costs) of a policeman amount to around € 11,700 per year. The costs of the breath tester are estimated at € 185 and the mouthpieces at € 0.10. The administrative and justice costs regarding offenders are estimated at € 100 per offender and the campaign costs are estimated at € 16,000 per year.

The number of additional tests is respectively 0.9 and 1.8 million. This will lead to additional personnel and material costs as mentioned above. At the same time the number of offenders will increase, leading to additional administrative costs. The campaign costs are estimated to be independent of the number of additional tests. This will lead to the following costs for a doubled or tripled amount of random roadside tests.

	Number of roadside breath testing doubled	Number of road side breath testing tripled
Personnel costs	0,7	1,3
Material costs	0,1	0,1
Administrative and justice costs	3,1	6,2
Campaign costs	0,02	0,02
Total	3,9	7,7

Table 7.2. *Summary of different costs elements (€ million).*

7.3.3. *Safety effects*

To determine the safety effects for the Czech Republic, we use the general assumptions (based on an ESCAPE working paper (Elvik, 2001)), namely that an increase of road side breath testing by a factor of 2 would yield 20% of the theoretically possible maximum potential benefit and an increase of the breath testing with a factor 3 would yield 30%.

For the Czech Republic we have determined the effects of a doubled and tripled number of breath tests. This means that 20% or 30% of the maximum possible benefits will be achieved, leading to a reduction of respectively 22 or 33 traffic deaths per year (total of 111 traffic deaths due to alcohol).

7.3.4. *Results*

In the following table a summary of the results for the Czech Republic is presented. The reduction in traffic deaths is valued at € 1.1 million per traffic death, being the Czech estimate of the value for a reduction per traffic death (input CDV, 2004).

Reaction	Number of road side breath testing doubled	Number of roadside breath testing tripled
Safety	24,8	37,2
Costs	-3,9	-7,7
Mobility	n.a.	n.a.
Environment	n.a.	n.a.
SUM (net annual benefit)	20,9	29,5
B/C ratio	6,4	4,8

Table 7.3. *Summary of results (€ million).*

The table shows that an increase in random roadside breath testing has a positive socio-economic effect, despite the small amount of alcohol related accidents. The BCR is larger than one, since the safety effects are larger than the related costs. A doubling of the random roadside breath tests leads to larger net benefits but a lower BCR than a tripling of the tests.

7.4. **Norway**

7.4.1. *Current situation*

Unfortunately, there exists no more recent Norwegian statistical data on alcohol-related road accidents. There are no easily available data on roadside breath testing either. This makes it virtually impossible to make a well-founded economic analysis of these two sub-projects. Thus, most of the current situation has to be presumed for the sake of performing something like a calculation exercise.

Since 2000 the BAC limit in Norway is 0.2 g/l (reduced from 0.5 g/l). Thus, for the BAC limit reduction one must need to know the shares of accidents (and injuries and fatalities) caused by young drivers driving with BAC levels between 0 and 0.2 g/l.

Elvik (1999) provides estimates of the safety effects, benefits, and costs of both intensifying roadside breath testing (tripling current efforts) and reducing the BAC limit from 0.5 g/l to 0.2 g/l *for the whole population*. We will apply these estimates at face value for roadside breath testing and also use it as a point of departure for the 'guesstimates' of reducing BAC levels (from 0.2 g/l to zero) for the age group 18-24. We simply presume that the

expected effect, if this were for the whole population, would be a quarter of the effect of the reduction from 0.5 to 0.2 g/l, approximating the observed relationship of an exponential growth of risk with increasing BAC levels. Applied to the whole population, this BAC reduction would be estimated to yield an annual safety effect of 0.75 avoided fatalities and 11 avoided injuries. Limiting the new BAC reduction law to those below 25, we will presume that 30% of the whole population effect can be applied, yielding 0.23 avoided fatalities (nearly one every fourth year) and 3 avoided injuries (1 serious and 2 slight).

Regarding the increased roadside breath testing Elvik (1999) presents the safety effects of a tripling of current efforts: 9 avoided fatalities and 144 avoided injuries. In the background data of this report, the safety effects of a doubled control are also estimated: 6 avoided fatalities and 99 avoided injuries.

7.4.2. *Costs – legal BAC limit equal zero for young drivers*

It seems adequate to presume similar cost figures for a 0.2 - 0.0 reduction as for the 0.5 - 0.2 reduction (Elvik, 1999). Limiting the project to young drivers we assume, for simplicity and prudence (and probable 'economies of scale'), as much as 50% of the costs compared to a project for the whole driver population. This yields an annual total cost of € 2.33 million, with investment costs of € 1.25 million, running costs of € 0.69 million, and tax costs (efficiency loss) of € 0.39 million (applying a €/NOK exchange value of 8 to the NOK values in Elvik, 1999).

7.4.3. *Benefits – legal BAC limit equal zero for young drivers*

The annual safety benefits follow from the multiplication of avoided deaths with their unit safety value according to the One Million Euro Test . This was estimated to € 1.36 million. However, there are also negative benefits from such a legal change since some of those driving legally today (with BAC between 0 and 0.2 g/l) may be impeded from driving following a similar behaviour as today (e.g., taking one small glass of beer after the cinema and then drive back home). It is even more difficult to assess the consumer surplus loss from such a change because the driver can still (probably) get some amusement (welfare) from his activities (going to a cinema, a pub, a restaurant or whatever) without taking that small glass of beer. However, as a coarse simplification we presume that some of the driving is annulled due to this legal change, and that it represents a share of the estimate presented by Elvik (1999) equal to the share of kilometres driven by this age group. This yields a negative mobility benefit of € 1.14 million. The environmental effect from the annulled kilometres is estimated to € 0.27 million. Thus, total annual benefits equal (only) € 0.49 million.

7.4.4. *Summary – legal BAC limit equal zero for young drivers*

The net benefit of the project is clearly negative based on the applied presumptions. It should be noted that these estimates are indeed very uncertain.

7.4.5.   *Costs – roadside breath testing*

For a doubling of control efforts the annual costs are estimated at € 16.54 million, with running costs of € 13.89 million and tax costs (efficiency loss) of € 2.76 million. For a tripling of control efforts the annual costs are estimated at € 33.08 million, with running costs of € 27.56 million and tax costs (efficiency loss) of € 5.51 million (Elvik, 1999).

7.4.6.   *Benefits – roadside breath testing*

The annual safety benefits for a doubling are estimated at € 35.4 million, while for a tripling these were estimated at € 53.1 million using the 1 Million-euro test. Increased police control and breath testing do not produce the same indirect benefits (negative mobility effects followed by environmental effects) as a legal change. Thus, overall gross benefits equal the safety benefits.

7.4.7.   *Summary – roadside breath testing*

The net benefits of increased police control are positive based on the applied presumptions, both for a doubling – with a BC ratio of 2.1 – and a tripling – with a BC ratio of 1.6.

7.4.8.   *Summary – both measures*

If roadside breath testing (for all drivers) and reduced BAC level to 0 (for young drivers) are to be considered as a common project, we would have the following estimated results:

Safety benefits	36,76
Environmental benefits	0,13
Mobility benefits	-0,55
Project costs	-18,86
SUM (annual net benefit)	15,14
BC ratio	1,93

Table 7.4. *Summary of results (€ million) – roadside breath testing for all drivers and zero BAC limit for young drivers.*

7.5.   **Spain**

7.5.1.   *Current situation*

The BAC limit in Spain is 0.5 g/l (reduced from 0.8 g/l in 1999). There is a BAC limit of 0.3 g/l for certain categories including inexperienced drivers and drivers of heavy goods vehicles and buses. In the Spanish case there is some data on driving with various levels of BAC and the BAC levels of samples of killed drivers (Del Río et al., 2002; Alvarez, 2004). The number of drivers with BAC level above 0.5 g/l is estimated to 634,343, based on survey data.

The percentage of the whole driver population with a BAC higher than 0.5 g/l was estimated to some 3% in 2000 and 2001, based on large surveys, while over 20% drove with BACs between 0 and 0.5 g/l. In samples of killed drivers from 2002 and 2003, approximately 40% had BACs above 0.1 g/l, and slightly more than 32% had BACs above 0.5 g/l. Thus, this would indicate that 1,704 drivers with BAC above 0.5 g/l are killed annually.

There is not any specific data available on current police control – roadside breath testing. Using averages from Dutch and Czech figures, we may estimate annual breath tests to approximately 6.3 million. Although driving with BAC levels above the limit (0.5 g/l) seems to be higher in Spain than in the other three countries, we also apply Dutch and Czech figures to estimate current annual positive breath tests to slightly more than 150,000.

There are approximately two million people under the age of 25 with a driving licence in Spain, representing approximately 9% of the driver population. We lack data combining BAC limits and accidents specifically for the group of drivers below 25. However, if the shares were equally distributed between age groups (something which the Dutch research indicates is not the case) the number of killed young drivers with BAC level above 0.3 g/l would be 447. There were 64 killed with BAC levels between 0.1 and 0.3 g/l. The estimated effect of a reduction of legal BAC limit for young drivers will be based on approximate ratios from the Norwegian analysis. If the effect from setting the BAC level to zero for young drivers is of the same order that in the Norwegian case it can be estimated that 13 fatalities can be prevented per year. This is probably an underestimate since the existing BAC level is 0.3 g/l for young drivers in Spain compared to 0.2 g/l in Norway.

7.5.2. *Costs – roadside breath testing*

Lacking original data, the estimated costs related to random roadside breath testing in Spain are based on averaging the cost figures for the Czech Republic and the Netherlands. For a doubling and a tripling of control efforts the numbers of additional tests are, respectively, 6.3 and 12.6 million. This will lead to additional personnel and material costs. At the same time the number of sentenced offenders will increase, leading to additional administrative costs. The campaign costs are estimated to be independent of the number of additional test. This will lead to the following costs for a doubled or tripled amount of random roadside tests.

	No. of roadside breath testing doubled	No. of road side breath testing tripled
Personnel costs	17,2	34,3
Material costs	1,8	3,7
Administrative and justice costs	82,1	164,4
Campaign costs	0,5	0,5
Total	101,6	203,0

Table 7.5. *Summary of costs elements (€ million) – increased roadside breath testing.*

7.5.3. *Benefits – roadside breath testing*

To determine the safety effects for Spain we use the general assumptions (based on Elvik, 2001), that an increase of roadside breath testing by a factor of 2 would yield 20% of the theoretically possible maximum potential benefit and an increase of the breath testing with a factor 3 would yield 30%. For Spain this would yield, respectively, 341 and 511 prevented fatalities per year. Applying the estimated Spanish value of the One Million Euro Test of approximately € 800,000, the annual safety benefits can be estimated to € 271 and € 407 million, respectively.

7.5.4. *Results – roadside breath testing*

In the following table a summary of the results for Spain is presented.

Effect	Doubling	Tripling
Safety benefits	271,0	406,5
Project costs	-101,6	-203,0
SUM (annual net benefit)	169,4	203,5
BC ratio	2.7	2.0

Table 7.6. *Summary of results (€ million) – roadside breath testing.*

The results indicate that an increase in random roadside breath testing would have a large, positive economic effect. The BC ratio is well above 2 for a doubling and equal to 2 for a tripling.

7.5.5. *Costs – legal BAC limit equal zero for young drivers*

Also the cost figures for reducing the BAC level to zero for young drivers will be approximated by the Norwegian cost relation figures between BAC limit reduction and roadside control. From this approach the project costs are estimated to € 14.3 million annually.

7.5.6. *Benefits – legal BAC limit equal zero for young drivers*

To determine the safety benefits for Spain we apply the estimated Spanish value of the One Million Euro Test of approximately € 800,000. Then the annual safety benefits can be estimated at € 10.2 million.

The negative mobility benefits from the impeded car driving, due to this legal change, will also be approximated by the Norwegian cost relation figures between BAC limit reduction and roadside control – taking into account the relationship between the estimated Spanish and Norwegian consumer surplus values from driving (€ 0.32 versus € 0.58). This provides an estimate of € 1.9 million annually.

The value of reducing emissions to environment from transport (reduced car driving) will also be approximated by the Norwegian cost relation figures between BAC limit reduction and roadside control – taking into account the relationship between the estimated Spanish and Norwegian environmental valuation. This provides an estimate of € 240,000 annually.

Results – legal BAC limit equal zero for young drivers

In the following table a summary of the results for Spain is presented.

Safety benefits	10,2
Environmental benefits	0,2
Mobility benefits	-1,9
Project costs	-14,3
SUM (annual net benefit)	-5,8
BC ratio	0.6

Table 7.7. *Summary of results (€ million) – zero BAC limit young drivers.*

The results indicate that a reduction of the legal BAC limit from 0.3 g/l to zero in Spain would not be efficient. The BC ratio is well below one. Safety effects seem not to be high enough to offset relatively high estimated project costs, and the negative mobility effects are also considerable. However, these results can be regarded as highly speculative.

7.5.8. *Summary – both measures*

If roadside breath testing (for all drivers) and reduced BAC level to zero (for young drivers) are to be considered as a common project, we would have the following estimated results:

Safety benefits	281.2
Environmental benefits	0.2
Mobility benefits	-1,9
Project costs	-115,9
SUM (annual net benefit)	163,6
BC ratio	2.4

Table 7.8. *Summary of results (€ million) – roadside breath testing for all drivers and zero BAC limit for young drivers.*

7.6. **Overview of results different countries**

In *Table 7.9* an overview of the benefits, the costs and benefits/costs ratio are presented. In each country a doubling of the number of roadside breath tests has been assumed.

	Netherlands			Norway			Czech Republic			Spain		
	B	C	B/C	B	C	B/C	B	C	B/C	B	C	B/C
Increased breath test	314	-42	7,5	35	-17	2,1	25	-4	6,4	271	-102	2,7
- Incl. zero BAC limit	376	-42	9,0	36	-19	1,9	-	-	-	280	-116	2,4
Note: (-) means not relevant, (n.p.) means not performed due to lack of data. In the Czech Republic the BAC limit is zero for all drivers so lowering the BAC limit for young drivers is not relevant.												

Table 7.9. *Results of random alcohol breath testing and zero BAC limit for young drivers (€ million, annual effects).*

Positive socio-economic yield
The increased random roadside breath tests lead to a positive socio-economic yield for the countries. For the Czech Republic the lowering of the BAC limit for young drivers is not relevant because this country already has a zero BAC limit for all drivers.

Different results for countries
Although the net benefits for increased random roadside breath testing are positive for all four countries, the benefit-cost ratio differ. They are quite high in the Netherlands and the Czech Republic and rather low in Norway and Spain. An important reason for this is that the estimates about the number of fatalities caused by drunk drivers differ greatly between the countries.

No loss of welfare due to withdrawal of the driving licence
The random road side breath testing and the zero BAC limit does not prevent people from driving, but only from drunk driving. This means that there is no loss of welfare with regards to mobility other than that some people will feel forced to drink elsewhere or use another mode of transport. This is however an internalised decision. The absence of effects on mobility also leads to an absence of environmental effects and of a second order safety effects.

Sensitivity analysis
Of course there are some assumptions used in order to calculate the safety effects and the costs. However, since this countermeasure has been studied before, most data was available and rather reliable for especially the Netherlands and Norway. The most decisive assumption is that if the random roadside breath test is doubled, 20% of the theoretically possible maximum benefit will occur. For instance for the Netherlands the socio-economic yield will turn negative if only 3% of the theoretically possible maximum benefit will occur. This however is rather opposite to the 26 evaluation studies that were assessed in the meta-analysis.

8.   CBA alcohol lock

8.1.   **Description of the measure**

This countermeasure includes the installation of an alcohol lock in cars for every driver that is caught with a BAC level of 1.3 g/l or higher or for drivers that are caught twice with a BAC level between 0.5 g/l and 1.3 g/l. Drivers the first time caught with a high BAC level or the second time caught with a moderate BAC level often are addicted to alcohol. Regular driver improvement training (about three group sessions) has little impact on drivers with a serious alcohol problem. An alcohol lock in combination with intensive driver improvement training might be a proper treatment for these addicted drivers.

In the United States, Canada, and Sweden the installation of an alcohol lock has led to good results. In a recent study in Maryland offenders were randomly assigned to the experimental and the control group, showing that recidivism was reduced in the first year of installation of a Breath Alcohol Ignition Interlock Device (Beck et al., 1999). Most studies show that after removal of the lock recidivism appeared to increase again, leading to almost no residual effect. Therefore some rehabilitation programme (after removal of the lock) should be included in the measure, including monitoring and enforcing (Bax et al., 2001).

The alcohol lock will have to meet certain technical standards related to reliability, accuracy, circumvention, and tampering and electromagnetic interference with the vehicle and vice versa. The most recent and most demanding standards are the Alberta standards (applied in Sweden). However, it is not to be expected that these standards will be used on a EU level, accurate function up to 3.500 metres or within a temperature range of –45° to +85° Celsius.

General assumptions:
– *no rehabilitation programme*; we assume that there is no accompanying or post project rehabilitation programme, so all effects are disregarded after two years, when the alcohol lock is removed.
– *medical tests during installation period*; we have assumed four medical tests per year during the two-year installation period.
– *suitability of offenders*; it might be possible that not all offenders are suitable to receive an alcohol lock. In this CBA however, we assume that 100% of the offenders that are caught are suitable for the alcohol lock programme.
– *no mobility and environmental effects*; the alcohol lock aims to prevent people from drinking more than the permitted amount of alcohol before driving. It does not prevent people from sober driving. If the aim is achieved, the mobility will not be affected. However some people will feel forced to choose another transport mode or stop travelling, leading to minor welfare losses. These effects are not taken into account, since the drunk driving with which the benefits were obtained was illegal. Since we do not take any mobility effects into account there will also be no environmental effects.

8.2. The Netherlands

8.2.1. *Current situation*

In the Netherlands the BAC limit is 0.5 g/l. Sanctions are imposed according to a system of penalty points (each point representing a fine of € 22). If the number of penalty points exceeds 30 the public prosecutor will, on top of the fine, request a probationary license suspension, a license suspension or imprisonment and license suspension. In the following table the number of offenders of the BAC limit are presented, including the related traffic deaths.

BAC-value	Number of drivers	Number of traffic deaths
0.5-1.3 g/l	95,145	54
1.3-1.8 g/l	32,000	109
>1.8 g/l	16,000	163

Table 8.1. *Overview of offenders of BAC limit and amount of related traffic fatalities.*

8.2.2. *Costs*

In the Netherlands some 1.5 million roadside breath test were performed in 2003. This means that in general one in seven car drivers is tested each year. However drunk drivers have a higher chance of getting caught since they drive more at night (when most road side tests are carried out), they are more involved in accidents, and have a noticeable driving pattern. We therefore assume that the chance of getting caught while having been drinking is 25%. This means that each year around 12,000 offenders with a BAC higher than 1.3 are caught (25% of 48,000 drivers) and 5,950 drivers are caught twice with a BAC between 0.5 and 1.3 (25% of 25% of 95,145 drivers), leading to a total of 17,950 participants each year.

For each participant there are introduction costs of € 420 (application, medical examination, administration and installation costs). After implementation, the annual costs consist of rent of the alcohol lock (€ 1344) and costs for four medical examinations per year (€ 672). After the installation period of two years, there are costs related to the dismantling of the alcohol lock (€ 112) (Bax et al, 2001). In total the costs per participant amount to € 4,564 for a two-year programme, leading to total costs of € 41 million per year for al offenders.

8.2.3. *Traffic safety effects*

In order to establish traffic safety, it is necessary to know the risk of recidivism. In the Netherlands it is estimated that the risk of repeated drunk driving is 70% for drivers with a BAC higher than 0.5 g/l and 80% for drivers with a BAC higher than 1.8 g/l. The alcohol-lock will lower the risk of recidivism to 70% for all drivers, leading to a risk reduction of recidivism of respectively 49% and 56%.

– The traffic safety effect of an alcohol lock for drivers with a BAC higher than 1.3 g/l is a reduction of 33 traffic fatalities (272 fatalities * 25% of getting caught * 49% less recidivist risk).

– The traffic safety effect of an alcohol lock for drivers caught twice with a BAC between 0.5 and 1.3 g/l is a reduction of 2 traffic fatalities (54 fatalities * 6.25% of getting caught twice * 49% less recidivist risk).

8.2.4. *Overview and results*

In the following table a summary of the results for the Netherlands is presented. The reduction of 35 traffic fatalities per year is valued at € 4.8 million per traffic death, using the Dutch value for the One Million Euro Test of the European Commission.

Reaction	Alcohol lock for drivers caught with BAC > 1.3 or drivers caught twice with BAC between 0.5 and 1.3
Safety	168
Costs	-41
Mobility	n.a.
Environment	n.a.
SUM (annual benefits)	127
BC-ratio	4.1

Table 8.2. *Summary of results (€ million).*

The results show that the annual benefits are larger than the annual costs, leading to a positive socio-economic result. The effects and costs will occur during the installation period of two years. After this period we assume the effects to be negligible, since there is no rehabilitation programme included in the measure. The costs are expressed in annual costs, so that the BCR will not be influenced by the time period for which the cost-benefit analysis is executed. The BCR is larger than 1, since the safety effects are larger than the costs.

8.3. **The Czech Republic**

8.3.1. *The current situation*

Only a very few cars in the Czech Republic are equipped with an alcohol lock. The practicability of this measure is expected to be rather low due to the missing legislation, lack of compliance, and the public opinion. However it will attribute to a reduction of the 195,850 road accidents per year. We have assumed that there are 140,000 car drivers under the influence of alcohol, since in 4.5% of the accidents alcohol was involved and the relative accident risk of alcohol is 1.8. The total number of car drivers under the influence of alcohol is thus 2.5% of all drivers (1/1.8 * 4.5%). The distribution of the BAC levels is estimated to be the same as in the Netherlands. Per year there are 1319 traffic deaths and 111 traffic deaths are related to alcohol abuse (input CDV, 2004).

BAC-value	Number of drivers	Number of traffic deaths
0.5-1.3 g/l	92,853	18
1.3-1.8 g/l	31,229	37
>1.8 g/l	15,615	56

Table 8.3. *Overview of offenders of BAC limit and amount of related traffic fatalities.*

Compared to the Netherlands, the number of drivers under the influence of alcohol is similar, but the number of traffic fatalities is a lot lower. This is due to the fact that according to Czech statistics some 8% of all accidents are related to alcohol, while in the Netherlands this is around 30%.

8.3.2. *Costs*

The costs related to the implementation of the alcohol lock are based on the average costs (Bax et al, 2001). These costs are adjusted by using the wage factor between the Netherlands and the Czech Republic [International Labour Organisation]. This leads to the following costs per alcohol lock:
– introduction costs € 104
– rent of alcohol lock € 332 per year
– costs medical tests € 166 per year
– removing costs € 28

These costs are related to 7,500 offenders of a BAC higher than 1.3 g/l and 2,375 offenders getting caught twice with a BAC between 0.5 and 1.3 g/l. The total annual costs are thus € 5.6 million per year.

8.3.3. *Traffic safety*

The risk of getting caught in the Czech Republic is some 16% (22,231 positive breath tests per year). The recidivist risk is unknown and thus the recidivist risk of the Netherlands is used, leading to a reduction of the risk of recidivism of respectively 49% and 56%. The total reduction in traffic deaths is 8 traffic fatalities for drivers with a BAC higher than 1.3 g/l and 0.2 traffic fatalities for drivers caught twice with a BAC between 0.5 and 1.3 g/l. The total reduction in traffic deaths is thus 8 traffic fatalities per year. The socio-economic value of a reduction in traffic deaths in the Czech Republic is € 1.1 million per traffic death, leading to socio-economic benefits of € 9.0 million per year.

8.3.4. *Overview and results*

In the following table a summary of the results for the Czech Republic is presented.

Reaction	Alcohol lock for drivers caught with BAC > 1.3 or drivers caught twice with BAC between 0.5 and 1.3
Safety	9.0
Costs	-5.6
Mobility	n.a.
Environment	n.a.
SUM (annual benefits)	3.4
BC-ratio	1.6

Table 8.4. *Summary of results (€ million).*

For the installation of an alcohol lock in the Czech Republic the safety effects are significantly larger than the costs. Therefore the BCR is higher than one, meaning that the socio-economic effect is positive.

8.4. **Norway**

8.4.1. *The current situation*

Few cars in Norway are currently equipped with an alcohol lock, but positive experience from other countries, especially from Sweden, has increased the political relevance of such a measure. However there is lack of recent data that, e.g., allows the differentiation between drivers sentenced with BAC levels below or above 1.3 g/l. An approximation can be made based on the extrapolated figures (extrapolated with the aid of 2002 figures from Statistics Norway) of the figures of Ruud & Glad (1990). The BAC limit intervals used by Ruud & Glad about the number of drivers caught for drinking and driving were 0.5-1.0, 1.0-1.5 and >1.5. The drivers over 1.5 can be approximated to the 1.3-limit for alcohol lock installation at first sentence. Updated to the situation in 2002, in Norway there are approximately 2,599 drivers per year that are first time sentenced for driving with a BAC > 1.3. If it is assumed that the proportion of drivers first time caught with a BAC > 1.3 and the second time caught with a BAC between 0.5 and 1.3 is the same in Norway as in the Netherlands, in Norway there are annually 217 offenders the second time caught with a BAC between 0.5 and 1.3.

8.4.2. *Costs*

If the same costs per participant are applied as for the Netherlands for the various segments of an alcohol lock programme (see *Paragraph 8.3.2*), the total costs for all participants transferred to the Norwegian price level are:
– introduction   € 1,18 million
– rent   € 3,78 million
– medical examination   € 1,89 million
– dismantling   € 0,31 million

The total annual costs are thus € 7.2 million per year.

8.4.3. *Traffic safety effects*

If the effects of the alcohol lock programmes are the same in Norway as estimated in the Netherlands (see *Paragraph 8.2.3*) then there will be 5.4 less fatalities annually because of alcohol locks installed in cars of first time offenders with a BAC > 1.3 and 0.1 less fatalities because of alcohol locks installed in cars of second time offenders with a BAC between 0.5 and 1.3. In total it is estimated that the annual reduction of fatalities will be 5.5.

8.4.4. *Benefits*

When applying the One Million Euro Test (see *Paragraph 5.2.2* in *Chapter 5*) without immaterial costs the benefits are 5.5 × 5.9 = 32.5 million euro per year.

8.4.5. *Overview and results*

In the following table a summary of the results for Norway is presented.

Reaction	Alcohol lock for drivers caught with BAC > 1.3 or drivers caught twice with BAC between 0.5 and 1.3
Safety	32.5
Costs	-7.2
Mobility	n.a.
Environment	n.a.
SUM (annual benefits)	25.3
BC-ratio	4.5

Table 8.5. *Summary of results (€ million).*

The results show that the annual benefits are larger than the annual costs. The BCR is rated 4.5. The effects and costs will only occur in the period of two years that an alcohol lock is installed.

8.5. **Spain**

8.5.1. *The current situation*

Although we lack specific input on alcohol locks in Spain, it is presumed that also in this country relatively few cars have such equipment installed. Further, since we lack information on alcohol control and positive breath tests (only having data from surveys on drunk driving), we will have to make assumptions about current control levels and how many would potentially be caught and participating in a (enforced) alcohol lock programme.

The number of killed drunk drivers is given as 1327 annually. Based on the data on drivers with BAC level above 0.5 g/l, estimated to 634,343, we will assume the following: as in the Dutch case we will apply 12.54% as the share of offending drivers as indicating how many would participate annually in the alcohol lock programme, i.e., 79,547 sentenced drivers, 26,674 with

BAC level above 1.3 g/l and 6,630 for the second time with BAC level above 0.5 g/l). Compared to the Czech figures this would indicate approximately 150 thousand positive breath tests annually. The risk of getting caught is implicitly assumed at 12.54%, as in the Netherlands. Also the recidivist risk is set equal to that applied for the Netherlands (and for the Czech Republic) – at 1.57%. With all these assumptions it is estimated that annually 26,674 drivers having a BAC > 1.3 are for the first time sentenced and 6,630 with a BAC between 0.5 and 1.3. are sentenced for the second time.

8.5.2. *Costs*

Without basic input it has been chosen to apply an average of Dutch and Czech costs, mirroring that the price/wage level of Spain is between that of these two countries. This leads to the following cost estimates per alcohol lock per participant:
– introduction costs   € 262
– rent of alcohol lock   € 838 per year
– costs medical tests   € 419 per year
– removing costs   € 70

Since the project horizon is only two years we may skip discounting and just find annual costs. As there are 26,674+6,630=33,304 participants this yields an estimate of nearly € 99 million per year.

8.5.3. *Traffic safety benefits*

Taking an average of the effect on saved lives between the Dutch and Czech figures (saved lives as a ratio of participants in the alcohol interlock programme), the estimated safety effect for Spain is 86 lives annually (presumably 83 due to the sub-measure against offenders with BAC level above 1.3 g/l and 3.9 due to the sub-measure against second-time offenders with BAC level above 0.5 g/l). The total reduction in traffic deaths is 86.5. Using an estimated Spanish value for the One Million Euro Test at approximately € 800,000, this yields an economic benefit of slightly more than € 69 million per year.

8.5.4. *Summary*

In the following table a summary of the results for Spain is presented.

Reaction	Alcohol lock for drivers caught with BAC > 1.3 or drivers caught twice with BAC between 0.5 and 1.3
Safety	69
Costs	-99
Mobility	n.a.
Environment	n.a.
SUM (annual benefits)	-30
BC-ratio	0.70

Table 8.6. *Summary of results (€ million).*

For the installation of an alcohol lock in Spain the costs are larger than the safety benefits. Therefore the BC ratio is lower than one. The combined effect of relatively low accident values (not much more than a tenth of the Dutch value) and presumed relatively high project costs is sufficient to make this project unprofitable in Spain. When only police reports are used and no blood samples are taken after each accident, the number of alcohol related accidents are rated much lower than they really are. In the Netherlands the estimated number of alcohol related accidents are based on a recent case-control study (see *Tabel 4.1* in *Paragraph 4.4.1*). For Spain such a study was not available. This may indicate that in Spain in reality the number of alcohol related accidents is much higher than the official data indicate.

8.6.   **Overview of results different countries**

In *Table 8.7* an overview of the benefits, the costs and benefits/costs ratio are presented.

	Netherlands			Norway			Czech Republic			Spain		
	B	C	B/C	B	C	B/C	B	C	B/C	B	C	B/C
Alcohol lock	168	-41	4.1	32.5	-7.2	4.5	9	-5.6	1.6	69	-99	0,7

Table 8.7. *Results of installation alcohol lock (€ million, annual effects).*

Mixed results for socio-economic yield
Only for Spain are the costs higher than the benefits. The reasons for this are that the benefits for lives saved are comparatively low for Spain and the number of 'caught' drivers is relatively low.

No loss of welfare due to withdrawal of the driving licence
The installation of the alcohol lock does not prevent people from driving, but only from drinking and driving. This means that there is no loss of welfare with regards to mobility, other than that some people will feel forced to drink elsewhere or use another mode of transport. This is however an internalized decision. The absence of effects on mobility also leads to an absence of environmental effects and of second order safety effects.

Sensitivity analysis
It is assumed that the risk of recidivism will decrease during the installation period due to the alcohol lock. The assumed decrease in recidivism is 49%. Besides this the risk of getting caught is estimated to be 25%, based on the number of random roadside breath testing and the increased risk of getting caught for a drunk driver. These two assumptions are very decisive for the safety effects. However since the results are rather positive for most countries, the assumptions are rather robust. For instance for the Netherlands the countermeasure will still have a slightly positive effect if the risk of getting caught is only 10% and the decrease in recidivism is only 20%.

9.   Conclusions and recommendations

9.1.   **Conclusions**

In the following the results of the cost-benefit analysis are summarized. The values are expressed in € million and represent annual effects. The annual effects are expected to remain the same over the project period. The benefit-cost ratio will therefore not be influenced by the chosen time period.

	Netherlands			Norway			Czech Republic			Spain		
	B	C	B/C	B	C	B/C	B	C	B/C	B	C	B/C
Testing eye sight												
- Visual acuity	-210	-30	-7	-10	-5	-2,0	4	-1.1	-4,0	-	-	-
- Standard eye test	-805	-40	-20	-29	-6	-4,8	n.p.	n.p.	n.p.	-	-	-
- Standard eye test incl. UFOV	-1047	-60	-17	-44	-20	-2,2	n.p.	n.p.	n.p.	81	-55	1.5
Alcohol – breath test												
- Increased breath test	314	-42	7.5	35	-17	2.1	25	-4	6.4	271	-102	2.7
- incl. zero BAC limit young drivers	376	-42	9.0	36	-19	1.9	-	-	-	280	-116	2.4
Alcohol – lock	168	-41	4.1	32.5	-7.2	4.5	9	-6	1.6	69	-99	0.7
Note: (-) means not relevant, (n.p.) means not performed due to lack of data. In Spain mandatory eyesight testing (excl. UFOV) is already in place. In the Czech Republic the alcohol limit for all drivers is zero BAC.												

Table 9.1. *Results of different measures for different countries (€ million, annual effects).*

Eyesight testing
The socio-economic yield of mandatory eyesight testing is in general negative. This is mainly caused by the loss of welfare due to the withdrawal of the driving licence. Especially when the driving licence is withdrawn at a young age, the mobility effects have a large negative impact. The percentage of trips that will not be made anymore is low for young people; most trips will be made by another mode. Also the average distance travelled and the value of time for young people is much higher than for older people.

Besides the large negative mobility effects, the traffic safety benefits are relatively small. This is caused by the rather small relative risk ratios and the rather large negative second order safety effect. The small relative risk seems opposed to what is generally believed, namely that for driving good eyesight is of utmost importance. Probably most impaired drivers are compensating; when drivers don't see clearly they will generally reduce speed and increase headway times. The negative second order safety effects depend on the modal shift to other modes of transport. Sometimes these new modes have an even higher risk ratio than the impaired car driving (for instance mopeds). The first order safety effect due to the decrease of impaired car drivers is partly undone by the second order safety effects due to the increase on other modes of transport.

The only eyesight testing that might lead to positive results is testing the reduced field of view. This eyesight impairment leads to considerable relative risk ratios, the car drivers that suffer from this impairment are older and therefore the mobility effects of withdrawing the driving licence will be less decisive. The disadvantage of the UFOV test is that the data regarding prevalence and effectiveness is not completely reliable. Most epidemiological studies stem from one source that is not completely reliable. This makes the UFOV test, at this moment, less qualified as a decisive test for acquiring a driving licence. The sensitivity and selectivity of the test is, compared to other medical tests, acceptable but there always remains a risk to include false positives and exclude false negatives.

In general the withdrawing of driving licences leads to large negative socio-economic effects, especially when the driving licence is withdrawn at a young age. It seems thus more promising to focus on various treatments rather than on driving licence regulations. However setting a certain norm may promote drivers to seek treatment.

Alcohol related measures
Three countermeasures for drunk driving have been assessed, namely increased roadside breath testing, a zero BAC limit for young drivers and the installation of an alcohol lock. All measures seem promising. This is mainly due to the fact that the countermeasures aim at preventing drinking and driving by means of deterrence. In principle, these countermeasures will not cause any mobility effects and thus also no second order safety effects. Only for the zero BAC limit for young drivers in Norway this mobility effect was estimated.

The Czech Republic already has a zero BAC limit for all drivers. The percentage of drunk driving however can be decreased by increasing the enforcement, through increased random roadside breath testing. In the Czech Republic however the data regarding drunk driving and the accidents related to this drunk driving is rather poor. For instance, statistics from the Czech Republic show that the percentage of road fatalities caused by drunk drivers is 8% as opposed to 30% in the Netherlands.

General conclusions
Cost-benefit analysis is a rather complex instrument and the results depend heavily on the quality of the input. Some input, especially regarding the different aspects of traffic safety, is missing or is rather speculative. Therefore it is necessary to make assumptions. The assumptions made in this study, however, will not change the general conclusion, namely that withdrawing the driving licence (especially at a young age) based on mandatory eyesight testing will lead to a negative socio-economic yield. Preventing drunk driving through random road side tests, decreasing the BAC limit for young drivers, and installing alcohol lock all seem promising, even though the prevalence of alcohol abuse and the contribution to the road fatalities seems to be underreported, especially in the Czech Republic.

9.2. **Policy recommendations**

The cost-benefit analysis provides objective information for policy makers by presenting an overview of all relevant socio-economic effects in a structured

manner. It has a normative foundation, based on aggregating individual/household preferences, but the choice for policy measures always remains a political choice that might be influenced by other factors than the socio-economic yield. However some policy recommendations are included:

– *treatment of eyesight problems*; the withdrawing of driving licences leads to large negative socio-economic effects. Although the first order safety effect, due to the withdrawal of impaired drivers, is not very large, it is possible to take countermeasures against poor eyesight. These measures will however lead to a more positive socio-economic yield if they are based on treatment rather than on driving restrictions. An additional advantage is that this will, in contrary to driving licence restrictions, not prevent people from seeking medical treatment.

– *research of UFOV testing*; the results of the testing of useful field of view provided promising results for some countries. However, nowadays the quality of the input data is (partly) questionable. This raises the feeling that the UFOV test nowadays is not ready to play a decisive role in the provision of driving licences. It seems more research is needed to provide insight in prevalence, relative risk ratios and effectiveness.

– *deregulation of license restrictions might be fruitful*: based on this analysis, it is clear that the withdrawing of a driving licence leads to large negative socio-economic impacts. Especially when the initial relative risk ratio of the impairment is not so high, this will lead to a negative socio-economic yield. In the past, decisions on driving licence regulations were based on less information. This analysis shows that it might be fruitful, based on socio-economic principles, to review existing regulations.

– *more countermeasures assessed*; the number of possible countermeasures is infinite and there will undoubtedly be more promising countermeasures against impaired driving than the ones assessed in this report. A pre-selection of promising countermeasures was made in *Chapter 4*. Although explicit criteria were used and choices were based on sound arguments, it is possible that more promising countermeasures will be 'invented'.

– *stricter regulations for registration of accidents*; one of the largest difficulties in this cost-benefit analysis was the lack of accurate and detailed information. In some countries the registration of accidents provides a sound basis for the analysis, but in most European countries the registration of medical impairments, prevalence, accidents, and accident related costs are not well known. In order to provide an objective and structured basis for decision-making it is necessary that the available data will be more accurate and detailed. The European Commission might provide a framework for registering accident data and perhaps even medical information.

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