Assessment of Road Safety Measures

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(Road Safety and Environmental Benefit-Cost and
Cost-Effectiveness Analysis for Use in Decision-Making)

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Kurzfassung – Abstract

Die ökonomische Bewertung von Straßenverkehrssicherheitsmaßnahmen

Die Europäische Union hat sich zum Ziel gesetzt, die Anzahl der Getöteten im Straßenverkehr bis zum Jahr 2010 zu halbieren. Um dieses Ziel zu erreichen, ist es notwendig, sinnvolle Prioritäten zu setzen und effektive Straßenverkehrssicherheitsmaßnahmen umzusetzen. Den Entscheidungsträgern dient die ökonomische Bewertung dieser Maßnahmen als sachliches Kriterium bei der Auswahl der umzusetzenden Sicherheitsmaßnahmen.

Nachfolgend wird ein Überblick darüber gegeben, wie Straßenverkehrssicherheitsmaßnahmen ökonomisch bewertet werden können, welche methodischen Prinzipien hierbei beachtet werden müssen, welche Daten notwendig sind und dem Evaluator zur Verfügung stehen und welche Barrieren bei der Bewertungsarbeit auftreten können. Darüber hinaus werden Beispiele bewerteter Maßnahmen und eine Kurzfassung über den Themenbereich der ökonomischen Bewertung in Form einer PowerPoint Präsentation dargestellt.

Die nachfolgend dargestellten Erkenntnisse wurden im Rahmen des EU Projekts ROSEBUD[1] gewonnen. Im Einzelnen haben an der Erstellung dieses Berichts folgende Autoren mitgewirkt:

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[1] Road Safety and Environmental Benefit-Cost and Cost-Effectiveness Analysis for Use in Decision-Making

Assessment of road safety measures

The European Union has the objective of halving the number of deaths on European roads by 2010. To achieve this it will be necessary to implement the most effective road safety measures. Efficiency assessment is a tool which should help policy makers to set more effective priorities for road safety measures, and hence lead to a considerable reduction of accidents.

This document provides an overview how the efficiency of road safety measures can be assessed, which methodological principles are

important, which knowledge and data are needed and available, and which barriers may hinder the process. A few basic principles for analysts are presented. In addition, examples of assessed measure are described. Finally, a short demonstration course is provided for the dissemination of this information.

Contents

1 Introduction

It is a challenge to develop effective measures for improving road safety – especially when resources are scarce and economic means are limited. Nevertheless, a major target for European policy as well as national, regional and local decision makers is to improve road safety significantly.

To improve road safety is not an end in itself – it is an urgent social task. In the year 2005 about 41 600[2] persons were killed in accidents on European roads. In general economic terms the economic loss of accidents for example in Germany amounts to over 30 billion Euro per year.

In order to help meet this challenge, the research project ROSEBUD[3] was funded by the European Commission as a thematic network to support users at all levels of government (European Union, national, regional, local) with information about road safety related efficiency assessment solutions. For this aim, ROSEBUD brought together researchers, policy makers, decision makers and other relevant stakeholders into a co-operative network.

The European Union has the objective of halving the number of deaths on European roads by 2010. To achieve this it will be necessary to implement a range of effective road safety measures to the fullest extent. Reliable knowledge about the effectiveness of road safety measures is a prerequisite for this task. Efficiency assessment is a vital tool which should help policy makers to set more effective priorities for road safety measures, and hence lead to a considerable reduction of accidents.

This document is a manual for the assessment of road safety measures. The following pages will provide an overview of how the efficiency of road safety measures can be assessed, which methodological principles are important, which knowledge and data are needed and available, and which barriers may hinder the process. A few basic principles for analysts are presented. In addition, examples of assessed measure are described. Finally, a short demonstration course is provided for the dissemination of this information. This document deals specifically with road safety and does not apply to other aspects of transport projects.

2 How road safety measures are assessed

This section sets out to describe, in layman's terms, how efficiency assessment tools can be used to improve road safety. Although many aspects of these tools are technical and experts normally use technical terms to discuss and apply them, the underlying aims and concepts are general and can be understood by everyone. Those who are entrusted by society to take decisions about which road safety measures to implement will thus be able to see how these tools can assist them in their task. The tools will not carry out the task for them; they provide crucial information which will help them to take the best decision, subject of course to constraints such as the resources available to them.

Roads and road transport play a central role in modern societies. Most of the goods needed for everyday life are transported by road, and the current generation has far greater opportunities for travel in the course of work and leisure than earlier generations. These advantages have, however, come at a cost. In addition to the obvious costs of building roads and vehicles and providing fuel, there are various less obvious costs: human and environmental. We focus here on the costs to society that are the result of road accidents.

These costs already existed before the modern era of motor transport: for example, large numbers of people were killed and injured in the 19th century while riding horses, or run down by horse-drawn vehicles. Nowadays, however, society does not accept these costs passively, but introduces measures that attempt to reduce the number of accidents – or ideally to eliminate them. These efforts have achieved great success in most European countries, with the number of fatal or severe accidents falling at a time when the volume of traffic has grown rapidly. Nevertheless, the level of accident risk on the roads is still unacceptable, even in the safest countries. Hence, so much remains to be done to improve road safety.

Over the past decades, a large body of practical knowledge has been built up to show which

2 In the EU25

3 Road Safety and Environmental Benefit-Cost and Cost-Effectiveness Analysis for Use in Decision-Making

measures are effective in which situations, and this helps greatly to develop new measures and programmes for improving road safety. The resources available, however, are rarely if ever sufficient to be able to do everything that is likely to reduce the number of accidents. Therefore, a decision must be made about which measures to implement.

This decision needs to take account of:

- the nature of the particular road safety problem being addressed,
- the range of potential measures,
- the resources available,
- potential physical or political constraints.

Each measure that is identified as being likely to address the particular problem is assessed in turn, taking account of:

- its predicted effects, including intended benefits such as casualty reductions but also potential drawbacks such as increased pollution or greater travel time,
- possible variation of effects within a time path,
- the costs of implementation.

In the final stage of the assessment process, the benefits and costs of the alternative measures are compared. The alternatives are then ranked according to the ratio of benefits to costs, and the most highly ranked effective measure can be selected. This selection offers the highest overall level of benefit relative to the costs of implementation, and ensures that the available resources are used in the most effective manner.

The two main methods used to assess road safety measures are:

Cost-Effectiveness Analysis (CEA)

and

Cost-Benefit Analysis (CBA)

Full details of both methods are presented in the third section of this document, with information about how to choose the more appropriate method when assessing a particular measure.

In the case of larger-scale measures, efficiency assessment can play an important part in developing the measure. Planning often takes many months if not years, and during this time information can be refined or new options can become available. Once the basic assessment framework has been established, the calculations can be readily updated and the implications assessed.

The problems being addressed in this report relate to road safety, so the estimation of the reduction of accidents and casualties that will be achieved by a particular measure is a crucial stage in the assessment. Road accidents are unpredictable events, so how can these benefits be predicted with any confidence? While it is true that individual accidents cannot be predicted, these are not random events and research has identified various factors which make an accident more or less likely to occur. This makes it possible to predict how the existing pattern of accidents would change if a new measure were to be introduced. Nevertheless, it is important to monitor the new pattern of accidents after a measure has been introduced in order to check the accuracy of the prediction.

The use of the structured decision making process outlined above has many advantages:

- it is transparent: this is likely to increase public acceptance since the various stages in the process are documented and can be defended against criticism,
- it is comprehensive: all effects that may be predicted are brought together in a single framework,
- it is in accordance with the principles adopted by national governments to ensure the best use of public money,
- the assessments can incorporate the best available knowledge about the effects of road safety measures,
- the assessments incorporate public preferences: they include, for example, the results of surveys which have investigated the public's willingness to pay for improved road safety.

3 Efficiency assessment methodology

3.1 Introduction

Decision makers and politicians face many difficulties when deciding upon the implementation of road safety measures. They are obliged to choose those measures from a variety of measures that fit best in a certain situation, but it is not clear how the term 'best' should be defined. It is possible that those measures should be applied that entail the lowest costs. But success might also be gained if more expensive measures are implemented that have greater road safety benefits.

It is not enough to look at a measure's costs or at its benefits when deciding about its implementation. Both, costs and benefits, need to be jointly assessed and balanced against each other.[4] This ensures that the selection of road safety measures will follow principles of efficiency. The purpose of efficiency assessment is to provide information which supports this selection.

ROSEBUD mainly deals with two closely related methods for efficiency assessment: cost-effectiveness analysis (CEA) and cost-benefit analysis (CBA). Both represent economic evaluations of alternative resource use and measure costs in the same way. They differ in the analytical questions that can be answered. Within the CBA, all relevant costs and benefits are measured in monetary terms. On the other hand, within the CEA costs are also measured in monetary terms but benefits are expressed in non-monetary terms (e.g. number of saved lives). While the CBA can be used to assess the absolute efficiency of a measure (by monetizing all costs and benefits), the CEA can only be used to ascertain the effectiveness of a measure in accomplishing a particular objective (e.g. reduce the number of road accidents). In the following sections the two methods will be presented and their differences and common features will be described.

4 A situation can be imagined where the road safety effects of a measure are 50 percent higher than the effects of the alternative, but triple costs will occur for the "more effective" investment. In such a case, the effectiveness in road safety per unit of implementation cost is twice as high for the "less effective" measure.

3.2 Cost-Effectiveness Analysis

Within a CEA two or more road safety measures can be screened and ranked according to their costs and effectiveness in accomplishing a particular objective (e.g. reduction of accidents). The combination of effectiveness and costs helps the decision maker to ascertain

- which measure provides a given level of effectiveness at the lowest cost or,
- which program provides the highest level of effectiveness for a given total cost.

Unlike the CBA, the CEA expresses the benefits in physical impacts (e.g. reduction of accidents) rather than in monetary terms. Therefore the CEA will often be used in situations where

- the efforts required to conduct a CBA (collection and editing of data etc.) will not be justified by the benefits that might be expected from implementing a measure,
- the monetization of benefits will cause difficulties or is not possible,
- a single objective will be pursued with the implementation of a measure (e.g. reduction of accidents) and it is not necessary or not sensible to assess other benefits as is done within a CBA.

Assessing effectiveness

To assess the effectiveness of a road safety measure, the goal of the measure has first to be defined and a means of quantifying its success has to be specified (e.g. reduction of accident severity or reduction in the number of motorcycle accidents). An explicit definition is important to assure that the alternatives are assessed according to their success in achieving the objectives.

The measures' impacts on this pre-defined objective have to be appraised (in physical terms). Statements have to be made e.g. about the number of accidents that can be avoided by implementing the measures. The estimated total impacts of each measure are then compared with its costs.

The total impacts are expressed per unit of implementation cost, i.e. the number of accidents that can be avoided per unit of implementation cost is estimated. This allows the non-monetary benefits to be compared with the monetary costs.

Cost estimation

Besides the actual costs of implementing a measure, the total project costs include the costs of operation and maintenance that will occur at a later stage of the project. The total costs of the road safety measures have to be estimated.

To make future costs and present costs comparable, future costs have to be discounted to a chosen base year (e.g. present time basis) or the total project investments have to be converted to annual costs[5]. This ensures that the implementation costs for all safety measures will be compared with a common basis and that differences in the duration of the measures will not affect the comparison.

Combining cost and impacts

When both the costs and the impacts of road safety measures have been estimated, they can be combined to express the cost-effectiveness of a project.[6] Within the CEA the cost-effectiveness is expressed with the cost-effectiveness ratio (CER). The cost-effectiveness ratio of a measure is obtained by dividing its effectiveness (E) by its costs (C):

CER = E/C

It is interpreted as the units of effectiveness that are obtained for each unit of cost that is incurred (e.g. in Euro). The higher the ratio the more effective a safety measure is.

The CER has to be calculated for every selected measure. A comparison between ratios of various measures can be done to ascertain the relative efficiency of the measures in the selection. The measures can be ranked according to their contribution to the achievement of the pre-defined objective. But, unlike a CBA, a CEA cannot ascertain whether a project should be undertaken or not. There are no well-defined thresholds that indicate when a measure becomes efficient respectively inefficient. Therefore, within a CEA the absolute efficiency of a measure (e.g. the benefits of a measure exceed its costs) cannot be estimated. This can only be done within a CBA.

Even if a CEA cannot show whether a road safety project is a worthwhile investment, there are several issues that might cause decision makers to prefer a CEA to other modes of assessment.

1. The CEA is much easier to perform than the CBA. A road safety project's benefits can be measured in physical terms (like numbers of accidents). Within a CBA these benefits have to be transfered to economic values. Therefore the CEA can be calculated with less information (e.g. on crash costs, on mobility effects) than the CBA.
2. The CEA is an effective evaluation tool for screening and ranking alternative investment projects, and is less complex than other modes of economic assessment (less time consuming, reduced data needs). This makes a CEA applicable for the economic assessment of smaller investments or local road safety measures.
3. A CEA can be used for highlighting a measure's impacts on a pre-defined objective. Within a CEA the costs of a road safety measure will only be compared with its road safety impacts. A CBA, however, takes into account other macroeconomic impacts in addition to road safety (e.g. impacts on mobility and the environment). Therefore, the importance of safety aspects within the assessment is reduced relative to other impacts.

3.3 Cost-Benefit Analysis

Definition

The cost-benefit analysis (CBA) aims to find whether a proposed objective is economically efficient and how efficient it is (and if alterations in the objective could make it more efficient). Various measures of efficiency are used to perform a CBA:

- the net present value of the project,
- the cost-benefit ratio,
- the internal rate of return.

[5] The costs (and benefits) have to be calculated and estimated for the whole lifespan of a measure. The correct determination of a measure´s lifespan is very important for the quality of the evaluation results. The lifespan generally is determined by the economic life.

[6] It has to be assured that the dimensions of costs and effectiveness are the same, i.e. if the costs are considered as annuities, the road safety impacts also have to be displayed in annual effects.

Net present value

The net present value of a project is defined as the difference between the monetary value of all the benefits of a specific intervention and the value off all the costs required to realize them. Different benefits are usually added to obtain total benefits while negative benefits (e.g. increased travel time) are subtracted.

The cost term usually describes the implementation costs of a measure, expressed in terms of the opportunity cost from a social point of view.

Cost-benefit ratio (B/C-ratio)

It is defined as:

$$\textbf{B/C ratio} = \frac{\text{Present value of all benefits}}{\text{Present value of implementation costs}^{7}}$$

A measure can be recommended if the cost-benefit ratio is greater than 1.0; the higher the ratio, the higher the benefits.

The CBA is particularly useful in those areas of policy making where:

- there are multiple policy objectives (e.g. safety, environment and mobility),
- some objectives are in conflict (which is well-known in the case of safety or environment versus mobility),
- the objectives refer to goods that do not have market prices (which actually is the case for aspects of safety, environment and mobility).

CBA is necessary if different levels of injury severity are to be considered.

General assessment frameworks

In many countries frameworks have been developed to assess road infrastructure investments and very often, they also include the monetized impacts of new road infrastructure investments on road safety. Well known examples for these assessment tools are among others

- from Germany: “Bewertungsverfahren der Bundesverkehrswegeplanung” (BVWP), “Empfehlungen zur Wirtschaftlichkeitsuntersuchung von Straßen” (EWS97, previous “Richtlinie zur Anlage von Straßenwirtschaftlichkeitsuntersuchungen” RAS-W) etc;
- from the United Kingdom: Cost-benefit Analysis for the Economic Appraisal of Road Schemes (COBA), Economic Assessment of Road Schemes in Scotland (NESA), Guidance on the New Approach to Appraisal (GNATA)/Guidance on the Methodology for Multi-Modal Studies (GOMMMS) etc;
- from the USA: Surface Transportation Efficiency Analysis Model (STEAM) etc.

The German BVWP is based on road network analysis modules containing e.g. traffic volumes, road lengths, road capacities etc. It considers base cases and improvement cases which are analysed by the models as a basis for the economic task of the cost-benefit analysis. The traffic development in Germany is simulated and forecasted. Interdependencies between investment projects are considered, too.

The economic evaluation of road safety impacts for the cost-benefit analysis is based on the costs incurred as a result of road accidents. Avoiding such costs represents an economic benefit of a road infrastructure investment. In the assessment method of the German BVWP the accident costs calculated by the Federal Highway Research Institute (BASt) were applied. The calculation of the road safety benefits of a road infrastructure investment is based on the number of accidents, road type specific accident rates and cost figures for accidents and personal injuries. All statistical categories of accidents with personal injury and property damage only are included. The accident reduction potential is calculated as the difference between the accident frequencies in the with- and the without-case. Subsequently, the reduction potential is monetized by applying the above mentioned cost figures.

COBA is a computer cost-benefit analysis programme for the economic assessment of road schemes in the United Kingdom. It is a part of the British Design Manual for Roads and Bridges. The COBA computer program is developed to compare the costs and benefits of a wide variety of road investments. It is normally required for a priority ranking of projects. The first step of the COBA appraisal is to define the alternative options which are to be appraised. These are the so-called

[7] Incl. maintenance

"Do-Minimum"-base case and all "Do-Something"-alternatives. COBA is principally concerned with estimating the effect of a road-related improvement on the users of the road system, including the costs of accident. As in other cost-benefit tools the user or public costs are balanced against the construction and maintenance costs. A comparison is made between the costs before and after the improvement.

In Sweden CBA is also one of the instruments to support decision making in transport planning. The Swedish National Road Administration is applying the EVA model for CBA in the planning process of the long-term transportation plan to balance and prioritise measures. Calculations in EVA are based on official statistics and state road data base. Traffic safety is one of the valued components of the EVA tool, i.e. beside time values, vehicle and transport costs, environmental costs of emissions, maintenance and investment costs and comfort costs, accident costs are considered, too. Fatalities as well as different levels of injuries and property damages are monetized.

In the United States of America the Federal Highway Administration (FHWA) developed an enhanced version of its own Sketch Planning Analysis Spreadsheet Model (SPASM) called STEAM – Surface Transportation Efficiency Analysis Model. This model was developed in order to provide an analytical tool for estimating impacts of multi-modal transportation alternatives and cost-effectiveness evaluation of alternatives in a system planning context. The main objective of STEAM is to assess the overall merits of the multi-modal transportation alternatives.

All these examples demonstrate that assessment tools are already applied to calculate the social and economic efficiency of new road investments. Nevertheless, none of these tools are specialised on road safety related assessment. All these tools have been developed to assess new road investments considering a large variety of relevant components. The effects of new road investments on road safety are included in this variety.

Performing CBA

The CBA of road safety measures can be structured as follows:

- Define units according to the road safety measure (e.g. accident types).
- Determine other parameters (e.g. duration of the measure, interest rates).
- Estimate effectiveness of relevant safety measure in terms of the number of (target) unit accidents it can be expected to prevent – per unit implementation of the measure, e.g. km/h speed reduction, hours of traffic control or money spend to a campaign of a specific type[8].
- Estimate additional effects of the measure, e.g. impacts on noise or air pollution.
- Estimate the costs of implementation and maintenance of the measures.
- Investigate the monetary values of all relevant effects (e.g. fatalities and injuries, emissions, travel time, mobility, noise).
- Estimate the benefits of measures.
- Convert all costs and benefits to present time basis (or an annual basis) by discounting.
- Calculate the benefit-cost ratio.
- Carry out additional analysis (sensitivity analysis or break-even analysis).
- Report and present results.

One of the biggest problems in CBA is to obtain valid and reliable monetary valuations for all relevant impacts. Due to the difficulty of deriving monetary values for all considered effects, it may be useful to divide the application of CBA for road safety measures into 'maxi-CBA' and 'mini-CBA'.

The maxi-CBA is to be understood as a complete analysis comprising the best available inputs and estimates of costs and benefits. The mini-CBA, on the other hand, involves a simpler estimation of main costs and benefits.[9]

Average values can be used to perform a mini-CBA, both for effects and economic values; therefore it could be used to perform preliminary assessments of road safety measures when resources are not available for a full analysis.

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8 It is also possible to define units of implementation, e.g. "one section of a road", "one area", "one vehicle" etc.

9 In this context, the safety effects as well as the implementation and maintenance costs have always to be included.

A maxi-CBA, on the other hand, should be more of a state-of-the-art analysis: it will be more complete (covering all relevant effects) and the estimates of costs and effects will make use of all available information, taking into account all circumstances. This will be more time consuming and costly than a mini-CBA. It would serve as confirmation after a measure has passed the first selection phase. Ideally, a maxi-CBA would be carried out for all larger infrastructure and safety projects.

Valuation of impacts of road safety policies in CBA

Literally hundreds of studies have been performed to determine the value of goods that do not have market prices, like the reduction of environmental pollution and reduced accident risk. The valuation of a non-marketed good is often based on the willingness-to-pay of the potential purchasers of the good. In order to estimate the willingness-to-pay for a non-marketed good (with no linkage to consumption of market goods), a hypothetical market is set up, in which people are asked to state their willingness-to-pay for a certain amount of the good, or to choose between various options that provide different amounts of the good.

The results of a detailed survey of practice in estimating road crash costs in EU and other countries that was made by an international group of experts as part of the EU COST[10]-research programme is briefly presented to illustrate and describe the complexity of evaluating road crash costs in cost-benefit analysis. The project report contained recommendations about the cost items that ought to be included in estimates of road crash costs and the methods for estimating the various cost items.

Five major cost items were identified:

- medical costs,
- cost of lost productive capacity (lost output),
- valuation of lost quality of life (loss of welfare),
- cost of property damage,
- administrative costs.

These five major cost elements can be divided into two main groups. The first group includes all the cost items for which market prices normally exist (a, b, d, and e). The other group consists of cost item c for which a market price does not exist. In the past ten or fifteen years a number of countries have tried to estimate the monetary value of lost quality of life.

Additionally, the cost of traffic delays (or travel time) can also be considered. The monetary value is difficult to estimate because the purpose of the trip will affect its value. Business trips will normally have a higher monetary value than leisure trips. The monetary value of time is estimated according to an opportunity cost approach: individuals are assumed to value their time according to what they could earn by working an additional unit of time.

Uncertainty

All the difficulties related to correctly estimating the impact of road safety measures represent sources of uncertainty in the assessment of these measures. ELVIK and AMUNDSEN (ROSEBUD, WP2) identify the following sources of uncertainty:

- Uncertainty in the definition of the target group of crashes or injuries affected by each road safety measure.
- Random variation in the number of crashes or injuries affected by each road safety measure.
- Incomplete and variable reporting of crashes or injuries in official crash statistics.
- Random variation in the estimated effect of each road safety measure on the number or severity of crashes or injuries.
- Unknown sources of systematic variation in the effects of each road safety measure on the number or severity of crashes or injuries.
- Incomplete knowledge with respect to how the effects of each road safety measure are modified when it is combined with other road safety measures to form a strategy consisting of several measures affecting the same group of crashes or injuries.
- Uncertain estimates of the social costs of crashes or injuries and the value of preventing them.
- Uncertainty with respect to the duration of the effects of each measure on crashes or injuries.

A practical way to deal with uncertainties is to prepare three scenarios: a 'golden mean'

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realistic/conservative scenario, an optimistic/upper scenario, and a pessimistic/lower scenario. This may highlight the fact that economic analysis cannot provide exact estimates but rather probable intervals.

3.4 Questions and answers

Decision makers face many problems and difficulties when confronted with the need to evaluate safety measures in a monetary way. This section deals with some of those. Questions are listed that might arise when carrying out a monetary assessment of road safety measures, and the aim is to provide appropriate answers.

This section cannot deal with all problems and difficulties associated with the monetary evaluation of measures, but those covered are the most frequently asked.

When will evaluation tools (like CBA or CEA) be needed?

Most measures that are invented to improve road safety do contribute to this primary goal. But at the same time the measures evoke costs (for implementation, maintenance etc.). In times of scarce financial resources and strict financial budgets for the implementation of road safety measures it has to be ensured that the money will be spent on those measures that are efficient in terms of costs and benefits.

To find out whether a measure with an impact on road safety can also guarantee efficiency on the cost side, costs and benefits have to be compared to each other. Within a CBA both – costs and benefits – will be transformed into monetary values. As a result the cost-benefit ratio will be achieved. It gives evidence of the absolute efficiency of a measure.[11] The CEA represents a simpler form of a CBA. Within a CEA the safety effects (benefits) will not be monetized, but compared, in physical terms (numbers of casualties prevented), to the costs of a measure. This shows the cost-effectiveness of a measure (but does not prove its absolute efficiency).

Another need for the use of evaluation tools arises from the fact that in most cases several measures can be implemented to avoid a certain safety risk. Out of a pool of possible measures that one has to be selected that does fit best in this situation. By monetizing the costs and benefits, different types of safety measures become comparable to each other. According to the cost-benefit ratio the most efficient measure in a certain situation can be chosen.

How can you compare different types of effects, such as casualty reductions, pollution and travel times?

A road safety measure might also have effects that are unrelated to road safety, e.g. environmental or mobility effects. Decision making on a national or regional level implies that all effects of a measure are taken into account, not only the safety effects. All effects have to be weighed against each other to make sure that the measure will be efficient. Therefore, it will be important to include other significant effects (aside from road safety) in the evaluation of a road safety measure.

Among the monetary assessment methods a CBA is able to include multiple effects (safety effects, environmental issues, mobility effects etc.) in the analysis by monetizing them. The effects to be considered need to be measurable and to have an economic value. By expressing effects in monetary units (e.g. in Euro), different aspects can be compared within the CBA. The monetization of impacts will be done using predefined values for the impacts (e.g. valuation of time by cost rates for labour time costs and time costs for leisure activities). The monetized benefits and the costs of road safety measures will be set against each other. The cost-benefit ratio is the final result; the ratio measures the absolute efficiency of each measure.

A CEA cannot be used to weigh safety against other policy objectives or to compare safety effects for different levels of crash severity. This can only be done within a CBA. Within a CEA, the effects of a measure are expressed in non-monetary terms (e.g. number of saved lives per unit implementation cost). The safety benefit per Euro of the project investment is highlighted: the higher the ratio the more safety-effective the measure is.

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[11] Within a CBA not only safety effects can be compared to the costs of a measure. Also other effects (on pollution, on mobility etc.) can be taken into account for the efficiency analysis.

How can you compare a cost in 2005 with a benefit in 2010?

The investment in road safety will generally not cause a simultaneous accumulation of costs and benefits; rather, today's investment in road safety will lead to future benefits. This leads to the following problems.

- A common reference time has to be chosen for the realisation of costs and benefits. The most common choice is the base year of the introduction of the new safety measure.
- Future costs and benefits have to be discounted to the chosen reference time. The purpose of discounting is to put all present and future costs and benefits in a common metric (present value). This is necessary because a Euro today is considered to be worth more than a Euro in five years time, even if inflation (the loss in the value of money over time) is excluded, because today's Euro can be invested to yield a higher value in the future. In the macroeconomic evaluation methodology for the Federal Transport Infrastructure Plan 2003 in Germany, the discount rate is 3%. The discount rate is based on the average of the expected long-term productivity growth in Germany. In other cases the interest rates of risk-averse long-term state securities are taken as discount rates (about 4% in Germany).[12] In the European guide to cost-benefit analysis of investment projects a social discount rate of 5% is determined.[13]
- The level of the chosen discount rate can affect the assessment. A low discount rate favours projects with long-term benefits and short-term costs. When evaluating alternative projects, a sensitivity analysis using a range of discount rates can determine the importance of the discount rate to the relative assessment of the projects.
- Rates of inflation will rarely be included in CBAs for the public sector. Estimations of future costs and benefits will be used that are expressed in terms of base year's prices. Consistent with this approach, the discount rate used in the CBA represents the time value of money after adjustment for inflation ("real interest rate").

Is the role of the decision maker simply to "rubber stamp" the measure which ranks highest in the efficiency assessment?

Politicians and decision makers might fear an increasing trust in the results of monetary assessments. They worry about becoming redundant in the decision making process about the introduction of road safety measures. But this fear is not justified. A cost-benefit or a cost-effectiveness ratio can only inform about the (economic) efficiency of a measure. But the process of decision making about the implementation of a road safety measure goes far beyond the economic terms. Factors like the users' acceptance of a measure, implementation strategies (e.g. involvement of citizens concerned by a measure), financial conditions, regional specifics or political interests can rarely be included in the monetary assessment. Therefore the future role of a decision maker will not be to rubber stamp the measure which ranks highest in the efficiency assessment, but to debate if there are factors besides the economic terms that influence the result and should not be neglected. It becomes clear that monetary efficiency assessment is no substitute for political dialogue and the process of decision making, but it can help to increase the transparency and objectivity of decision making.

If a measure has not been applied before in my country, can knowledge of this measure gained abroad be used for the assessment?

Road safety measures have been applied in many countries around the world, in many cases with monetary assessments. Some of the tools and the data (e.g. accident data) gained during these assessments have been published and can be used to assist further assessments.

- Databases for monetary assessment have already been set up in some countries. They contain data and results of evaluation studies that have been performed in various fields of application. Many countries also have developed evaluation tools that can be used for the monetary assessment of measures in multiple situations.[14] A review of international

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[12] FMTBH, 2002, p. 35

[13] European Commission, Guide to Cost-Benefit Analysis of Investment Projects, Brussels 2003

[14] Examples for evaluation tools are COBA, STEAM or BVWP 2003.

experiences with road safety measures and data on safety effects was published recently by the European Transport Safety Council (ETSC, 2003).

- But it has to be checked whether the data used in other countries can be easily applied to the specific application. In particular, there is still a need to harmonise national accident data (e.g. the definitions of severe and slight injuries).
- To ease problems of data availability there should be a European approach to set up and maintain a database that can support monetary assessments of road safety measures. A system should be established so that the relevant data[15] can be automatically ordered[16] and collected, also checked for reliability and applicability.

How can you assess an innovative road safety measure, i.e. one that has not been tried before?

For monetary valuation, the impacts of road safety measures have to be expressed in monetary terms. If the measure has not been implemented before, it is rarely possible to use values based on experience, but these measures can nevertheless be assessed by monetary methods. The missing input data for the calculation have to be supplied in another way. The expected impacts of a road safety measure (in terms of reduced accident or crash severity) can increasingly often be modelled by computer simulations and quantified by the use of accident costs. To make sure that the simulation of impacts has been reliable, the theoretical derivation of impacts and values can be validated by field tests and test runs. A sensitivity analysis can additionally be performed to assess the reliability of the result.

If efficiency assessment depends upon knowledge gained from previous measures, will its use stifle innovation?

Monetary assessment often relies on knowledge gained from previous measures. But this does not inevitably impede the implementation of new, innovative road safety measures.

- Values based on experience cannot be used in the case of new, innovative measures, so missing input data for the calculations have to be supplied in another way. This can be done e.g. by computer simulations, conclusions by analogy or back-up data, but inevitably monetary assessment of new, innovative measures is more complicated. However, there is no general, methodological barrier against the assessment, so its use cannot act as a barrier to innovation. On the contrary, monetary assessment sometimes demonstrates the economic efficiency of a new, innovative measure and facilitates its implementation.
- It cannot be taken for granted that measures, having once been assessed positively, should also be considered as efficient in other situations. The efficiency of a measure has to be proven for every implementation. Where different measures can be chosen for implementation, the cost-benefit or cost-effectiveness ratio gives evidence which measure should be preferred provided that each measure is assessed to the same standard.
- When an established measure is valued higher than a new, innovative one, this should not be interpreted as a hindrance to innovation. It should rather be understood that the established measure will suit better than the innovation in this specific situation and will provide a greater benefit.
- To ensure that innovation will not be stifled by the use of monetary assessments, the common objective must be to improve the assessment methodology continuously and to develop the evaluation tools further. An example for the successful enhancement of the assessment methodology has been the inclusion of the benefits of carbon dioxide reduction in the monetary assessment for the German Federal Transport Infrastructure Plan. This helped also to push the development and implementation of those measures that aimed to reduce carbon dioxide emissions.

CBA relies on forecasting changes over a number of years. Forecasts are inevitably uncertain, how is this uncertainty taken into account?

Although a CBA is intended to minimise uncertainty, it cannot eliminate it, and therefore must take

[15] E.g. on safety effect values or implementation costs of the measure

[16] E.g. for various groups of accidents and severity levels, for different geographical levels (local, national or European)

account of it. There are many sources of uncertainty in road safety projects (e.g. variation in the estimated effects of the measure, uncertain duration of effects, uncertain forecasts of traffic volume, economic development etc.). The forms of uncertainty can be included in the calculation in several ways:

- Different scenarios can be calculated. A 'golden mean' realistic/conservative scenario that is characterised by a high occurrence probability is supplemented by an optimistic/upper scenario (highest benefits, lowest costs) and a pessimistic/lower scenario (lowest benefits, highest costs). The benefits and costs will be monetized for every scenario. The cost-benefit ratios of all scenarios show the range of possible results. The 'golden mean' scenario can serve as a benchmark for the most probable result.
- Confidence intervals of the effects can be displayed and taken into account. Confidence intervals can usually be calculated for the expected impacts of a road safety measure. Therefore, the range of values can be shown and the reliability (in statistical terms) of the results will increase.
- A sensitivity analysis can examine how the outcome of a CBA changes with the input factors, assumptions etc. Within a sensitivity analysis the calculations will be done for an optimistic/upper, a pessimistic/lower and a 'golden mean' value for input factors or for different kinds of assumptions. A single factor can be varied, all other factors remaining constant, or all factors can be varied. The results of the calculations can then be compared in monetary or graphical manner. In the decision making process it is important to know whether this type of variation can influence project rankings or profitabilities.

If I have a fixed budget, how do I decide whether to spend it on one large scheme or on several smaller ones?

Monetary assessment methods can be used to spend a fixed budget on the most efficient measures (in economic terms). The results of the monetary evaluation give evidence of the efficiency of a measure.

If there is a choice between a large investment and several smaller ones, the monetary assessment has to be carried out for every available measure, and the choice made by comparing the results of the assessments. But it is not enough to compare just the net present values or the amount of road safety impacts (in terms of accident reductions) of the single measures, for this will certainly prefer the large investment.

Instead, the cost-benefit ratios of the single measures have to be compared. By ranking small measures according to their ratio (until the amount of the fixed budget will be exploited) a set of highly efficient measures can be found. The accumulated net present value of this set of small measures can be compared to the net present value of the large investment. Is the accumulated net present value higher than the single one of the large investment, the set of smaller measures will exploit the fixed budget in the most efficient way. This procedure can guarantee that smaller projects with a high efficiency get the chance for implementation.

Is choice or ranking of projects the only application of road safety related assessment?

Many countries compile programmes of road safety measures and targets for improving safety (e.g. percentage of fatalities to be saved by a certain year). The programmes are based on a range of strategies and rarely on full ex-ante evaluations of the measures considered. If applied, CBAs and CEAs are most often used for setting priorities for safety measures within the framework of a national or local safety programme.

But the assessment of road safety measures should not only be a single process at a particular stage in the process (normally at the beginning) or only to create a single programme. The application of CBAs and CEAs allows the results of systematic monitoring of road safety activities to assess.

Monitoring road safety is an essential step in a systematic evaluation process. The observation of safety plans or programmes should comprise the systematic recording of the activities and actions and of the development of the accident and performance indicators.

After comparing road safety plans with the reality, decision makers have the chance to steer the activities in a new direction if necessary, and CBAs and CEAs should be the basis for these decisions.

The whole process could be divided into 3 steps:

Monitoring and controlling of implementation (controlling I)

After identifying all responsible institutions, the milestones for implementation should be defined (targets of the measures, their beginning, implementation steps and completion). The plan and real development should be compared at specific milestones. This process should identify any problems or barriers to implementation.

Monitoring and controlling of the effects (controlling II)

As described above, target variables and indicators should be defined and the expected effects should be compared with the results reached in reality. At this step, measures with unsatisfactory results or (unintended) side-effects should be identified.

Monetary evaluation of the outcomes (controlling III)

A comparison of ex-ante and ex-post CBAs and CEAs should be made. This step should identify the efficiency or inefficiency of road safety activities. The budget planning of the next years should depend on the results of this monitoring and controlling step.

All steps provide the decision maker with information to replan, to reorganise or to steer the road safety activities. Especially, controlling II and III enable to allocate funds to profitable safety activities and away from low-yielding ones.

Democratic politicians who face re-election may tend to favour measures with short-term benefits; can the efficiency assessment take account of this preference?

To make costs and benefits of measures with different time horizons comparable to each other, in a monetary assessment all effects are discounted to a common base year.

This means that effects that occur later weigh less than effects that occur sooner. The discounting of effects, therefore, considers the appearance of costs and benefits of a measure at different points in time.

Attention has to be drawn to the discount rate. The choice of the discount rate is decisive for the valuation of short-term and long-term costs and benefits. A high discount rate favours projects with long-term costs and near-term benefits. On the other hand a low discount rate favours projects with long-term benefits and near-term costs.

The methodology of the CBA contains adjusting devices to consider a time preference within the assessment. But the question comes up if a preference for short-term benefits of politicians generally should be regarded within the assessment (in either direction: for or against the politician's preference). The choice of the discount rate should rather be determined by other factors

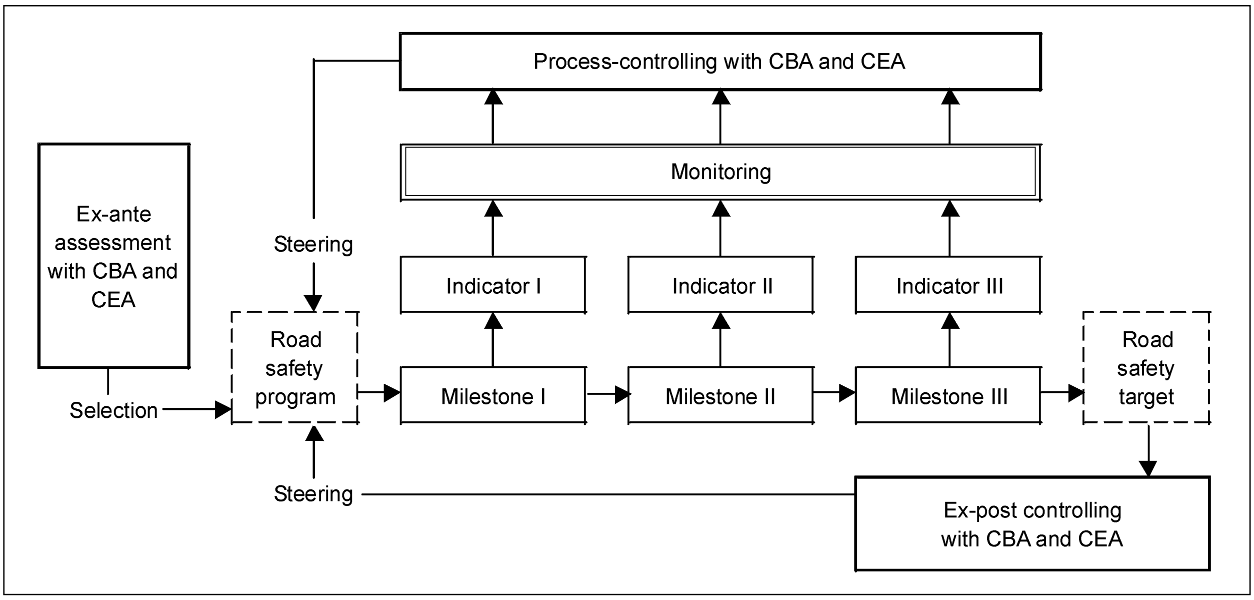

Figure 1: Possible scheme of a systematic evaluation of road safety activities

(long-term interest rates, inflation rates, risk components).

Are there guidelines about the maximum percentage of a scheme budget that it is worth spending on an efficiency assessment?

There are no precise guidelines about the maximum percentage of a scheme budget that is worth spending on an efficiency assessment.

But it is obvious that the expenses for the efficiency assessment should be in due proportion to the project scale and especially to the financial budget that is underlying the implementation process of the safety measure. It cannot be the objective to conduct a detailed monetary assessment for a small regional measure that exhausts nearly half of the project's financial budget.

Therefore, for every assessment it has to be verified that the project details (characteristics, scale, financial resources etc.) require a detailed monetary assessment. In those cases where a detailed analysis can not be afforded, other techniques have to be regarded [e.g. a "Mini"-CBA (see above), where detailed time- and cost-consuming assessments and calculations are substituted by rough estimations with average values for effects and economic valuations and approximate data on the measure's costs].

Is it possible that there are significant effects which cannot be included in a CEA or CBA? If so, how should they influence the final decision?

In a monetary assessment only those effects (benefits and disbenefits) can be regarded which do have an established monetary value. CBA deals only with benefits and costs that can be expressed in monetary terms. The monetary benefits will be opposed to the costs of a measure. By comparing costs and benefits the macroeconomic efficiency of a project can be proven.

But a project can also cause effects than can not be expressed in monetary terms. Benefits or disbenefits of such kind will be for example:

- effects – perhaps in case of an infrastructural measure – on urban development (urban planning objectives, quality aspects, aesthetics etc.),
- specific environmental hazards of a measure (e.g. endangerment of biological reserves),
- social aspects and equity considerations (e.g. effects on personal income distribution, effects on social structures and surroundings),
- (user) acceptance of a measure.

Mostly, it will not be possible to find monetary values for such (dis-)benefits. This will generally keep them out of the evaluation process. However, it has to be taken care that important non-monetary benefits or disbenefits will not be left out of the assessment process. The efforts to include non-monetary effects into the assessment should of course strongly depend on the importance of these aspects relative to other effects, the dimensions of the project and political considerations. But if such effects are considered to be relevant for the evaluation of a measure, it should be sought for a possibility to include them. In some cases it might be possible to establish monetary values for the effects (by rough estimations). In other cases a non-monetary assessment can be done additionally to the monetary assessment.

The example of the German Transport Infrastructure Plan 2003 demonstrates that also non-monetary effects and objectives can be included in the macroeconomic assessment of infrastructure projects. In addition to the monetary evaluation within a CBA, the transport projects will undergo an environmental risk assessment and a regional impact analysis that go far beyond the aspects which are at the momtent included monetarily in the CBA.[17]

How can the economic assessment of accidents be done?

When doing the economic assessment of accidents, different types of crashes have to be distinguished (fatality, severe injury, slight injury, property damage only). Crash costs have to be calculated for each category of accident.

The total accident costs arise as the sum of different cost components:

[17] Federal Ministry of Transport, Building and Housing, Federal Transport Infrastructure Plan 2003, Basic features of the macroeconomic evaluation methodology, Berlin 2002, p. 35

- human losses: loss of life or injury suffered personally by the victim and the pain and grief of the victim and the victim's relatives,
- lost gross output of production from the casualties,
- direct and indirect costs of restitution (medical aid, post treatment, police, administrative costs of insurances etc.).

In the EU member states different evaluation methods are used. Differences arise from the question whether the damage costs should be estimated or the willingness-to-pay approach should be applied to evaluate the accident costs. Within the damage-cost approach the damages arising from casualties and fatalities are accumulated, within the willingness-to-pay method the cost calculation is based on the amount of money a victim is willing to pay for not being hurt. The most appearing difference within the two approaches is, that the evaluation of human losses in the willingness-to-pay approach leads to significantly higher valuations than the damage-cost approach.

Both approaches have weaknesses. The damage-costs approach, for example, may cause significant problems by applying different damage costs due to the individual's contribution to productivity (depending on whether it is a full- or a part-time employee, an employee or an unemployed etc.). The willingness-to-pay approach may fail because of divergences between the hypothetical and the real situation. The information state of the respondent will match the information state of a real market participant only by chance. This may lead to wrong or over-/underestimated cost rates.

It ought to be the future objective to harmonize the European assessments and to create a consistent standard for the estimation of crash costs throughout Europe. Methodical differences that are practised in Europe by using two approaches for cost calculations, may lead to irritations of users and can reduce creditability and acceptance of the results in the public scene.

4 Knowledge and data

This chapter deals with the knowledge and data elements which are required in order to perform an efficiency assessment (CBA/CEA) of a safety-related measure.

4.1 Safety effects

The quantification of the effects of measures aimed at reducing crashes represents a critical point for the application of the CBA and CEA techniques to road safety. The major source of knowledge on safety effects are evaluation studies of past treatments.

The most common form of a safety effect is the percentage reduction of crashes following the treatment (sometimes called the crash reduction factor). The quality of the efficiency assessment of a safety measure (i.e. a prediction of the crash reduction likely to be attained) depends on the quality of the available values of safety effect. The latter depends on a number of factors, such as:

- The availability of values: does data exist (values of crash reduction factors) relevant to the type of measure considered and applied at the particular type of site?
- Validity of data: were the effects estimated properly, i.e. accounting for confounding factors that may have influenced the results?
- Variability of the effect: if there is a range of results for similar treatments, what is the best estimate of the effect of the intended measure?
- Local versus general effects: how to combine the evaluation results attained under local conditions (in a country, region, authority) with a more general experience on the subject (e.g. safety effects known from international practice)?
- Changeability of the effect: how can we handle a situation where the safety effect is not stable but depends on traffic volumes?

The main source of evidence on safety effects is the observational before-after studies (HAUER, 1997). However, due to the diverse nature of road safety measures and the limitations of empirical studies, there are also other methods for quantifying safety effects (WP1, 2003). Those, mostly, provide theoretical values of the effects based on known relationships between risk factors and accidents.

The structure of safety measures can be presented as follows (WP1, 2003):

(1) User-related measures (training and education; traffic law; incentives and enforcement).

(2) Vehicle-related measures (active safety, passive safety, telematics).

(3) Infrastructure-related measures (road design; road construction; maintenance).

(4) Organisation (planning; financing; controlling).

(5) Rescue services (alert, rescue).

Screening the results of the evaluation studies reviewed in ROSEBUD (WP1, 2003) revealed that, in most cases (categories 1, 3, 4, 5), the effects can be quantified by observing reality and applying appropriate statistical methods.

In the cases of infrastructure-related measures, the quantitative approach is facilitated by the fact that the effects are geographically localised on the road network. In other cases (e.g. user-related measures or organisation) the link between the measures adopted and the results in terms of a reduction in accidents are less direct, permitting, at times, only qualitative evaluations.

For safety measure category 2, in the case of passive safety (e.g. use of seat-belts or airbags), the effects of the measures can be quantified by means of statistical observation of reality. In general, as to this group of measures, the observation of reality is accompanied, and always preceded, by laboratory experiments, simulations or trials, which permit the evaluation of their effects before the measures are introduced on a large scale.

If we take a close look at the literature, we find a huge amount of publications on road safety which are devoted to the observed effects of safety treatments. However, the degree of such effects is frequently unclear when a specific project is under consideration. Not rarely, in usual practice, an estimate is supplied which is primarily based on intuition, expectations or some professional experience and not on evidence available in the literature.

Searching for the reasons for this situation, one can conclude that the reported studies differ in ways of treatments’ grouping, evaluation methods, sites’ conditions, sizes of accident sets considered, etc. Therefore, there is a need for arranging the findings of various studies on a systematic basis, making them available for application.

To systematize the values of safety effects, three ways are possible (ELVIK, 1997):

a) to document the effects based on a meta-analysis;

b) to document the effects based on traditional literature surveys;

c) to provide for theoretical effects based on known relationships between risk factors and accidents.

A detailed description of the various methods to obtain reliable data on the estimated safety effects of a road safety measure can be found in deliverable 4 of the project (WP3).

4.2 Number of accidents affected by the measures

The number of crashes affected by a measure multiplied by the value of the safety effect provides for the number of accidents likely to be prevented by the measure. Considering the number of accidents affected, there are two basic alternatives.

Alternative 1:

When a safety measure is chosen for a specific crash site (area, population), the implementation unit is known. The number of accidents affected by a measure depends on two factors: the statistics of accidents observed at the site over the last few years and the target crash group of the measure.

The target accidents are usually obvious as they are dictated by the nature of safety-related measures. Examples of target crash groups associated with different safety measures are given in Table 1. The definitions were given by ELVIK (1997a), within the framework for a CBA of the Dutch road safety plan.

In most cases, a safety treatment is considered for a site with a 'bad safety record', i.e. with a bad record of crashes occurring at the site. Due to random fluctuations of accidents on the one hand, and the phenomenon of 'selection bias' (HAUER, 1997) on the other, the annual number of crashes in the 'before' period should be estimated on a 3-5 year basis (and not on the last year which would attribute a higher crash-saving potential to the measure than it actually has).

Alternative 2:

When a safety measure is considered for implementation within a large-scale road safety

Description of measure	Target group of accidents
Cycle lanes in urban areas	All accidents on affected roads
Roundabouts	All accidents in affected junctions
Blackspot treatment	All accidents at treated blackspots
Truck lanes on rural roads	Accidents involving trucks on rural roads
New road lighting	Accidents in darkness on unlit roads
Upgrading road lighting	Accidents in darkness on lit roads
Shoulder rumble strips	Ran-of-road accidents on rural roads
Extending 30km/h roads	All accidents in areas changed into 30km/h zones
Reduced speed limit on 80km/h roads	All accidents on affected roads
Lowered speed limits at junctions	All accidents in affected junctions
System of optimal speed limits	All accidents on all roads where speed limit is changed
Speed reducing measures at pedestrian crossings	Accidents at pedestrian crossings
Upgrading pedestrian crossings	Accidents at pedestrian crossings
Prohibiting mopeds from using cycle tracks	Accidents involving mopeds on cycle tracks
Law requiring use of daytime running lights	Multi party daytime accidents involving cars
Speed limiters on mopeds	All accidents involving mopeds
Speed limiters on heavy vehicles	All accidents involving heavy vehicles
Speed limiters on all cars	All accidents involving cars
Provisional licensing and demerit point system for new drivers	Accidents involving new drivers in the first two years of driving
Raising minimum licensing age for moped riders	Accidents involving new moped riders in the affected age groups
Reforming licensing age system for motor vehicles	Accidents involving drivers in the affected age groups
Child pedestrian training	Pedestrian accidents involving chilfren in the affected age groups
Increased speed enforcement	All accidents during period of enforcement
Increased enforcement of drinking and driving	Accidents involving drinking drivers during period of increased enforcement
Increased seatbelt enforcement	Injuries to car occupants not wearing seatbelts
Extending automatic enforcement	All accidents on roads subject to automatic speed enforcement
License withdrawal for drinking and driving	Accidents involving dinking drivers
Driver side airbags	Frontal impacts involving cars
Rear seat belts mandatory	Injuries to rear seat occupants in cars
Extra high mounted brake lights	Rear end collisions

Table 1 : Examples for definitions of target accident groups: target accident groups for safety measures for the Dutch road safety plan (Source: ELVIK, 1997)

program, a typical 'unit' of implementation should first be defined, and then the number of target accidents expected to occur per year for a typical unit, should be estimated.

In the case of infrastructure improvements, the appropriate unit will often be one junction or one kilometre of road. In the case of area-wide or more general measures, a unit may be a typical area or a certain category of roads.

In the case of vehicle-related measures, one vehicle will often be a suitable unit or, in the case of legislation introducing a certain safety measure, the percentage of vehicles equipped with this safety feature or complying with the requirement.

As far as education or training is concerned, the number of trained pupils according to a certain training scheme may be a useful unit of implementation (ELVIK, 1997a).

For police enforcement, it may be a kilometre of road with a certain level of enforcement activity (e.g. the number of man-hours per kilometre of road per year); in the case of public information campaigns – the group of road users, which is supposed to be influenced by the campaign.

For example, an economic model developed for the Israeli safety programme was based on estimates of savings in severe crash injuries, which could be attained due to the implementation of the programme (HAKKERT and GITELMAN, 1999).

Considering each field of programme's activity, three stages were completed:

(1) definition of target crash groups;

(2) evaluation of the expected safety effect of the treatments;

(3) definition of the scope of implementation which is attainable during the program.

Regarding the third stage, two types of activity were defined: national (e.g. 'enhancing the use of safety restraints in cars') where potential injury savings were estimated using average nation wide indices; and variable, i.e. those activities whose scale and sites of application depended on a marginal cost-benefit analysis.

The latter type included the road environment and enforcement measures, where the evaluation concerned:

- five categories of geographic units, i.e. one-kilometer road sections and junctions in urban and rural areas (as potential black-spots), and rural sections of variable length (as candidates for creating forgiving roadside conditions);
- three variants of treatment, i.e. improvement of road infrastructure only, intensive speed enforcement only or both measures combined. For each geographic unit, the most cost-effective variant was chosen.

To avoid any possible bias caused by regression-to-the mean, estimates of the number of accidents that can be prevented by road related measures should be based on accident rates representing the typical level of safety for various categories of road elements and road types (ELVIK, 1997a).

Two more factors are essential to estimate the reduction in the number of crashes:

- The measure may already be implemented to a certain extent. For example, in some countries the initial level of wearing safety belts in cars is rather high, therefore a public information campaign on the issue will have only a limited effect on the number of casualties. Similarly, black-spot treatment measures are widely applied in many European countries; there is some initial level of police enforcement etc. As a result, the actual safety potential of a measure will depend on the local conditions.
- The same crashes can be influenced by several kinds of treatments. A combined effect of these measures will be lower than a direct sum of the initial values (e.g. ELVIK, 2001).

ETSC (2003) provides examples of accounting for the implementation scale of safety measures. For example, the reduction of fatalities following the compulsory introduction of daytime Running lights (DRL) in the EU was estimated as:

- the number of fatalities (observed),
- an average 90%-use of DRL,
- a 40% of the DRL relevant crashes,
- a 20%-effect of DRL for fatalities,

where both the scope of use and the share of relevant crashes were stated based on the analysis of crash and behaviour data in different countries. According to the estimate, 2,827 fatalities per year are expected to be saved in the EU.

Another measure was the promotion of Random Breath Testing (RBT) in the EU countries. Having considered the data on alcohol involvement in fatal accidents, the level of drink-driving in traffic and the current level of RBT in different countries, two basic sets of assumptions were applied (ETSC, 2003):

- 3% drink-drivers (in traffic) and 30% alcohol-related fatalities;
- 2% drink-drivers and 40% alcohol-related fatalities.

Three forms of safety effect were considered:

- a 9% reduction in all fatalities;
- a 30% decrease in alcohol-related fatalities (as was found in Norway, following a tripling of the enforcement level in low frequency RBT areas);
- a 25% decrease in alcohol-related fatalities (as was observed in a Dutch study in the city of Leiden where the RBT was doubled).

According to these estimates, a reduction of 2,040 to 2,500 fatalities per year can be expected in the EU.

4.3 Existing road accident databases

One of the problems which complicate decision making at the international level is absence of relevant international data on road accidents and traffic. Today, the following international databases on road safety exist:

IRTAD database

This database is operated by the Joint Transport Research Centre (JTRC) of OECD/ECMT. The data from 29 OECD member states are included in this database, also separate data for the territory of both former German states, for Great Britain proper and for Northern Ireland. All data are aggregated[18]. Killed numbers are recorded for the 30-days term after accident, if necessary by applying correction factors. In addition to the main accident indicators[19] exposure data[20] are also included in the database. The data are registered from 1970[21].

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[18] I.e. only total numbers, not data on individual accidents.

[19] Number of injury accidents, number of killed, injured and hospitalized, in distribution by the age of victims, user type, road type

[20] Population number, motor vehicle number, road length, area of state and modal split of transport volumes to individual transport modes

[21] Some data also monthly

The data can be obtained online on the website http://irtad.bast.de[22].

CARE database

CARE is the European road traffic accident database created and operated in the framework of the European Commission – General Directorate for Energy and Transport. It is the only existing database with disaggregated data at the EU level, which should serve for the detailed analysis of the accidents at both national and international level, and for creation of both national and European traffic safety policy.

FARS is a similar system operated at the federal level in the USA (see below).

At present, CARE involves data from 14 old EU member states (without Germany), but its extension to all 25 EU member states with Norway and Switzerland is being prepared. In addition to the main database involving source data from these countries (in the common agreed structure transformed from original national structures), supplementary data on population, vehicle park, drivers, road network, traffic volumes, safety measures etc. should gradually be added.

Confidence in the individual data must be, of course, strictly assured. All outputs are created by the aggregation of source data by the selected parameters. The output is a two-dimensional contingency table with utilization of a row of filters for value selection. Individual variables involve all accessible information from EU member state accident statistic files.

Comparability of data from different member states with regard to definition, structure, quality, accuracy and underreporting is a continual problem. Individual variables are gradually being harmonized.

Observed variables include the number of accidents and casualties by injury severity (fatal, severe and slight) distributed by age, sex, user type (driver, passenger, pedestrian), vehicle type, place, time and circumstances (lighting, weather) of the accident, vehicle age, driver practice etc. Where necessary, correction factors are applied to the number killed to take account of the 30-day definition.

Database users are bodies at different levels in the state administration (with online access), ministries of transport, public works, interior, justice, public health, statistical offices, local authorities, police; hospitals, universities, research institutes, industrial institutions, professional associations, intergovernmental and non-governmental international organizations use the CARE database.

Provision of national data must be authorised by the competent authorities. Delivery of standard reports is assumed to be free of charge for national administrations, for other users it will be charged.

A general review of the main CARE data is published at

http://ec.europa.eu/transport/roadsafety/road_safety_observatory/care_en.htm.

ECE-UN database

At present, ECE-UN involves all European states (i.e. 36 including the smallest, excluding ex-USSR states), further ex-USSR states (15), Cyprus, Israel, USA and Canada (in total 55 states). The data are collected and incorporated in the database by means of representatives of individual states (ministries and statistical offices). The yearbook "Statistics of Road Traffic Accidents in Europe and North America" is published with data from all member states (usually with a delay of 2 years).

The Intersecretariat Working Group for Traffic Statistics (IWG) comprises representatives of the secretariats of individual international governmental organizations ECE-UN, ECMT and Eurostat (EU). The IWG coordinates their statistical activities by means of common statistical questionnaires, because all of these bodies operate with similar datasets.

ECMT database

ECMT involves all European states (i.e. 32, excluding the smallest and ex-USSR states), also European states of ex-USSR including Transcaucasian republics (10), as well as Morocco, USA, Canada, Australia, New Zealand, Japan and South Korea (in total 49 states). The data are collected and incorporated in the database by representatives of individual states (ministries and statistical offices). The yearbook "Statistical Report on Road Accidents" is published every 2 years with data from all member states (usually with delay of 3 years).

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[22] Only for authorised members

ECMT resides in Paris in the same place as OECD. Their transport statistics activities are now combined in the Joint Transport Research Centre (JTRC) of OECD and ECMT.

These data are also published by the ECMT at the website

http://www.cemt.org/stat/accidents/index.htm.

EU (Eurostat) database

Eurostat (the statistical office of the EU, located in Luxembourg) operates at present its own database for the 25 member states of the EU, including aggregated accident data. Correction factors for the number killed in individual countries are not used. The data are collected and incorporated in the database by representatives of individual states (ministries and statistical offices).

With respect to close cooperation of traffic statistics activities, Eurostat is also represented in the Intersecretariat Working Group for Taffic Statistics (IWG).

These data (for transport area, both states and regions) are accessible at

http://epp.eurostat.cec.eu.int/portal/page?_pageid=0,1136162,0_45572076&_dad=portal&_schema=PORTAL.

In addition, there is a small yearly publication by the General Directory for Energy and Transport involving main road accident data, at the website

http://ec.europa.eu./dgs/energy_transport/figures/pocketbook.

FARS database

The Fatal Accident Reporting System (FARS) is operated by the National Highway Traffic Safety Administration (NHTSA), within the US Department of Transport. This database includes disaggregated road traffic accident data (i.e. for individual accidents) for the USA (both total and separate states) and it is freely accessible at

http://www-fars.nhtsa.dot.gov.

By means of input forms, it is possible to create queries with selections of conditions (possibly selecting from many variables related to the accidents, vehicles, persons and drivers) and immediately receive corresponding aggregated output in the form of one- or two-dimensional tables, or even lists of cases (without personal data). Moreover, it is possible to illustrate selected accident variables on the USA map.

Other accident databases

In addition to the databases mentioned above, some other traffic accidents databases of both intergovernmental (e.g. WHO http://www.who.int/topics/injuries_traffic) and non-governmental organizations (IRF, IRU, ERSF) exist.

The problems connected with international databases on road accidents and on road transport may be summarised as follows: the reporting rate for national databases is poorly understood, and every country uses its own definitions which are not always comparable with other countries. This allows data to be extracted which may not be comparable.

Every national database which feeds into the international databases has its own system for collecting data – the protocols on road accidents and their consequences differ from country to country; no common protocol is used to collect the data for the international databases.

Aside from the road accident databases mentioned above, there are databases on injuries, including road traffic, which are collected within the World Health Organisation (WHO) based on national medical data on injuries and deaths. These data are collected nationally by medical institutions and even at this level there is no consistency with data collected by the police. It is clear, for example, in the case of single cycle accidents, which are very much under-reported by the police.

Existing international databases collect mostly basic data on road accidents and their consequences. Although data on traffic flow and the nature and operation of the vehicle fleet appear to be vital for road safety work and decision making, they are rarely collected systematically.

Furthermore, there are problems with the age of the data contained in international databases, e.g. UN data published are at least two years old. The situation with CARE and IRTAD data is better.

4.4 Implementation costs of measures

The implementation costs are the social costs of all means of production (labour and capital) that are employed to implement the road safety measure (ETSC, 2003).

The implementation costs are generally estimated on an individual basis for each investment project. As to road investment costs, the average cost rates to be used in master plans are measured on a per junction or per kilometre of road basis. Road maintenance costs are measured on a per kilometre of road per year basis.

The typical values of costs are essential to perform a CBA/CEA, especially at the preliminary evaluation stage. However, these values are usually not published, which increases the uncertainty of the evaluation results.

For the efficiency assessment of safety measures at different levels (national, regional, local), there is great interest in implementation costs applied to relevant conditions.

ETSC (2003) provides detailed specifications of costs of five 'PROMISING ' road safety measures for the EU:

- daytime running lights (DRL),
- random breath testing (RBT),
- audible seat-belt reminder in the front seat of cars,
- use of EuroNCAP as an incentive for developing safer cars,
- road safety engineering (best practice guidelines).

For example, for the DRL introduction, the cost components are as follows:

- the price for a switch in a new vehicle = € 5 per unit;
- the price of retrofitting = € 50 per vehicle;
- maintenance and repair costs of automatic light switches = € 15 per vehicle;
- extra fuel consumption due to the use of DRL = 1%-2% (a more detailed consideration was applied for different vehicle types).

Combining these assumptions with the number of vehicles in EU countries and their kilometers, the estimated present value costs were

- € 23 billion for standard low beam headlights and
- € 16 billion for special DRL-lamps (fitting with special DRL lamps (21W) would have the advantage of consuming about 38% less fuel than would be required were low beam headlamps (55W) are utilised. This leads also to a lower level of pollution).

For the RBT, the costs included (ETSC, 2003):

- costs of police personnel at the roadside (with 180 days/year, 6 hours/day, 15 tests/hour, i.e. 16,200 tests in one person-year; € 100,000 per person-year);
- equipment costs, where each personal device costs € 750 and 20,000 mouthpieces costing € 0.25 each are needed per year, or € 5,750 in total;
- costs of publicity – € 2 million per country, where the low enforcement areas comprise 9 countries;
- extra costs of administration of justice (with € 1,000 per offender; 107,000-150,000 extra offenders per year).

Taking account of the number of breath tests to be taken annually, the net present value of the costs of the measure was estimated to be € 185-228 million.

4.5 Side effects

Road safety measures can produce three kinds of effects: safety, mobility, and environmental effects (ETSC, 2003). The mobility effects comprise changes in travel time and vehicle maintenance expenses; qualitative techniques for estimating the mobility effects of transportation projects are well developed and can be found in guidelines and computer programmes for economic evaluations in transport, e.g. BVWP, EWS-97, RAS-W in Germany; TUBA, COBA, NESA in the UK; STEAM in the USA (WP 1, 2003).

As many road safety measures affect the amount and/or speed of travel, they may also have impacts on emissions and noise. For example, DRL increases the use of fuel and the emission of exhaust gases. An estimate exists that the total costs of pollution due to fuel emissions in road transport in the EU amount to € 20 billion per year. As the additional fuel consumption due to DRL use for all vehicles is about 1%, the environmental effect of the measure will result in expenses of € 200 million per year (ETSC, 2003).

Unit of valuation	Norway in NOK (1 NOK = $ 0.107 US)	Sweden in SEK (1 SEK = $ 0.092 US)		
	Rural areas	Urban areas	Rural areas	Urban areas
Traffic noise per kilometre of driving	0.00	0.14	0.008	0.067
Traffic noise per bus or truck kilometer of driving	0.00	1.14	0.040	0.617
Emission of 1 kilogram of carbon dioxide (CO_2)	0.37	0.37	1.50	1.50
Emission of 1 kilogram of nitrogen oxide (NO_x)	33	66	60	72
Emission of 1 kilogram of volatile organic compounds (VOC)	33	66	30	50
Emission of 1 kilogram of sulphur dioxide (SO_2)	18	70	20	118
Emission of 1 kilogram of particulate matter (PM_{10})	0	1700	0	3343

Table 2: Monetary valuations of environmental impacts of speed choice in Norway and Sweden (national currencies; 1999 price level). Source: ELVIK (2002)

Considering the effects of setting different speed limits for rural roads, ELVIK (2002) applied the official estimates of environmental impacts accepted in Norway and Sweden. These estimates were published by the highway authorities in both countries and are used for CBA of highway-related projects.

CAMERON (2003) performed a similar evaluation for Australian rural roads. To consider the environmental impacts of changes in speed limits, CAMERON applied the results of the EU MASTER project (ROBERTSON et al., 1998) – estimates of the levels of emissions from a typical stream of vehicles traveling at a steady speed. The air pollution emission impacts in grams per km were estimated for carbon monoxide, hydrocarbons, nitrogen oxides and particulates, at each travel speed. ROBERTSON et al.'s estimates have been recently updated, and carbon dioxide emission rates have been added, based on KALLBERG and TOIVANEN (1998).

Air pollution cost estimates were provided as follows (in year 2000 A$):

- carbon monoxide – $ 0.002 per kg,
- hydrocarbons – $ 0.44 per kg,
- oxides of nitrogen – $1.74 per kg,
- particulates (PM10) – $ 13.77 per kg,
- carbon dioxide – $ 0.022 per kg.

The impact of noise pollution from vehicles usually relates to the population living in the vicinity of roads who are exposed to noise in excess of 55 decibels. As the population living in the vicinity of the rural roads considered was negligible, noise pollution was ignored in this Australian study (CAMERON, 2003).

Emission factors	At initial speed, g/km	At final speed, g/km
Carbon monoxide CO	2.41	2.75
Hydrocarbons HC	0.43	0.49
Oxides of nitrogen NO_x	1.54	1.61
Particles PM	0.034	0.040
Carbon dioxide CO_2	239.1	257.1

Table 3: Air pollutant emission coefficients (average), following the increase from 100kph speed limit to 130kph speed limit on rural freeways. Source: CAMERON, 2003

5 Barriers to the use of efficiency assessment tools

Efficiency assessment tools (EAT) support decision making about the implementation of road safety measures. They can separate efficient measures from inefficient ones as well as rank measures according to their efficiency. But the use and the implementation of EAT within road safety policy faces limitations, restrictions and constraints. Barriers to the use of EAT can arise before and during the whole decision-making process. They can hinder the application of EAT or even prevent their use.

In this chapter, the most important barriers to the use of EAT for the implementation of road safety measures will be examined. The barriers are subdivided into different categories (clusters). The categories cover the whole decision making process: from the institutional settings (independent from the EAT) to the technical requirements of the use and the methodology of EAT. In addition, the categories differ according to their importance for a monetary assessment of road safety measures: in some cases the use of EAT for monetary assessment is not possible.

Even if some categories of barrier (absolute and institutional barriers) continue to limit the field of application of EAT and will not be avoided or eliminated in the short term, other categories might easily be removed.

5.1 Types of barrier to the use of efficiency assessment tools

Monetary efficiency assessment tools that aim to support decision making about the implementation of road safety measures and to select efficient measures are neglected or not used for a variety of reasons. It is possible, for example, that particular road safety measures have to be introduced hurriedly because of public or political pressure, so decisions about the implementation have to be taken rapidly. In this case, rough calculations will more or less substitute for intensive monetary assessment. Other reasons for not using EAT might include missing input data for the necessary calculations (e.g. because of lack of knowledge about relevant impacts), or decision makers that lack the knowledge needed to conduct a monetary assessment. Additionally, conflicts of interest may arise and impede the application of EAT, or decisions may be taken without following the principles of efficiency but instead for political objectives (e.g. protection of particular groups of people, equity aspects). These examples demonstrate the wide variety of restrictions and constraints to the application and implementation of EAT.

To draw up the whole spectrum of possible barriers, the second work package of the ROSEBUD project investigated barriers to the use of EAT for the implementation of road safety measures. A survey was carried out to shed light on barriers that lead directly to the abandonment of monetary assessment for road safety measures. A questionnaire was developed and handed out to decision makers and experts at different policy levels (regional, national, European) within the partner countries.

They were mainly asked about

- the current road safety policy in their countries,
- the use of formal efficiency assessment tools for setting priorities for road safety measures and
- the main reasons, why formal efficiency assessment tools are not used as a stable element of road safety policy.

In addition, the relative importance of various barriers to the use of efficiency assessment tools was assessed. The result of the survey and the complementary desk research was a broad catalogue of barriers that continue to limit the applicability of monetary assessment methods for the implementation of road safety measures. The most frequently mentioned barriers (all policy levels, all partner countries) are

- rejection of the welfare-economic principles that underlie the EAT,
- rejection of the efficiency criterion as a measuring unit,
- rejection of the monetary valuation (e.g. of human lives),
- political opportunism in decision making, different political objectives (e.g. equity aspects),
- scarcity of resources (financial budget, time),
- lack of recommendations for using EAT,
- lack of practical EAT knowledge, difficulty of performing EAT, inadequate tools and guidance,
- lack of (political) responsibility and non-funded mandates,
- wrong timing of EAT in the decision-making process,
- lack of knowledge about impacts or monetary values,
- unreliability of method or impact data, lack of impartial quality check,
- unsuitability of methods for certain kinds of measures and
- conflicts of interest or possible vested interests.

Barriers to the use of EAT derive from different aspects of making decisions about the implementation of road safety measures. On the one hand, they might result from the monetary assessment tools themselves (e.g. theoretical background of the methods, practical use of the tools), on the other hand they might be based in the environment of the political decision-making process (political interests and opportunism, conflicting policy objectives) or the institutional structures (unfunded mandates, lack of a mandate that requires efficiency assessments).

In order to develop appropriate “countermeasures” and proposals for increasing the use of EAT it is not enough to simply know about the existence of such barriers; the aim must be to counteract the emergence of such obstructions. This is helped by forming categories or clusters of similar barriers. Presumably, similar means can help to eliminate each barrier in a cluster. Several suggestions have been made within ROSEBUD for clustering barriers to the application of EAT.[23]

Four different clusters of barriers to the use of efficiency assessment tools (according to their nature or origin) were generated (see Table 4).

Cluster		Examples of barriers to the use of EAT
A	Fundamental barriers = resulting from the theoretical basis of the assessment tools	Rejecting principles of welfare economics Rejecting efficiency as a relevant criterion of desirability Rejecting monetary valuation of risk reductions
B	Institutional barriers = resulting from the institutional settings	Lack of consensus on relevant policy objectives Unfunded mandates and excessive delegation of authority Wrong timing of EAT information in decision making
C	Technical barriers = resulting from the EAT itself (technical requirements, data needs)	Lack of knowledge of relevant impacts Inadequate monetary valuation of relevant impacts Inadequate treatment of uncertainty
D	Implementation barriers = related to the implementation process of cost-effective measures	Lack of power (related to unfunded mandates etc.) Lack of incentives to implement cost-effective solutions Lack of marketing of efficient policies (presentation)

Table 4: Clusters of barriers to the use of efficiency assessment tools in road safety policy (Source: Rosebud, WP 2 Report, Oslo 2003, p.13 ff.)

In the first work package of ROSEBUD a main distinction was identified between barriers to use and barriers to implementation.

- Barriers to use are more or less comparable to categories A, B and C in the classification presented above. In work package 1 two items were stressed as important barriers to the use of EAT.
    - Efficiency assessments of road safety measures are not mandatory (it is not even mandatory to include road safety impacts in CBAs for infrastructure investments).
    - There is no regular guidance on the analysis of safety effects.
- Barriers to implementation arise basically from category D mentioned in Table 4. Additionally, problems resulting from the methodology of the EAT (referring to the technical barriers mentioned in Table 4) may constitute barriers to implementation.

Absolute barriers are mainly in category D (implementation barriers) and category B (institutional barriers) used in Table 4. The barriers presented in these categories cannot be removed easily or avoided in the short term. Processes have to be rearranged and organisational settings have to be restructured. This requires – in addition to expenditure of time and money – the willingness of politicians, experts etc. to change the decision making process. In addition to implementation or institutional barriers, fundamental barriers (category A) also belong partly to the category of absolute obstructions which cannot be influenced, at least, if such objections are not based on misunderstandings or lack of information about EAT.

Relative barriers can be influenced or even removed by proposals or improvements to the use of EAT for decision making. The provision of knowledge and guidance about impact assessment for decision makers and users of EAT can certainly help to eliminate this kind of barrier. Compared to the earlier classification of barriers, this category will mainly contain technical barriers (category C), also some institutional barriers (especially those that are linked to technical barriers).

[23] See also ROSEBUD WP 2 report, p. 13 ff., Rosebud WP 1 report

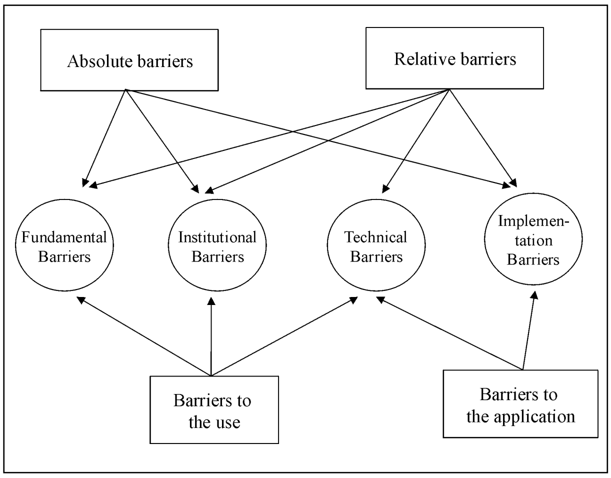


Figure 2: Relations between different classifications of barriers to the use of EAT (Source: ROSEBUD, WP 2 report., p. 35)

It was mentioned when presenting the different classifications of barriers that these classifications are linked. The relations and connections between the different clusters of barriers are illustrated in Figure 2.

The various classifications that have been developed in the ROSEBUD project actually represent different points of view about the problems that decision makers and users of EAT face when making decisions about implementing road safety measures; however, they mainly deal with the same problems. The following section deals with ideas for overcoming barriers to the use of efficiency assessment tools, and it will be important here to classify barriers as absolute or relative, since the section concentrates on the possibility of finding solutions and bypasses the objections to using EAT.

5.2 Overcoming barriers to the use of efficiency assessment tools

Overcoming the existing barriers will be a long term process during which various types of steps need to be taken. Road safety experts with relevant knowledge about CBA and its benefits should play a vital role in this process. Their role lies mainly with collecting and disseminating information and hence persuading responsible decision makers and politicians at all levels of the necessity of using CBA of road safety measures when reaching decisions.

An international methodology and better data about road accidents should create a good background for implementing CBA, especially at the national level. The whole system of overcoming the barriers and obstacles should also be supported by the necessary funds, for otherwise the efficiency and scope of the whole process would be very limited. Last but not least, national conditions (e.g. administrative structures, various bodies involved, system of financing etc.) should be taken into account when trying to overcome obstacles.

Economic assessment is successfully applied in many countries. This indicates that barriers were successfully removed in these countries. Aiming to reduce or remove barriers to the use of EAT in road safety policy does not imply a technocratic position which insists that CBA and CEA dictate public policy – with the politicians as somewhat superfluous masters of ceremonies who rubber stamp the irrefutable truths from the economic analyses. It should be recognised that politicians in democratic countries are elected to represent the will of society, and their role is to take account of the results of the EAT.

There are several basic ways to overcome existing barriers to implementing EAT:

- Create a standardised economic methodology for road safety assessment. Public authorities at the national and EU level can improve the quality and uniformity (comparability) of efficiency assessment studies, e.g. by establishing good practice guidelines for the methods and techniques.
- Establish a system for exchanging information about ways of operating CBA and the impact of various road safety measures, to serve as the background for decision makers. To stimulate the more uniform and reliable evaluation of safety effects in the EU, it would be useful for example to establish a database with typical values of the effects, based on international experience. The quality of efficiency assessments can be improved by introducing impartial quality control.
- There should be more scope for CBA at the European level, executed both by the DG TREN and especially by expert support of the EU bodies[24]. The use of EAT can be stimulated, for

24 This would not only lead to more efficient EU road safety policy but also provide inspiration for decision makers and politicians at the national level to take CBA seriously.

example, by legally embedding EAT in the decision making process for large road investments.

Road safety experts should make greater efforts to disseminate information and knowledge about the operation and impact of CBA within their countries, drawing upon international experience. Such information should be disseminated with great expertise, using very clear and understandable arguments. Presentation of the benefits of CBA using non-technical language should help to widen understanding of CBA, especially among politicians at all levels.

The dissemination of information is limited by the available financial resources. More money for disseminating information and better explanations of the CBA of road safety measures could play a very important role in gaining greater acceptance.

Special attention should be paid to politicians at all levels. Involvement of NGOs in disseminating information about the benefits of CBA could play an important role in overcoming political opposition.

It is vitally important to overcome institutional barriers. National road safety administrations (ministries) and national road safety institutes should play a crucial role in achieving this, and international co-operation both at the EU level and bilaterally should make an important contribution.

One of the most fashionable ideas currently influencing governmental reform in many states is to delegate as many tasks as possible to the lowest level of government. The arguments made for such reforms are that local problems are best solved at the local level, and that local government can be reinvigorated if it is given more tasks and more freedom to choose how to solve these tasks. The problem at the local level is very often lack of resources. If the delegation of responsibilities is not accompanied by extra funding, an extra barrier can be created and the effect of keeping decision making as close as possible to citizens can be lost. This barrier should thus be overcome by providing sufficient funding at the local level.

Creating one very detailed road accident database or, as a preliminary, co-operation between existing databases should help to encourage the wider use of CBA. Good information, possibly comparing international road accident trends and the impact of road safety measures, should create a favourable environment for introducing CBA with the benefit of international experiences. An important step for achieving this is to create a common methodology for collecting road accident and traffic data at national level among member states. At the international level, closer co-operation between the various international organisations charged with improving road safety and road transport should be encouraged,

The importance of CBA should be emphasised by incorporating CBA in EU, national, regional and local road safety plans and strategies.

6 Professional code for analysts

The following guidelines give an overview about the minimum conditions which should be fulfilled by a professional road safety related assessment. These guidelines should give decision makers support when they have to decide about the conduct of a road safety related assessment. It could also be useful for consultants and analysts to consider these guidelines when drafting a proposal.

The professional guidelines can be summarised by the following short rules:

6.1 Networking

The consortium or team which carries out the assessment should possess all the skills and experience which are necessary to solve the assessment problem. While an experienced knowledge in road safety related analysis is always necessary, additional knowledge is required when, for example, economic or environmental effects are also to be assessed. Good knowledge in one field cannot outweigh missing qualities in other fields. The whole quality of the assessment would suffer if one aspect is addressed in an inadequate manner.

6.2 Agreement on the term of reference

Several items should be agreed and fixed between the decision makers and the analysts before the assessment starts:

- objective of the study;
- number of case studies to be assessed (and relevant alternatives);

- assessment method (see below);
- degree of completeness of analysis;
- lifetime and sustainability of the measure (i.e. how many years could effects be attributed to the measure);
- agreement on evaluation criteria and on degree of thoroughness;
- milestones (see below);
- all relevant circumstances, including already detected barriers;
- reports (see below);
- installation of a quality control group (see below).

6.3 Quality control

The quality of the efficiency assessment could be improved by introducing a quality control procedure. To this end, it is advisable to consider introducing a permanent or ad-hoc evaluation board to accompany large assessment projects. General assessment experts and specialists for the specific item under assessment should form such a group.

6.4 Milestones

Important interim results during the assessment process should be defined as milestones (e.g. completion of the data sets, estimation of the reduction potential etc). When a milestone is reached, it should be possible to end the assessment project, if the expected result documented by the milestone is not reached and adequate alternative strategies are missing.

6.5 Transparency

The whole assessment process has to be distinct and transparent. Decision makers have no use for “black boxes” where only the analyst knows how input leads to output. Data sources, calculation methods, costs and benefits have to be documented. It is necessary to document the assumptions which are made and the influence of these assumptions on the results of the assessment.

6.6 Application of the state of knowledge

To assess a road safety measure means to apply the up-to-date scientific knowledge to a specific assessment task. Such an assessment task is not the playground for theoretical discussions and controversies. Where official or superior approaches are missing and competing approaches exist, it is the task of the analyst to decide which approach should be applied and to explain succinctly the reasons for this decision.

6.7 Assessment method

The choice of the assessment method depends on the variety and characteristics of the considered effects, the intentions of the client and the kind of decision which is to be supported by the

Professional guidelines for analysts
The competence of the consortium has to be adequate for the assessment task.
Several items have to be fixed before the assessment starts.
A quality control board could be established for large assessment projects.
Important interim results during the assessment process should be defined as milestones.
The whole assessment process has to be distinct and transparent (no “black box”).
Assessment of a road safety measure requires the application of the current state of scientific knowledge to a specific assessment task.
The choice of the assessment method depends on the variety and characteristics of the considered effects.
All effects, which could be caused by the implementation of the measure, have to be considered in the assessment.
Data has to be attributed correctly to its sources and it has to be documented where and how estimations were made to fill data gaps.
The most important step of any road safety related assessment is the estimation of the accident reduction potential, therefore it would be highly undesirable for this estimate to be hidden somewhere within the text.
Analysts should avoid to create own figures where official monetary values exist.
It has to be explained under which conditions results are valid and which developments could influence the result.
Decision makers should not be flooded with irrelevant information.
The whole assessment process has to be documented in a report, starting with a summary and highlighting the main results.

Table 5: Professional guidelines for analysts

assessment. In principle, analysts should try to carry out a CBA due to the advantages of this method.

A CEA could be carried out if only one-dimensional safety effects (usually the reduction of fatalities) have to be considered, e.g. for ranking different measures.

6.8 Coverage

All effects of the measure which influence the allocation of ressources have to be considered in the assessment.

Always to be included are the values of:

- safety effects,
- implementation and maintenance costs.

In ROSEBUD such an assessment has been called a “mini-CBA”.

When basic traffic parameters like speed distributions or traffic volumes are influenced by introducing a measure, additional effects should be taken into account:

- travel time changes,
- changes in fuel consumption,
- pollution,
- global warming.

To consider environmental effects (pollution) it is necessary for at least the emission changes of NO_X, HC and CO to be considered. To consider the effects on global warming, CO_2-emissions should be considered. Depending on the assessment task, the inclusion of further effects, such as noise, could be recommended.

6.9 Data bases

Data have to be attributed correctly to its sources, especially when different data sources like national or international accident databases or in-depth databases are used. Where and how estimations were made to fill data gaps needs to be documented. Regression models should be used to generate future time series; trend extrapolations can replace them where available data are insufficient for regressions.

6.10 Estimation of the accident reduction potential

The most important step of any road safety-related assessment is the estimation of the accident reduction potential. Many different techniques are available to derive an accident reduction potential, e.g. field studies, meta-analyses, surveys or expert judgements.

Independent from the chosen approach analysts must:

- give reasons why this approach was chosen and
- document how the chosen technique was applied.

What has been mentioned before regarding the transparency of the whole assessment process is especially true for the estimation of the accident reduction potential. Above all, the estimation of the reduction potential should not be simply hidden somewhere in the report.

6.11 Appraisal

In many European countries official values are available to assess the above mentioned effects. Analysts should avoid creating their own figures where official values exist.

Where official figures are not appropriate the analyst should raise the problem and carry out a sensitivity analysis with the official and unofficial values.

Where official values are missing analysts should use available figures from other countries, but taking account of welfare differences between countries, e.g. by using weights like income per capita.

6.12 Discussion of the results

After an assessment result has been derived it is the duty of the analysts to explain the stability of the result, i.e. to explain under which conditions the result is valid and which developments could influence the result. Above all, analysts have to be honest about the weak points of their assessment, e.g. where judgements were necessary to close data gaps or where small changes of specific parameters could influence the whole assessment result.

The discussion of the results should not be done in difficult, technical terms, but by translating the assumptions and uncertainties in different outcomes of the efficiency assessment (sensitivity analysis). If this is not done, decision makers may become suspicious, because they could not understand the outcomes.

Effects which cannot be addressed by means of CBA or CEA should be mentioned, e.g. distributional effects.

Finally, unresolved questions should be presented clearly.

6.13 Brevity

Road safety related assessment is carried out to enable decision makers to make an adequate decision although they are usually facing a very complex situation. The complexity of the situation is condensed into one figure like the cost-benefit ratio. This advantage of the assessment should not be weakened by flooding the decision makers with all other information which has been collected during the assessment process. Thick reports, unclear tables and incomprehensible language are undesirable and counter productive.

Nevertheless, decision makers often demand something more than one figure. To this end a summary e.g. in tables can be used.

6.14 Documentation

The whole assessment process has to be documented in a report, fulfilling all the requirements as described above regarding transparency and brevity. At the beginning of every report a summary should inform about the key results. The main results should be highlighted and not hidden in the report. Complementary to the report, a personal presentation can be given by the analyst. It would be recommended that a clear and simple presentation of the results is provided together with the report. The presentation has to ensure that the subject is understandable and accessible.

7 Examples of assessed road safety measures

One objective of ROSEBUD was to gather relevant experience with road safety efficiency assessment.

The following pages will provide some examples of assessed road safety measures, their descriptions and significant assessment results.

Most of the measures considered in this chapter are recently introduced, planned to be introduced soon or under discussion in at least some of the European countries.

The assessments considered have been carried out by renown researchers and institutions. They were published as self-standing publications or in scientific journals. With each assessment result the source is given for further studying.

7.1 User-related measures

7.1.1 Reforming and improving basic driver training, education and licensing

Although basic driver training and testing have been widely established, the number of accidents caused by novice drivers world-wide is still high. Therefore, different approaches are being discussed to reform and improve national driver training, education procedures and licensing systems. For example, basic driver training can be improved (e.g. requirement to undertake more practical driving lessons) and new pre- or post-licensing measures can be introduced (e.g. license for novice drivers on probation, second phase training after licensing). Moreover, the age at which driver training is permitted could be reduced by one or two years to allow accompanied driver training in earlier years.

In Sweden for example the age at which training is permitted was reduced from 17.5 years to 16 years. The licensing age remained 18 years. The objective of this reform was to give novice drivers more opportunities for training before becoming fully licensed. It was assumed that a longer period before passing the driving test would mean that novice drivers would be more experienced when they took the test and hence have a lower accident rate.

The evaluation of PROMISING (2001) found a reduction of 35% in the injury accident rate of those

Selected assessment	B/C-ratio	Source
Reforming basic driver training in Sweden	1.43	ELVIK, R. (2001), ELVIK, R. (2003), ELVIK, R.; AMUNDSEN A.H. (2000)
Introduction of a two-phases model of driving education in Switzerland	3.50	VESIPO (2002)
Graduated licensing – lowered age limit for driving training in Sweden	1.82	PROMISING (2001)

Figure 3: Driver training (Source: DVR)

who started driver training at 16 compared to those who started at 17.5. The savings in accident costs obtained during the first year of driving outweigh the additional costs of training.

It seems likely, though, that any effect during the second and third year of driving will be smaller than during the first year of driving.

7.1.2 Road safety campaigns

Road safety campaigns complement other activities aimed at improving road safety. Important tasks of road safety communication include raising the public acceptance for road safety measures (e.g. enforcement measures) and decreasing the public acceptance of risky behaviours.

Media can influence attitudes e.g. by informing about rules, explaining consequences of risky behaviour, informing about police enforcement and about possible punishments. Since the target of the campaigns are people or groups of people, and as their behaviour may differ from one country to another, the specific messages addressed to the target group chosen for a campaign may vary from country to country and even within a single country.

Selected assessment	B/C-ratio	Source
Road safety campaign against drinking and driving in Germany	4.7	Source: BRILON, W. et al. (2002)
Road safety campaign addressing young road users in Sweden	20.0	Trivector Information AB (2002)
Extending ‘speak out’ safety campaign in Norway	16.8	AMUNDSEN, A.H., ELVIK, R. and FRIDSTRØM, L. (1999)

In 1998/1999 for example a road safety campaign against drinking and driving was carried out in 17 German counties in 12 Bundesländer. Young citizens (females aged 16-24) received a letter and an information brochure informing about the risks of drinking and driving. Also different media (e.g. local radio) in the counties supported this road safety campaign. In some counties police enforcement was also intensified during the road safety campaign.

In many cases it is difficult to estimate the impact of the campaign itself, especially if the campaign is combined with elements of enforcement or other road safety targeted measures whose effects possibly overlap. Furthermore, the effects of a campaign have to be separated from general developments in road safety.

7.1.3 Voluntary training for bus and truck drivers

Standardised safety training procedures for new and experienced drivers could contribute to a reduction of the number of accidents with trucks and buses that are caused by driving errors. Voluntary training courses are being designed to increase the competence of professional bus and truck drivers.

The training of bus and truck drivers should include information on vehicle inspections, adjusting safety-related equipment, seat-belt wearing, procedures for loading and unloading, traffic regulations and driving procedures, overtaking another vehicle, driving at night, adverse weather conditions,

Selected assessment	B/C-ratio	Source
Training of bus and truck drivers (voluntary) in Norway	2.16	ELVIK, R. (1999), ELVIK, R. (2001), ELVIK, R. (2003)

Figure 4: Example of bus training; Source: DVR

Figure 5: Safety education. Source: DVR

skidding and aquaplaning, what to do in case of an accident and first aid.

Furthermore, training courses should include controlled braking exercises at different speeds and on roads of different surfaces, manoeuvring exercises, slalom driving and driving on ascending slopes as well as learning evasive manoeuvres.

Apart from the more technical part of the training, behavioural elements such as defensive driving techniques relating specifically to bus and truck drivers should be stressed throughout the courses.

7.1.4 Traffic safety education and information for children and adolescents

Traffic safety education and information aim at ensuring that children and adolescents travel safely to and from school. They should be well prepared for their active participation in traffic by walking, riding a bicycle, using a bus or a car as passenger.

Therefore, comprehensive education programmes are necessary to build road safety awareness among school children and adolescents. These programmes should be developed by road safety professionals together with teachers. Furthermore, traffic safety education should take place on all school levels to reduce the number of accidents with children of all ages.

A survey in 2004 indicated that safety education in Germany differs from region to region and in a lot of cases there is a lack of interest amongst teachers at the upper secondary stage in instruction traffic safety education.

Selected assessment	B/C-ratio	Source
Mobility and safety education on all school levels in Switzerland	4.3	VESIPO (2002)

7.1.5 Alcohol interlocks

Alcohol interlocks (also termed alcolocks) are devices to require the driver to take a breath test before starting the car. If the driver fails the test, the device locks the ignition of the car. Recent technical innovations made alcohol interlocks largely fraud-resistant. Drivers have to hum while blowing into the device or briefly inhale at the end, depending on the type of device. Both requirements prevent drivers from using a breath sample that was provided earlier. Drivers could also be retested regularly in the course of the journey. This helps to avoid fraud at the start of the journey, because the sober person doing the test for a drunk driver would have to stay in the car with that driver throughout the trip. In principle, alcolocks can be installed as aftermarket devices in any type of car.

In Sweden the implementation of alcolocks is already decided.

In France a pilot project was started in 2004: drink driving offenders caught with a BAC of 0.8 to 1.6mg/ml may participate in an alcohol interlock programme as an alternative to prosecution. An

Selected assessment	B/C-ratio	Source
Alcohol interlock in the Netherlands	4.1	IMMORTAL (2005)
Alcohol interlock in the Czech Republic	1.6	IMMORTAL (2005)
Alcohol interlock in Norway	4.5	IMMORTAL (2005)
Alcohol interlock in Spain	0.7	IMMORTAL (2005)

alcolock stays in the car for 6 months. Offenders have to pay 1,260€. The trial has been conducted with 40 offenders with the goal of including 400 offenders eventually.

The examples of IMMORTAL (2005) describe the installation of an alcohol interlock in cars for every driver that is caught with a BAC level of 1.3g/l or higher or for drivers that are caught twice with a BAC level between 0.5g/l and 1.3g/l. Furthermore, there is no accompanying or post project rehabilitation programme for the driver. Any safety effects after two years (when alcohol interlock is removed) are discounted.

7.1.6 Physical examination of vehicle drivers

In some countries, medical examinations especially are required for elderly drivers. The driving licensing practice for elderly drivers could include various combinations of age-dependent requirements for re-licensing such as road tests, medical reports or vision testing. A physical examination of elderly drivers is an alternative to rigorous age limits for driving and should allow people to drive as long as they can do so safely. Compulsory periodic testing of drivers' eyesight aims at reducing the number of crashes caused by drivers with poor eyesight. If the test shows that the eye sight is not adequate for driving, the driver should be obliged to wear a seeing aid. This duty should be noted in the driving license. If the bad eyesight is not correctable, the driving license should be withdrawn.

The study IMMORTAL (2005) assessed eyesight testing in various European countries. The measure consists of mandatory tests after the age of 45 every time the license has to be renewed. After the age of 65 every five years a "Useful Field Of View" test (UFOV – criterion: reduction of field of view should not exceed 40%) is included in the standard test. A moderate decline of the relative accidents risk ratio led to relatively many lives being saved in the Czech Republic.

Selected assessment	B/C-ratio	Source
Licensing procedures for older drivers in Australia	0.11 - 0.60	FILDES, LANGFORD, DEERY, et al. (1998)
Mandatory eyesight test for car driver (age >30) in Switzerland)	1.8	VESIPO (2002)
Eyesight Testing in Spain and the Czech Republic	1.5 - 4	IMMORTAL (2005)

7.1.7 Reduced alcohol limit for selected groups

A lower alcohol limit for selected groups (e.g. truck drivers) or a trial period (e.g. for novice car drivers) could reduce the number of accidents caused by road users under the influence of alcohol. Violations should be punished with the suspension of the driving license. The driving license on probation for novice drivers is sometimes combined with a period of zero alcohol limit.

A reduced alcohol limit would leave no tolerance for drinking and would avoid peer pressure upon young people to have "just one drink". Drivers could make easier decisions about whether or not to drive. As proposed by the Belgium BOB campaign, groups of young novice drivers could select one of their group to act as an alcohol-free driver ("BOB").

Selected assessment	B/C-ratio	Source
Alcohol limit of 0,20/00 for novice drivers, motorbike riders and truck drivers in Switzerland	71.0	VESIPO (2002)
Lower BAC limit for novice drivers and license on probation in Austria	8.91	PROMISING (2001)
Lower BAC limit for novice drivers in the USA	11	ELVIK, VAA (2004)

The Austrian law for example prescribes a probation period of two years for novice drivers. In addition, the legal BAC-limit (blood alcohol concentration) for novice drivers was lowered. During the probation period, the following offences lead to compulsory participation in a driver improvement programme as well as to extension of the two years probation period by an additional year: offence against the BAC limit, causing an injury or fatality, committing a dangerous offence, for example, seriously exceeding the speed limits.

Even taking account of the reduced number of novice drivers in the Austrian example, the analysis indicates an accident reduction of 18.7% (number of novice drivers involved in accidents with personal injuries and fatalities related to the number of holders of driving licences on probation.) The benefits outweigh the costs by a wide margin.

7.1.8 Disco buses

Young male car drivers are at high risk of being involved in a fatal or severe accident. Their risk is especially high at weekend nights, particularly when alcohol is involved. It is sometimes argued that they had no alternative to the car if they wanted to participate in their preferred entertainment at weekends. Disco buses can avoid nighttime accidents involving young drivers, particularly under the influence of alcohol, by offering a safe alternative to young people unfit to drive and to young people dependent on taking lifts from unfit drivers. The disco bus is an alternative to car use designed to meet the specific mobility needs of young people.

In order to reduce the high number of late-night road accidents involving 18- to 24-year-olds at weekends, numerous public transport services, in particular disco buses, have been set up in Germany since the early 1990s.

Selected assessment	B/C-ratio	Source
Disco buses in Germany	4.06	PROMISING (2001)

When introducing disco-buses, special care must be taken to identify the needs of young drivers and to achieve a high level of acceptance in order to run the system effectively. As shown below the received results are PROMISING so far.

Figure 6: Disco buses in Germany; Source DVR

7.1.9 Randomly scheduled and enhanced police enforcement

Traffic law enforcement is a factor that contributes significantly to normative road user behaviour and road safety. Randomly selected sites and times for enforcement achieve good results. Traffic rules are usually enforced by traffic police forces whose activity and success are generally limited by the resources than can be applied and by established priorities. Nevertheless, many studies have shown that increased police enforcement efforts would have a major impact on road safety.

Selected assessment	B/C-ratio	Source
Randomly scheduled low level police enforcement in Australia	55.4	NEWSTEAD, CAMERON, LEGGETT (2001)
Selective traffic enforcement programmes at high-risk times and locations in the USA[25]	$ 5,200	TENGS et al. (1995)
Intensified police enforcement in Greece	6.6 - 9.7	ROSEBUD WP4 (2005)

Random road watch (RRW) – a programme of randomly scheduled low level police enforcement has been applied in Queensland since 1991. With 279 police stations involved and 40 road segments per station, the project covered some 11,000 RRW sites. The total deployment was some 40,000 hours per year. The state-wide effect of the programme is equal to a 15% reduction in fatal crashes and 8.2% reduction in total reported crashes.

Selected assessment	B/C-ratio	Source
Concentrated general enforcement in Israel	3.5 - 5.0	ROSEBUD WP4 (2005)
Tripling stationary speed enforcement in Norway	6.5	ROSEBUD WP4 (2005)
Tripling drink-driving and seat-belt enforcement in Norway	1.2 - 3.6	ROSEBUD WP4 (2005)

7.1.10 Random breath testing

All EU member states have legal BAC-limits, mostly of 0.5mg/ml. Random breath testing (RBT)

[25] In this study, cost-effectiveness is defined as the net resource costs of an intervention per year of lives saved (in 1993 US-Dollars), documented here with 5,200$.

can be conducted by traffic police officers in normal police vehicles and performed in combination with their other duties or, alternatively, by specialised police groups with special-purpose vehicles. Random means in this context that there is no requirement to suspect drunken driving in advance for stopping a driver and carrying out a breath test.

Such a strategy should aim at increasing the current level of enforcement in the area of drink-driving substantially and permanently. A high probability of being stopped and tested should be reached by exposing a large number of road users to unpredictable, well publicised, and highly visible roadside checks. In most EU countries the police are entitled to use the instrument of RBT.

Selected assessment	B/C-ratio	Source
Increased random breath testing in Norway	1.02 - 1.65	ESCAPE (2001)
Random breath testing in Sweden and Norway	1.50	ELVIK, R. (1999), ELVIK, R. (2001), ELVIK, R. (2003), ELVIK, R.; AMUNDSEN A.H. (2000)
Random Breath Testing	36 - 55	ETSC (2003)

7.1.11 Speed enforcement

Speed enforcement techniques include mobile and stationary radar, laser speed measurement devices, aerial enforcement and mobile patrols. Common manual and stationary speed enforcement involves a configuration that includes an observation unit, typically an unmarked police car more or less hidden at the roadside, and an apprehension unit comprising of one or more clearly visible marked police cars.

The observation unit is equipped with a measurement device such as a radar or a laser device and possibly a documentation device such as a still or video camera. Radar units use high frequencies to measure the speed of target vehicles approaching or receding from a stationary or moving patrol vehicle while laser instruments use pulses of infrared light to measure the speed. Speeding vehicles are detected at the first station, their description is relayed to the apprehension unit downstream, which flags them to stop and issues citations to drivers.

Figure 7: Stationary radar; source: BASt

Selected assessment	B/C-ratio	Source
Speed enforcement in Norway and Sweden	2.89 - 3.62	ELVIK, R. (1999), ELVIK, R. (2001), ELVIK, R. (2003), ELVIK, R.; AMUNDSEN A.H. (2000)
Tripling stationary speed enforcement in Norway	6.5	ELVIK, VAA (2004)
Automatic speed control in Sweden	2.98	ANDERSSON, G. (2003b)
Current use of automatic speed enforcement	2.03 - 8.88	ESCAPE (2001)

7.1.12 Seat-belt enforcement

Seat-belts are intended to reduce the incidence and severity of personal injuries when an accident occurs. According to most national traffic laws, car occupants and all children above a specific age anywhere in the vehicle must be secured by a seat-belt (and younger children by special child restraint systems). Low levels or decline of safety belt use in some regions are worrying. Enforcement of seat-belt laws should raise seat-belt wearing rates. Intensive police enforcement efforts are a major component of seat-belt enforcement and education

Figure 8: Child restraint; source: DVR

programmes designed to reduce avoidable traffic fatalities and injuries. Surveys have often shown that seat-belt use has risen following police enforcement campaigns.

According to ETSC estimates, seat-belt wearing rates in the EU vary between 45% and 95% for front seat occupants and between 9% and 75% for rear seat passengers (ETSC, 2003).

Studies have shown that so-called 'blitz' actions, lasting only some weeks, can be very effective in producing sharp increases in seat-belt wearing rates. To achieve long-term effects they need to be repeated several times a year.

Selected assessment	B/C-ratio	Source
Increased seat belt enforcement	3.23 - 3.65	ESCAPE (2001)
Seat-belt enforcement in Norway and Sweden	2.67 - 3.85	ELVIK, R. (1999), ELVIK, R. (2001), ELVIK, R. (2003), ELVIK, R.; AMUNDSEN A.H. (2000)
Seat belt enforcement in Norway	3.6	ELVIK, R., VAA T. (2004)

7.1.13 Section control

Section control systems do not measure speed at a certain point in space and time, but calculate the average speed by means of passage time in a defined area. The aim is to force drivers not only to

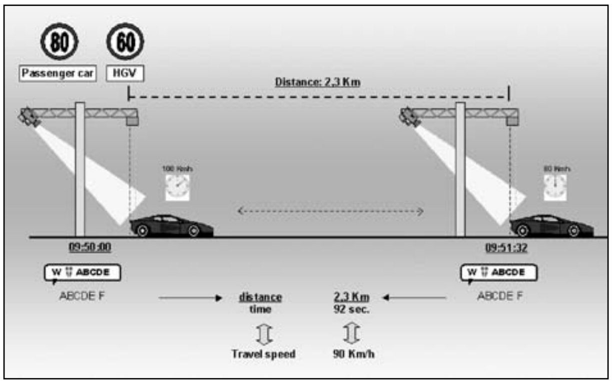


Figure 9: Section Control – Automatic Speed Enforcement in the Kaisermühlen Tunnel (Vienna, A 22, motorway) ; source: ROSEBUD WP4

slow down at certain points of stationary speed control (e.g. automatic speed cameras), but adhere to the speed limit over the whole distance. It provides live monitoring of traffic flow behaviour and contributes to harmonising traffic flow performance.

The Kaisermühlen Tunnel is an urban tunnel with separate tubes for each direction of traffic. The tunnel provides 3 to 4 lanes per direction with entrance and exit ramps within the tunnel. More than 90,000 vehicles use this part of the motorway every day (about 10% are heavy goods vehicles.) In its first year of operation, a reduction in average speed by more than 10km/h was recorded.

Selected assessment	B/C-ratio	Source
Section control in the Kaisermühlen Tunnel	5.5	ROSEBUD WP4 (2005)

7.1.14 Red light cameras

Stationary red light cameras collect all of the evidence authorities need to prosecute light-runners at intersections. Usually, a picture of the number plate of the offending vehicle and a picture of the driver's face are taken. In some countries, the picture of the number plate is sufficient evidence, whereas in other countries it is not. As the system is usually immobile, a second camera is needed for the picture of the driver's face. In a typical red-light system, cameras are positioned on poles at the corners of an intersection, pointing inward to photograph cars driving through the intersection. Generally, a red-light system has cameras at all four corners of an intersection, to photograph cars going in different directions and to get pictures from different angles. Red-light systems use film or digital cameras. The traffic signals and the triggers of the system are constantly monitored. If a car sets off a trigger when the light is red, two pictures at the edge and in the middle of the intersection are taken to record the violation.

Selected assessment	B/C-ratio	Source
Red light cameras at signal controlled junctions and pelican crossings in Glasgow	2.20	HALCROW FOX (1996)
Red light cameras in Sweden	1.69	ELVIK, R. (2001), ELVIK, R. (2003), ELVIK, R.; AMUNDSEN, A.H. (2000)
Red light cameras in Norway	0.84	ELVIK, R. VAA, T. (2004)

7.1.15 Combined enforcement and publicity campaigns

In order to increase the acceptance of a road safety measure by the public and thereby render it more successful, road safety campaigns should be launched simultaneously with enforcement programmes. The public should be extensively informed about the road safety problem that is addressed. Mostly, the costs for the campaign are paid by local or national authorities, whereas the control costs have to be borne by the police authorities.

Selected assessment	B/C-ratio	Source
A package of enforcement and publicity measures aimed at drink-driving and speeding in New Zealand	7.0	BLISS, GURIA, VULCAN, CAMERON (1998)
Road safety television advertising supporting increased police enforcement in Australia	3.9 - 7.9	CAMERON, HAWORTH et al. (1993)
Campaign and controls against dangerous and risky driving in Switzerland	20.0	VESIPO (2002)

As an example, campaigns and controls of the suitability to drive can be combined. The driving suitability of vehicle drivers, especially when driving under the influence of alcohol, drugs and medication, should be controlled as well as the effect of fatigue and the supervision of the prescribed resting periods for truck drivers. These enforcement measures could be accompanied by an information campaign. The campaign should make drivers aware of their own suitability for driving.

Publicity campaigns should make use of as many different kinds of media as possible to reach a high proportion of the public. Printed media (e.g newspapers, magazines, flyers) could be involved as well as television or radio.

7.1.16 Bicycle helmet related campaigns and legislation

Head injury is known to be a major cause of disability and death resulting from bicycle accidents (e.g. fractures of vault or base of skull or intracranial injuries). Increasing bicycle helmet wearing should help to reduce the number of head injuries. Bicycle helmets contain a thick layer of polystyrene which absorbs the force of an impact and could reduce the consequences of an accident. To reduce head injuries to cyclists in all forms of accidents, including those involving a motor vehicle, every cyclist could be required to wear a bicycle helmet, and violations would be punished. Additionally, such an obligation could be accompanied by an information campaign.

In Germany, 62% of the German population uses a bicycle at least occasionally. Annually, about 600 Germans are killed as bicyclists in road traffic. A little less than 50% of the bicyclists injured in road traffic suffer head injuries. 65% of the head injuries occur in regions of the head that are covered by a helmet. In total, about 20% of the fatal and severe

Selected assessment	B/C-ratio	Source
Mandatory wearing of bicycle helmets in Norway	2.7 - 6.2	PROMISING (2001); ELVIK, R., BORGER-MYSEN, A. and VAA, T. (1997)
Bicycle helmets, campaign and law in Norway and Sweden	1.30 - 3.09	ELVIK, R. (1999), ELVIK, R. (2001), ELVIK, R. (2003), ELVIK, R.; AMUNDSEN A.H. (2000)
Compulsory bicycle helmet wearing in Germany and Austria	1.14 - 4.45	ROSEBUD WP4 (2005)

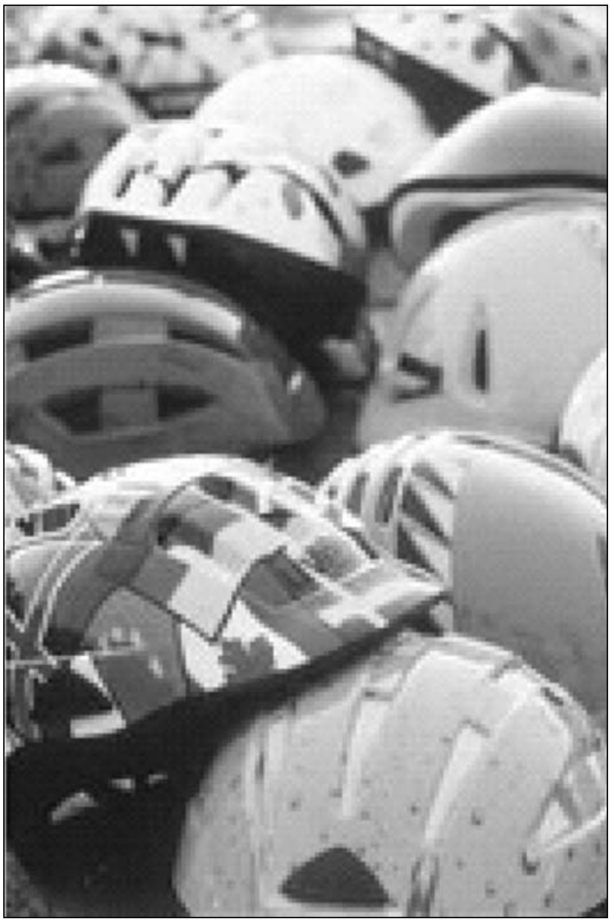


Figure 10: Bicycle helmets for children; source: DVR

injuries may be avoided by helmet wearing, if all bicyclists wore helmets. The current average helmet wearing rate is 6% (2004) almost constant over the recent years. The calculation in ROSEBUD WP4 has shown that at an increase of the helmet wearing rate up to 26.6% the measure would start to be cost-effective (break-even helmet wearing rate).

7.2 Vehicle-related measures

7.2.1 Safety inspections of heavy vehicles

To reduce the number of crashes attributable e.g. to fatigued drivers or to mechanical defects or unsafe equipment in commercial vehicles, vehicle safety inspections could be undertaken to ensure that vehicles are well maintained for safe operation. Technical inspections of vehicles should be carried out several years after the first registration, then repeated periodically. Licensed inspection technicians should perform these inspections, familiar with all the regulations required for the technical inspection of motor vehicles. Vehicle

Figure 11: Inspection of a truck in Germany; source: DVR

equipment should be inspected to ensure that all vehicle related safety standards and regulations are met. Roadside inspections of trucks should include checks of the driver's requirements, the presence of hazardous materials, the sides and the front of the tractor, the steering axle, all sides of the trailer, brake adjustment, wheels etc.. Violations which could be detected by roadside inspections of trucks comprise for example driver's records of duty status violations (e.g. regarding driving hours and rest periods) or technical problems like brakes out of adjustment or inoperable lamps. The inspections could be carried out by the police or authorised staff.

Selected assessment	B/C-ratio	Source
Roadside inspections for trucks in Sweden and Norway	1.24 - 10.13	ELVIK, R. (1999), ELVIK, R. (2001), ELVIK, R. (2003), ELVIK, R.; AMUNDSEN, A.H. (2000)
Periodic inspection of heavy vehicles in Norway	2.6	ELVIK, R., VAA T. (2004

First of all, the commercial advantage gained by road transport companies that disobey regulations, especially by having drivers work excessively long work hours, could be reduced by carrying out roadside inspections of trucks.

7.2.2 Automatic tracing of emergency calls

One weakness of many national emergency response systems is their inability to pinpoint the location of a call, in particular from a cell phone, following an accident. If the accident victim cannot tell the alert system operator which road he had been driving on, an important piece of emergency response information is missing – the accident

Figure 12: Accident site, source: DVR

location. A combination of technical solutions could be used to reduce the time between the emergency call and the rescue activity, e.g. technical devices to trace the location of mobile phones sending emergency calls and automatic emergency calls sent from the vehicle with the help of airbag sensors, crash data storage devices and GPS-devices.

The in-vehicle eCall is an emergency call generated either manually by vehicle occupants or automatically via activation of in-vehicle sensors. When activated, this in-vehicle eCall system will establish a voice connection directly with the relevant PSAP (public safety answering point). At the same time, a minimum set of incident data (MDS) will be sent to the eCall operator receiving the voice call. When medical care for critically and severely injured people is available at an earlier time after the accident, the death rate can be lowered.

The CBA of ABELE and BAUM calculated two scenarios (basis year 2002): “pessimistic view” (low success rate and high cost figures) and “optimistic view” (best case).

Selected assessment	B/C-ratio	Source
eCall	1.3 - 8.5	ABELE, BAUM et al., 2005

7.2.3 Daytime running lights

To reduce the number of daytime multiparty accidents that occur, when a driver or rider fails to see another vehicle in time to avoid a collision, some countries already require vehicle running lights to be illuminated at daytime. A compulsory rule for lights to be switched on, when the vehicle is in motion, could be considered, as well as a campaign to inform the public. As an alternative to a compulsory rule for the driver one might consider the equipment of all new cars with a device which automatically switches the lights on, when the vehicle’s engine is started. Another option is the mandatory installation of dedicated daytime running lights (DRL) which turn on automatically, when the ignition is started, and are overridden, when regular headlights are activated. Because of their characteristics, dedicated daytime running lamps have the advantage of consuming less fuel than conventional low beam headlights and therefore lead to lower levels of air pollution.

Selected assessment	B/C-ratio	Source
Mandatory use of daytime running lights (DRL) in Europe	1.24 - 1.80	KOORNSTRA, M., BIJLEVELD, F. and HAGENZIEKER, M. (1997), PROMISING (2001)
Campaign and compulsory rule for lights to be on when vehicles are in motion	7.70	VESIPO (2002)
DRL	4.4 - 6.4	ETSC (2003)
DRL in Austria	3.6	ROSEBUD WP4
DRL in the Czech Republic	4.3	ROSEBUD WP4
Daytime running lights	1.42 - 1.96	ELVIK, R.; CHRISTENSEN, P. and OLSEN, S.F. (2003)

If dedicated running lamps are combined with a light sensitive switch, the problem of drivers forgetting to turn on their standard low beam headlights during dusk and dawn periods or during periods of poor visibility can be avoided effectively. ETSC calculated that the additional contribution due to DRL-use for all vehicles to the total costs of pollution (as a result of fuel emissions in road transport) would be 1,0%.

7.2.4 Pedestrian and bicycle visibility enhancement

When driving in the dark on roads without street lighting, drivers can only see the part of the road which is lit by the headlights. At the same time, the eye´s ability to discern contrasts is poorer than in daylight. It is particularly difficult to see pedestrians and cyclists in the dark.

Figure 13: Cyclist in the dark, source DVR

Selected assessment	B/C-ratio	Source
Improving bicycle conspicuity in Norway	>1	PROMISING (2001)
Use of reflective devices by pedestrians in Norway and Sweden	5.09 - 7.58	ELVIK, R. (1999), ELVIK, R. (2001), ELVIK, R. (2003), ELVIK, R.; AMUNDSEN, A.H. (2000)

The accident rates of bicyclists and pedestrians could be reduced, if more would be done to make these vulnerable road users as visible as possible. Lights and reflectors are essential for their visibility. With reflective devices cyclists and pedestrians could improve their own conspicuity and thereby make themselves easier to be detected and identified by other road users. Every bicycle should be equipped with reflective material of sufficient size and reflectivity to be visible from both sides, when directly in front of a motor vehicle's head lamps. Reflective materials on clothes could also make pedestrians more visible to motorised road users.

7.2.5 High mounted and multistage stop lamps

Rear impact crashes often involve pre-impact braking by the leading vehicle. A normal brake lamp is usually only visible to the car immediately behind the braking car in a queue. When driving in queues, this means that the driver's delayed reaction spreads backwards through the queue, and the available reaction time becomes shorter and shorter for each car, the further back it is in the queue. The purpose of high mounted stop lamps is to safeguard vehicles from being struck in the rear

Figure 14: High mounted stop lamps; source: DVR

Selected assessment	B/C-ratio	Source
Centre High Mounted Stop Lamps (CHMSL) in passenger cars and light trucks in the USA	3.18	KAHANE, C.J. (1998).
Installation of high mounted stop lamps in Norway and Sweden	3.89 - 9.07	ELVIK. R. (1999), ELVIK. R. (2001), ELVIK. R. (2003), ELVIK, R.; AMUNDSEN, A.H. (2000)
Installation of multistage stop lamps in vehicles in Switzerland	3.40	VESIPO (2002)

by another vehicle. When brakes are applied, the high mounted stop lamp warns drivers of following vehicles that they have to slow down. Today, high mounted stop lamps are required in a growing number of countries. These stop lamps which are installed higher and midway between the rear brake lights to form a triangular pattern have become a standard equipment on new generation vehicles.

Multistage stop lamps have a differentiated light intensity depending on the brake pedal power. The higher the brake power on the pedal, the brighter the stop lamps will shine. Because of the differentiated light signal, the following drivers can react faster and can assess the brake power more accurately.

There are different varieties of multistage stop lamps. With some of them the shining area is enlarged, with others the stop lamps start flickering.

7.2.6 Truck visibility enhancement

Retro-reflective material could increase the conspicuity of trucks at nights and in bad weather.

Figure 15: Visibility of retro-reflecting contour marking on lorries; source DVR

Selected assessment	B/C-ratio	Source
Retro-reflecting contour marking on lorries in the Netherlands	>1	SWOV (2002)
Enhancing the visibility of heavy trucks in Switzerland	1.7	VESIPO (2002)

The sides and rear of the trailers can be equipped with retro-reflective tape or reflex reflectors to reduce side and rear impacts into heavy trucks. The retro-reflective material brightly reflects other motorists` headlights, especially in the dark, and warns them, that they are closing on a heavy trailer. Additionally, it is easier for the other road users to assess the distance to and the speed of the truck. Because of the enhanced visibility of heavy trucks and trailers, a large-scale introduction of retro-reflecting contour marking could reduce the probability of side and rear impacts by other vehicles.

SWOV studied the road safety effects, economic efficiency and possibilities of large-scale introduction (voluntary or compulsory) of retro-reflecting contour marking on lorries. Each year there are about 9 deaths and 83 in-patients resulting from collisions with the flank or rear of lorries during twilight and night-time hours in the Netherlands.

It is estimated that the complete introduction of retro-reflecting contour marking would reduce this by 2-3 deaths and 20-30 in-patients per year.

7.2.7 Seat-belt reminder in passenger cars and ignition interlock for seat-belts

New cars could be equipped with a seat-belt-ignition-interlock system to reduce injuries of car occupants involved in a crash by increasing the seat-belt wearing rate. In cars with seat-belt-ignition-interlocks the ignition of the engine is only possible when all occupants have fastened their seat-belts. Alternatively, several devices have been developed to remind vehicle occupants to buckle up. The information could be transmitted by symbol-only reminder systems, flashing lights on the dashboard or a warning tone of reasonable intensity. An audible seat-belt reminder gives a warning tone whenever a seat is occupied but the seat-belt is not fastened. A simple continuous reminder is a device, that gives a warning as long as the seat-belt is not worn, but it is not designed with an ignition interlock function.

Selected assessment	B/C-ratio	Source
Seat-belt reminder in passenger cars in Sweden	11.34 - 11.85	ELVIK,. R. (2001), ELVIK,. R. (2003), ELVIK, R.; AMUNDSEN, A.H. (2000)
Ignition interlock for seat-belts in Norway and Sweden	4.40 - 28.36	ELVIK,. R. (1999), ELVIK,. R. (2001), ELVIK,. R. (2003), ELVIK, R.; AMUNDSEN, A.H. (2000)
Compulsory seat-belt-ignition-interlock-systems in Switzerland	1.10	VESIPO (2002)
Audible seat-belt reminder	6	ETSC (2003)

It is estimated that an audible seat-belt reminder for the front seats can raise seat-belt wearing among front seat occupants up to 97%. Based on a review of evaluation studies it could be assumed that wearing a seatbelt reduces the fatality rate by 50% for front seat occupants.

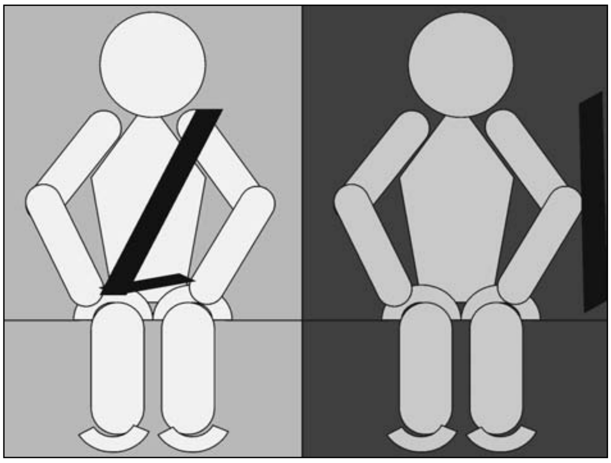


Figure 16: Possible reminder signal

The European New Car Assessment Program (Euro-NCAP) provided added point bonuses for cars if vehicles are fitted with seat-belt reminders.

7.2.8 Underrun guard rails on trucks

Many motorised road users are killed due to collisions of their vehicles with the rear end or sides of trucks that are not equipped with adequate underrun guards. When a car collides with the rear end or side of a truck, it could continue to drive under the chassis of the truck. The invasion of the passenger compartment that follows the underriding could have horrible consequences for the car occupants. Car occupants could be decapitated or cause severe head and upper body injuries. An injury reduction for road users involved in a crash with a truck could be reached by providing guard rails around all sides of trucks to prevent underriding and to make the crash less severe. Therefore, the compulsory equipment of trucks with comprehensive side, front and rear underrun protection devices could be recommended.

Selected assessment	B/C-ratio	Source
Front, side and rear underrun guard rails on trucks in Norway	>1	PROMISING (2001)
Improving underrun guard rails on trucks in Norway	1.18	ELVIK, R. (1999), ELVIK, R. (2001), ELVIK, R. (2003)
Comprehensive underrun protection devices for trucks in Switzerland	4.10	VESIPO (2002)
Under-run guard rails on trucks in Norway	3.9	ELVIK R., VAA, T. (2004)

Figure 17: Underrun guard rails, source: DVR

The objective of side underrun protection is mainly to prevent pedestrians and riders of two-wheeled vehicles from being run over, by getting caught in the open space between the wheel axles on large vehicles. Side underrun protection can also prevent smaller cars from driving under or between pairs of wheels on larger vehicles.

7.2.9 Measures to prevent blind spot accidents with trucks

A truck driver must use side mirrors to see what is happening behind him, but a truck's rear-view and side mirrors are not always sufficient and “blind spots” are created. Large trucks have those blind spots located around the front, back, and sides. Common blind spots for a truck driver exist near the right front wheel of the truck and at the rear of the trailer. When other road users are in a blind spot, the truck driver is unable to see them. For example, in passing close behind a truck which is preparing to back up, a car would enter the truck's blind spot and an accident may occur. Several vehicle-related, infrastructure-related, organizational and educational measures could help to reduce the number of blind-spot accidents with trucks, particularly involving cyclists. These include improvements at traffic intersections and the installation of special mirrors in trucks; supporting thematic campaigns could be considered.

Selected assessment	B/C-ratio	Source
Measures to prevent blind-spot-accidents with trucks in Switzerland	1.4	VESIPO (2002)

In Denmark, an extra close-up mirror and a wide-angle mirror on the right side have been

Figure 18: Special mirror for lorries; source: DVR

compulsory since 1988. The measure was introduced to reduce accidents, where cyclists ride under lorries, when these are turning right at intersections. Studies have shown a tendency for the number of injury accidents to increase and the number of fatal accidents to go down. None of the changes were statistically significant (ELVIK 2004). It was found that more than half of the close-up and wide-angled mirrors were wrongly installed.

In the VESIPO study measures to prevent blind-spot accidents between cyclists and trucks at intersections include: infrastructural improvements of traffic intersections, installation of TRIXI-mirrors at traffic intersections, installation of special TOWISPICK-mirrors in trucks, information campaigns for truck drivers, information and education campaigns for children.

7.2.10 Improvement of car front protection to increase the safety of pedestrians and cyclists

Pedestrians are mainly killed in accidents with cars. An improvement to the design of car fronts can reduce the number of casualties and fatalities associated with collisions with car front-ends. Softer and more flexible bumpers and bonnets could save lives.

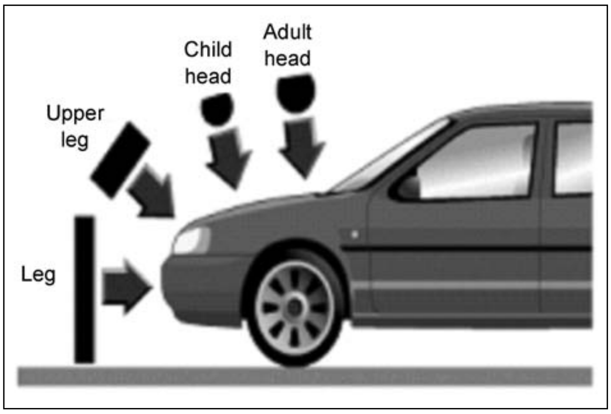


Figure 19: Car front; source: EuroNCAP

Selected assessment	B/C-ratio	Source
Improvement of car front design to increase crash-safety of pedestrians and cyclists in the Netherlands	3.0	van KAMPEN, Ir L.T.B. (1994)
Tightening the law for front protection devices in Switzerland	150.0	VESIPO (2002)
New safety standards for front and bumper in Sweden and Norway	4.66 - 6.80	ELVIK, R. (1999), ELVIK, R. (2001), ELVIK, R. (2003), ELVIK, R.; AMUNDSEN, A.H. (2000)

On the contrary, external features such as bull bars pose an obvious danger. Stronger rules for frontal protection devices and front and back spoilers could be recommended, demanding that these devices do not cause any further damage to a crash victim than the standard vehicle model.

For the Netherlands, it is estimated that the annual number of casualties could be reduced by 750 (including 11 fatalities and 263 hospitalised) as a result of improving the car front-end design. A positive benefit-cost ratio may be attained at a cost of up to 50€ per new car assuming that each year some 500,000 new cars replace the same number of older cars. A positive ratio of benefits to costs of 3:1 is possible.

7.2.11 Crash data recorder

A crash or event data recorder (EDR) is an on-board device capable of monitoring, recording, displaying or transmitting pre-crash, crash, and post-crash data parameters from a vehicle. All vehicles could be equipped with such an compulsory, crash-resistant and non-manipulable digital device to record the speed profile and other relevant vehicle operation data.

A data recorder can inform traffic accident investigators about, for example, the vehicle's speed, pressure on the accelerator pedal and application of the brakes. This information is collected directly before the impact. Crash data recorders are expected to contribute to road safety in two ways.

On the one hand, the sequence of events preceding crashes could be clarified. Statements on the cause of the crash and conclusions drawn (e.g. if there was a chance to avoid the crash) can be made quickly and qualified. These are important advantages from a juridical point of view. On the other hand, EDRs could also have a preventive effect for the drivers and thus improve road safety in general.

The EDR is in some ways similar to data recorders used on airplanes and trains, the car's recorder springs into action as part of the air bag system. The recorder can tell traffic accident investigators about the car's speed, how far the accelerator pedal was pressed, if the brakes were applied, whether the driver's seatbelt was buckled and what warning lights were on – all from a few seconds before impact. When an air bag deploys, the data is recorded onto a computer chip. The data can be retrieved and presented in a report.

Selected assessment	B/C-ratio	Source
Crash data recorder in Sweden and Norway	1.11 - 1.50	ELVIK, R. (1999), ELVIK, R. (2001), ELVIK, R. (2003), ELVIK, R.; AMUNDSEN, A.H. (2000)

7.2.12 Occupant protection measures for buses

Several measures are under discussion to prevent injuries to bus occupants. These measures include techniques like seat spacing, seat back padding and seat-belt systems. Often, primary focus is placed on school bus safety. In the discussion of passenger seat-belts in school buses it is argued that children could be killed or injured because there are no restraint devices and without these devices the safety standards are not sufficiently effective. Seat-belts could offer superior protection in the case of rollovers, side impact or angle

Selected assessment	B/C-ratio/ cost per life year saved	Source
Seat-belts for passengers in school buses in the USA[26]	$ 2,800,000	TENGS et al. (1995)
Seat-belts for passengers in buses in Norway	0.02	ELVIK, R., VAA, T. (2004)

collision of school buses. On the other hand, in a head-on collision a belted child in a school bus could receive worse head injuries than an unbelted child. Consequently, seat-belts might do more harm than good in a frontal bus collision.

In Norway, to equip one bus with seat-belts create costs of NOK 16,500 (ELVIK, R., VAA, T. 2004). This is far more than the benefit of injuries prevented. Even if seat-belts could eliminate all injuries to bus passenger the measure would not be cost-effective.

7.2.13 Adaptive cruise control

Adaptive cruise control (ACC) will enable the vehicle to maintain a driver-defined distance from the preceding vehicle, while driving within a maximum speed limit set by the driver. Since the system only functions at speeds between 30km/h and 200km/h, it is designed primarily for use on motorways and rural roads. If, however, there is a rapid reduction in the vehicle's speed, the system will warn the driver and switch off to let the driver assume control.

The time gains attainable using ACC can reduce rear-end collisions and can influence the severity of those accidents which cannot be avoided (lower

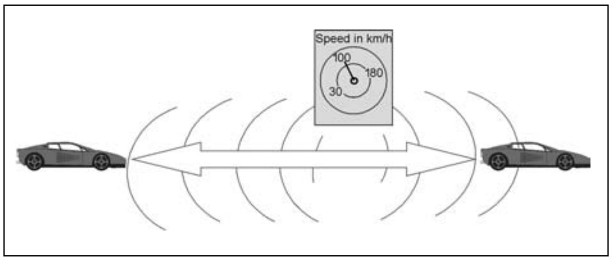


Figure 20: Intelligent influence on distance

26 In this study, cost-effectiveness is defined as the net resource costs of an intervention per year of live saved (in 1993 US-Dollars).

Selected assessment	B/C-ratio	Source
Safe Following – ACC	0.9 - 1.2	ABELE, BAUM (2005)

vehicle speed and crash impact, leading to a reduction in accident severity.)

7.2.14 Lane departure warning and lane change assistance

Lane departure warning (LDW) systems assist drivers in keeping to their lanes by warning drivers, when their cars are in danger of leaving their lane unintentionally (mainly due to lack of driver attention). Current systems use either an audible beep or a “rumble strips” noise, which mimics the sound made whrn a tyre runs over a lane divider. Lane change assistants (LCA) assist drivers intending to change lanes. The LCA monitors the adjacent lanes and warns the driver, if another vehicle is likely to come within colliding distance during the lane change. This occurs, for example, if the other vehicle is located in the LCA-equipped vehicle’s blind spot. LDW can avoid or reduce the severity of accidents in which two vehicles collide frontally (head-on collision) and in accidents in which a vehicle leaves the road without colliding with another vehicle.

LDW warning enables a driver to react, on average, 0.5 seconds earlier than without the system. This effects a collision reduction of 25% of all relevant accidents. The time gain of LCA is 0.7 seconds. This leads to expect a 60% reduction of the number of relevant accidents.

In the CBA of ABELE et al. (2005) both systems have been analysed as a single combined system.

Figure 21: Lane markings; source: BASt

Selected assessment	B/C-ratio	Source
LDW and LCA	2.0 - 2.1	ABELE, BAUM (2005)

7.2.15 Anti-lock braking system for motorcycles

Anti-lock braking systems (ABS) compensate for rider error in emergency situations. The reflex of emergency braking on a motorcycle usually leads to locking one or both wheels, which immediately creates a high risk of falling off the vehicle; this is prevented by the use of ABS. Generally, it will enable motorcycle riders to improve their braking performance significantly. On the one hand, ABS is highly beneficial in reducing motorcycle accident numbers and severity. On the other hand, ABS is relatively expensive and still not very popular among motorcycle riders, mostly due to the high costs. From the road safety point of view, measures must be taken to encourage fitting of ABS to motorcycles, i.e. to raise consumers' willingness to invest in ABS.

For the motorcycle, the reflex of emergency braking usually leads to locking one or both wheels, which immediately creates a high risk of falling off the vehicle. Motorcycle riders are well aware of this danger and leave a huge “safety gap” between the decelerations they actually apply and the real decelerating potential of their vehicles. Motorcycle drivers use only about 60% of the deceleration potential of their vehicles.

Selected assessment	B/C-ratio	Source
ABS for motorcycles (with and without tax reduction)	1.11 - 11.73	ROSEBUD WP4 (2005)

The ROSEBUD study considered a crash reduction potential of min 8% and max 10%.

7.3 Infrastructure Measures

7.3.1 Variable message signs

Variable message signs are infrastructure-related facilities which could supply traffic-related and safety relevant information to the road user. Variable message signs include simple prism displays as well as fully graphic-enabled display boards. For example, traffic signs, lane signals or

Selected assessment	B/C-ratio	Source
Variable message signs in Sweden and Norway	1.13 - 1.45	ELVIK, R. (1999), ELVIK, R. (2001), ELVIK, R. (2003), ELVIK, R.; AMUNDSEN, A.H. (2000)
Variable speed control sign in Finland	<1.00	NOKKALA, M; SCHIROKOFF, A. (2001); LÄHESMAA, J. (1997)

Figure 22: Variable speed signs; source: DVR

textual displays can be brought rapidly to the attention of the road user. The importance of variable message signs for road safety depends on the messages that they convey. Variable message signs can have at least a short term effect on driving behaviour.

In the example from Finland two variable speed signal zones consist of weather observation points which are connected by data transfer systems to a computer that sets the speed limits according to the weather conditions. The project has been implemented despite its economically unconvincing starting point. However, there are signs that these projects bear additional unforeseen benefits, too, deriving from an increasing knowledge of the road authority for carrying out similar arrangements in future.

7.3.2 Traffic surveillance and control systems and interference management

Traffic surveillance and control systems are expected to provide incident management, speed control, queue detection and warning, lane control and co-ordination with the urban traffic control system and other agencies. The main reasons for the introduction of traffic surveillance and control systems are mostly related to capacity and demand management and not to road safety. Nevertheless, these systems have an effect on road safety through preventing or warning as well as through optimising of emergency services. Traffic interference management comprises the localisation and the assessment of traffic interferences as well as the selection of countermeasures which have to be introduced to return to the normal condition. Modern traffic interference management carried out in control centres could comprise automatic devices to detect incidents like fires, traffic accidents or wrong-way drivers as well as automatic lane and tunnel monitoring systems.

The Ayalon freeway in Israel, which links the Tel Aviv Metropolitan area and the central business district as well as being an essential north-south route between Jerusalem and Haifa, was extended in 1991. The road began to suffer from regular congestion. New control strategies, including speed control and queue detection and warning, were expected to reduce both primary and secondary accidents. Moreover, direct communication with a traffic control centre promised a quicker call for emergency services which could improve the survival rate of serious injury. The introduction of the traffic surveillance and control system for the urban highway proved to be beneficial. Cost savings due to safety effects were estimated at only 20% of the total benefits.

Selected assessment	B/C-ratio	Source
Traffic surveillance and control system for an urban freeway in Israel[27]	1.7 - 6.3	KELLY, BLUM (1992)

7.3.3 Road safety audits

A road safety audit is a systematic examination of the safety standard of a road, usually at the design stage, but sometimes also immediately before the road is opened to traffic. The idea of the road safety audit was first developed in Great Britain and is applied now in many other countries.

[27] The evaluation considered future disbenefits of current operation mode (no control), and savings in these disbenefits which can be attained due to the introduction of a control system. The estimates were prepared for a 20 year period, with 8% discount rate. The disbenefits included: accidents, incidents, congestion, maintenance and off-ramp queues' costs.

The two main potential benefits from the road safety audit process are to reduce the frequency of accidents and casualties and to reduce the need to redesign a scheme, after it has been implemented. Audits are performed by independent auditors and are based on detailed checklists listing the items to be examined.

The independent auditor or an auditor team is commissioned by the owner of the infrastructure (federal, regional and local authority, private owner). The auditor should have experiences with road safety and construction.

Road safety audits are often described as a first step to implement a complete quality management system for roads. The aim of the safety audit is to put a value, from the standpoint of traffic safety, on all new road construction projects and major road maintenance works on existing roads, so that any shortcomings in road safety could be detected in time.

Selected assessment	B/C-ratio	Source
Safety Audit – Denmark	1.46	HERRSTEDT, L. (1999); HERRSTEDT, L. (2000)
Implementation of road safety audits (RSA) in Germany	4 - 99	BASt (2002)
Road safety audits in Norway	1.34	ELVIK, R. (1999), ELVIK, R. (2001), ELVIK, R. (2003)

The effects of road safety audits depend on the application of the proposals made by the auditor. The effectiveness of road safety auditing is a “derived effectiveness” – depending on the effectiveness of the implementation of the proposed measures.

7.3.4 Black spot management

“Black spot” is a colloquial term for points, sections or junctions in the road network which show a regional higher-than-average density of fatalities and severe injuries. Black spot treatment makes use of the accident record and other information to identify the measures that are likely to be most effective.

Black spot treatment is an iterative procedure with a regional scope based on accident reporting, accident analysis, data storage and presentation. In detail, black spots are identified with the help of information on the precise accident location and on the accident scenario of fatal and severe accidents – displayed on a map.

Experts on road safety should visit those sites, discuss and identify remedial measures. Regarding the type of measure, low cost measures can be distinguished from major repair works or even a reconstruction. For each measure an accident reduction potential should be identified and costs estimated and finally, a benefit-cost ratio is calculated.

A ranking of the measures for the entire region according to the benefit-cost ratio and the time frame allows to define a work programme.

Selected assessment	B/C-ratio	Source
Black spot treatment program in Australia	4.10 - 5.10	NEWSTEAD, CORBEN (2001)
Measures at accident black spots in Hamar municipality, Norway	35.00	Statens Vegvesen, Hamar kommune (1993)
Redevelopment of locations with large numbers of traffic accidents in Switzerland	13.00	VESIPO (2002)

In the example from Norway 62 sites with most road accidents in Hamar municipality were selected. The number of reported accidents was used as the selection criterion. The sites were inspected by representatives of the local office of the National Road Administration, the municipality, the police, vehicle inspectorate and others. At each inspected site measures were proposed. Two separate cost assessments were made for the measures that could be taken immediately and for some of the “future” measures. The types of measures taken were: setting of road signs, imposition of give way rules, construction of refuges, moving of traffic signal posts, setting of barriers, marking out of traffic lanes, designation of separate lanes for turning traffic, raising the level of pedestrian crossings, reduction of the sizes of intersections, improvements to visibility and road maintenance.

The performance of black spot management programs relies heavily on systematic methods for identifying hazardous locations and on implementing appropriate treatments to target predominant casualty crash types.

7.3.5 Tracks for walking and cycling

Many pedestrians and cyclists do not feel safe in traffic, especially when they are travelling in mixed traffic on roads with heavy vehicle traffic. Tracks for walking and cycling, together with footbridges and pedestrian tunnels, are intended to separate pedestrians and cyclists physically from motorised traffic. Another objective is to give pedestrians and cyclists increased mobility and feeling of security when travelling in public traffic areas.

Many cyclists are killed as a consequence of conflicts between their own road use and the road use of vehicles. Specific lanes for bicycle riders could be useful to reduce the number of accidents of these vulnerable road users. Bicycle lanes can and should be used to improve riding conditions for bicyclists as well as protecting bicyclists by separating them from vehicle traffic. On bicycle lanes cyclists can ride undisturbed from motor vehicles or pedestrians. Bicycle lanes help to better organise the flow of traffic and reduce the chance that motorists will stray into cyclists' path of travel. Moreover, lanes and paths for vulnerable road users could be combined to a whole network to create higher benefits than isolated lanes.

Figure 23: Bicycle lane, source: DVR

Selected assessment	B/C-ratio	Source
Bicycle lanes in urban areas in Norway	9.74	PROMISING (2001)
Pedestrian tunnel in Norway	4.2	ELVIK and VAA (2004)

7.3.6 Traffic calming

Traffic calming has been widely implemented in Europe. The purpose of traffic calming is to improve traffic safety for vulnerable road users. Traffic calming is the combination of mainly physical measures to alter driver behaviour and improve conditions for vulnerable road users. Driving speed has a major influence on the probability of becoming involved in an accident and on the severity of injuries. A common problem for example in school zones is excessive vehicle speed and traffic volume in areas, where children must cross streets and where they are picked up and dropped off.

To avoid conflicts, traffic calming devices should be simple, self-enforcing and easy to modify to accommodate emergency and other service vehicles. Speed humps are frequently chosen as a typical solution, when there is a need to reduce travel speeds on a local street and to provide the street with a calmer and safer character. The main advantage of speed humps is their self-enforcing nature creating a visual impression that the street is not designated for high speeds or for passing traffic. The length is usually larger than the distance between the wheels of vehicle (usual length 3.6m), their height oscillates between 7.5-10cm and the recommended distance between successive humps varies from 60m to 10 m.

Figure 24: Speed hump in Athens

Selected assessment	B/C-ratio	Source
Road narrowing and road humps in residential areas in Germany	17.00	FGSV (2001)
Speed humps on urban streets	2 - 4	ROSEBUD WP4 (2005)
Low cost traffic engineering measures in Greece	1.7 - 1.8	ROSEBUD WP4 (2005)

In Athens for example a limited number of traffic calming measures has been constructed. The municipality of Neo Psychiko is the only area in the greater athens Area which inaugurated an extensive road traffic calming programme at the beginning of the 1990s. The measures mainly include speed humps and woonerfs. A reduction of 8.3% in the total number of accidents was observed in the area considered, while an increase of 47% was recorded in the region of control group. A before and after accident analysis with a large control group was used to evaluate the effects of low cost measures in Greece. The control group chosen consisted of the neighbouring municipalities of Holargos and Agia Paraskevi in the Athens greater area.

7.3.7 Bypass roads

Over the years, existing road networks in urban areas can often not cope with expected traffic volumes, even with extensive upgrading works. This results in increased negative safety impacts for the affected communities and their citizens, in particular vulnerable road users like cyclists and pedestrians. A bypass road on a new alignment promises to improve safety for regional traffic and local communities. Bypasses should mitigate adverse road safety effects of the transport network on local communities. Heavy traffic and other long-distance main road traffic can be moved away from local streets.

Figure 25: Bypasses are designed to carry long-distance traffic outside towns and cities

Conflicts between local traffic and long-distance traffic are avoided. The construction of bypasses makes it easier to introduce traffic calming measures on the main road through a town.

Bypass roads increase mobility for both long-distance traffic and local traffic. Bypasses can make it easier for pedestrians and cyclists to cross roads in towns, since less traffic reduces waiting times. On the other hand, an increase in speed may make it more difficult to cross the road. A bypass road can be a barrier to local travel.

Selected assessment	B/C-ratio	Source
Bypass roads in Norway and Sweden	0.84 - 0.88	ELVIK, R. (1999), ELVIK, R. (2001), ELVIK, R. (2003), ELVIK, R.; AMUNDSEN, A.H. (2000)
Bypass roads in Norway	1.03	ELVIK, R. VAA, T. (2004)

The analysis of ELVIK and VAA (2004) include amongst others reduced traffic volume on the old main road, reduced traffic noise, vibrations, local air pollution and estimates the costs of building a bypass around NOK 20 million per km road.

7.3.8 Signal control at rural junctions

A road junction presents a natural point of potential conflict between different traffic streams. As traffic volumes increase, the probability of conflict increases, too, and traffic delays worsen. Traffic signal control at intersections separates traffic streams and improves the flow. Traffic signal control can be achieved by using light, which may be either time-controlled (phases change after a given time irrespective of the amount of traffic) or vehicle-actuated (the length of the phases is adapted to the amount of vehicles up to a given maximum phase length).

In Israel, some 10% of both injury accidents and fatalities occur at rural junctions (CBS, 2003). When the accidents occur at unsignalised intersections, the majority of accidents are usually right-angle, rear-end and pedestrian accidents. For unsignalised intersections, introducing traffic lights are frequently suggested as a safety treatment to reduce all accident types.

Selected assessment	B/C-ratio	Source
Signal control at rural junction in Israel	1.25	ROSEBUD WP4 (2005)

The CBA of the measure in Israel accounts for safety effects only; a consideration of time savings would strengthen the benefits of the measure. International experience demonstrates (ELVIK and VAA, 2004), that the effect on accidents of traffic signal control at intersections was mostly positive, providing on average a 15% accident reduction at T-junctions and a 30% accident reduction at crossroads.

7.3.9 Roundabouts

An increasing number of intersections is being converted into roundabouts. These have a traffic calming effect and help limit the severity of any collision that might occur. Modern roundabouts can be used at a wide variety of intersections.

Figure 26: Roundabout outside area; source: ADAC

Selected assessment	B/C-ratio	Source
Roundabouts in urban areas in Norway	1.23 - 8.61	PROMISING (2001)
Roundabouts in Norway and Sweden	1.52 - 2.26	ELVIK, R. (1999), ELVIK, R. (2001), ELVIK, R. (2003), ELVIK, R.; AMUNDSEN, A.H. (2000)
Roundabout in urban areas in the Czech Republic	1.5	ROSEBUD WP4 (2005)

An advantage of roundabouts is the reduced number of conflict points compared with uncontrolled intersections. Decision making is simple, combined with a lower level of conflicts. Furthermore, roundabouts slow down all vehicles. The tighter the curve, the lower the speed, which means, that it is easier to stop or at least a possible impact would be relatively minor. Consequently, roundabouts reduce the number and severity of accidents. On the other hand, especially in the beginning, roundabouts can be unfamiliar to the average driver, which could lead to more accidents. Nevertheless, crashes at roundabouts are primarily rear end or low speed merge crashes.

In the Czech Republic for example, in 2003 more than 70% of accidents took place in urban areas and about 10% of them occured at four-arm intersections. Between 1995 and 2001, eight four-arm intersections in urban areas without traffic lights were rebuilt as four-arm roundabouts. By that, an average accident reduction of 37,6% was reached.

7.3.10 Roadside guard rails

Roadside guard rails can prevent collisions with solid obstacles such as trees alongside the roads, mostly outside towns. They are often set up along the side of the road in places where circumstances render it impossible to make the roadside area safe. Under normal circumstances solid obstacles should have a minimum distance to the edge of the road, but if this is not possible for any reason, a guard rail can be installed at this place.

This measure treats both, road safety and ecological problems.

Selected assessment	B/C-ratio	Source
Measures against collisions with trees in France	8.69	ROSEBUD WP4 (2005)
Measures against collisions with solid obstacles on roads outside towns in Switzerland	32	VESIPO (2002)
Guard rails on the roadside in Norway and Sweden	0.69 - 1.18	ELVIK, R. (1999), ELVIK, R. (2001), ELVIK, R. (2003), ELVIK, R.; AMUNDSEN, A.H. (2000)

Figure 27: Guard rail; source: BASt

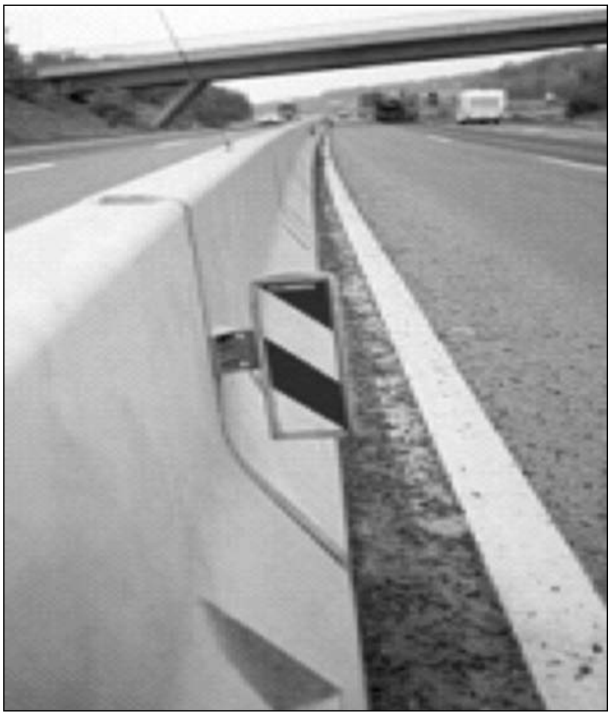


Figure 28: New Jersey elements on the M0 Budapest Ring Road; source: KTI

Example from France: The RN 34, which crossed the forest of “Landes” (South-West of France) along 64,5km has long tree-lined stretches of road on which 38,5% of the accidents occurred against trees. The problem was to take measures to reduce the number and the severity of the crashes alongside the stretch having the highest and increasing level of risk (a stretch of 26,5km). The measure consists of the implementation of 7.800 meters of guardrails, 13 frontage accesses and 8 lay-bys. The problem was here to propose and negotiate measures to reduce the number and the severity of crashes by ensuring the protection of the row of trees by the means of guardrails, when it is possible, or otherwise by the mean of tree felling.

7.3.11 Middle guard rails and other lane barriers

Middle guard rails and other lane barriers are installed to prevent collisions with oncoming vehicles on roads mostly outside towns, especially fatal collisions caused by vehicles crossing the central line. Therefore, roads outside towns should be equipped with guard rails, if the average daily traffic volume is sufficiently high. Moreover, guardrails between foot and cycle paths and the road can increase safety amongst pedestrians and cyclists using foot and cycle paths.

Selected assessment	B/C-ratio	Source
Moveable lane barrier on a motorway bridge in New Zealand	6.80	LEAK, HAWKINS, SANSOM, DUNN (1993)
Placing additional New Jersey elements along the central line of existing sections of M0 Budapest Ring Road (M0 BRR) in Hungary	1.35	TOMASCHEK, TAMÁS ATTILA (2002)
Installing bollards (plastic post delineators) at exit gore areas of highways in Israel	1.84 - 2.65	HAKKERT, GITELMAN (1998)

Two sections of the Budapest Ring Road (M0 BRR) functions as a 2x2 lane expressway. Traffic lanes are 3.50m wide, and there are no emergency lanes. It was decided to increase the physical central separation by placing additional concrete New Jersey elements. It has been demonstrated that the break-even point is reached within less than 7 years. For a 10 years project life period, the B/C-ratio is around 1.35, reflecting strong economic efficiency of the measure.

7.3.12 Two plus one roads

Two plus one (2+1) road construction is a measure, where an existing road is updated to have a middle

Figure 29: Two plus one (2+1) road; source: BASt

lane changing direction every 1-2.5 kilometres. Alternatively, the construction method can be applied to new road sections, but since the upgrading is a low-cost measure (compared for instance to construction of a new motorway), the standard application is to existing road sections. In principle, the 2+1 road construction takes place on 13-meter-wide roads, and it is considered as means of upgrading other solutions, mainly wide shoulders or wide lanes. The distinctive advantage of the 2+1 solution is that it prevents the head-on collisions. A possible way to construct the 2+1 road is to set a fixed steel median cable on the road, which then shifts to the other side when the overtaking lane is switched to the other direction.

Head-on collisions have been a severe problem as a percentage of total fatalities in Finland, between 1996-2000 an average of 80-85 % of fatal accidents on two-lane highways were due to head-on crashes.

Selected assessment	B/C-ratio	Source
2+1 roads in Finland	1.25	ROSEBUD WP4 (2005)
2+1 roads in Finland	2.26	ROSEBUD WP4 (2005)

The main source of benefits in the Swedish 2+1 roads was the safety impact (reductions in estimated deaths) and the time savings due to the overtaking lane.

7.3.13 Redevelopment of railway crossings

Even if the number of fatalities has decreased during the last decade, many people are still killed at railway crossings. Too many drivers believe, that they can still cross, even though traffic lights do not allow them to cross, and underestimate the breaking distance of a train. Some of these accidents could be prevented by a better crossing design.

Level crossings could be equipped e.g. with or without signs, signals, half or full barriers. Especially open crossings are considered to be more risky than crossings with gates. A grade-separation of a road-rail crossing means building a bridge or a tunnel instead of an existing at-grade crossing. Grade separation eliminates existing railway-road crossings and, consequently, removes the problem of train-vehicle collision at the site considered. It considerably diminishes road traffic delay at the site caused previously by crossing closures due to train movements. A grade-separated crossing is usually considered, where crossings are already protected by automatic gates.

Selected assessment	B/C-ratio	Source
Grade separation at road-rail crossings in Finland	0.25 - 0.65	ROSEBUD WP4 (2005)
Grade separation at road-rail crossings in Israel	1.0 - 2.8	ROSEBUD WP4 (2005)

Grade-separation of an at-grade crossing can be beneficial under certain conditions. The daily number of trains and daily road traffic volume are the main crossing parameters as they influence both the accident frequencies and the extent of traffic delays at the crossing.

7.3.14 Road lighting

At night, visual capabilities are impaired and visibility is reduced. In order to drive safely on roads at night drivers must be aware of the conditions around their vehicles and see other road users adequately far away from them. Road lighting is a potential countermeasure to reduce the number of night-time accidents at locations with inadequate illumination. These locations, especially junctions, intersections, access roads and tunnels, should be redeveloped regarding their road lighting equipment.

Most of the information drivers utilise in traffic is visual. Visual conditions can therefore be very significant for safe travel. Many studies have shown that road lighting reduces the number of fatal accidents in the dark by nearly 65%, the number of accidents in the dark involving personal injuries by almost 30% and the number of accidents involving material damage by close to 15% (ELVIK and VAA, 2004).

Selected assessment	B/C-ratio	Source
Road lighting in Norway and Sweden	1.21 - 2.51	ELVIK, R. (1999), ELVIK, R. (2001), ELVIK, R. (2003), ELVIK, R.; AMUNDSEN, A.H. (2000)
Upgrading substandard road lighting in Norway	2.62 - 4.32	ELVIK, R. (1999), ELVIK, R. (2001), ELVIK, R. (2003)
Installing of road lights in Norway	7.23 - 9.25	PROMISING (2001)

7.3.15 Hazard warning

Safety, hazard and warning signs ensure that road users and emergency staff have adequate information concerning specific dangers related to this road section. Hazard warning signs have to be consistent. A hazard warning should indicate a potentially hazardous situation which, if not avoided, could result in death or serious injury. Confusion among the road users should be avoided by using standardised patterns, phrases, colours, shapes and pictograms. There are two types of hazard warning signs: those that warn of a permanent hazard, and those that warn of a temporary hazard.

The installation of utility poles with flashing lights could increase drivers' attention in dangerous road sections. The hazard warning sign should be used beside the road, when it is needed to indicate the presence of a specific danger.

Selected assessment	B/C-ratio	Source
Installation of utility poles with flashing lights in Switzerland	2.7	VESIPO (2002)

7.3.16 Preventing accidents with animals

Some road safety measures are dedicated especially to prevent accidents with animals. A successful accident reduction technique requires a certain understanding of animal movement patterns and behaviour. One approach is to place deer fences beside the roads, designed to keep these and other large animals from straying from the forests across the road. Another infrastructural approach is to build over- and underpasses for animals. Furthermore, odorous substances and reflective apparatuses could be applied to prevent animals from crossing roads. Habitat alteration tries to solve the problem on an ecological basis.

Figure 30: Animal on lane; source: DVR

Setting up stationary game danger signs has proved to be ineffective if used as the sole measure to prevent accidents with game. The probability of encountering game in these areas is too low for the road user to take the sign seriously, even if it is much higher than in other areas.

Selected assessment	B/C-ratio	Source
Preventing accidents involving animals in Norway and Sweden	0.11 - 1.83	ELVIK, R. (1999), ELVIK, R. (2001), ELVIK, R. (2003), ELVIK, R.; AMUNDSEN, A.H. (2000)

7.3.17 Measures regarding skid resistance

Road surface characteristics and conditions can influence the occurrence of accidents. All road surface structures gradually deteriorate with time. This deterioration is normally evidenced by the appearance of various types of surface distress caused by a combination of environmental conditions and road use. If the road surface is not repaired, surface distress may become severe enough that road safety could be affected. Maintenance needs can be identified through pavement condition surveys. For example, skid resistance of the pavement surface must be maintained to provide for safe braking. Some accidents happening on wet surfaces could be prevented, if the road surface maintenance were carried out in time, assuming that wet weather crashes would increase with lower skid resistance. Therefore, one might consider that road surfaces in risky conditions should be rehabilitated in accordance with a fixed time schedule. When maintenance only is no longer effective, restoration should be required.

Selected assessment	B/C-ratio	Source
Management of skid resistance on the Australian road network	3.7 - 12.6	CAIRNEY (1997)

Skid resistance is the force developed, when a tyre that is prevented from rotating slides along the pavement surface. Many studies have shown that weather crashes increase with lower skid resistance.

7.3.18 Winter road maintenance

Adverse weather conditions in winter can dramatically affect the road transportation system. In winter, with the road surface covered with snow or ice, the situation is almost always critical for road safety. Emergency braking situations occur frequently. Winter road maintenance should make roads passable throughout winter times and thus can help to increase road safety if wintry conditions occur. The intensity of winter maintenance on a road often depends on its traffic capacity and functional classification. To plough the road network clear of snow is one duty of winter road maintenance. Moreover, clearing winter roads to the bare pavement usually requires de-icing chemicals. Depending on the temperature and the desired result, materials for winter maintenance like salt, calcium chloride, calcium magnesium acetate or sand have to be chosen to ensure the effectiveness of maintenance operations.

Selected assessment	B/C-ratio	Source
Winter maintenance of roads in Norway and Sweden	2.67 - 3.17	ELVIK, R. (1999), ELVIK, R. (2001), ELVIK, R. (2003), ELVIK, R.; AMUNDSEN, A.H. (2000)

Winter maintenance of roads increases the average speed of traffic and that is why it has a major effect on mobility. On the other hand several

Figure 31: Winter maintenance; source: ADAC

environmental side effects are possible, e.g. increased salt content in soil and the groundwater. Salt also contributes to increased rust on cars, but this effect is difficult to isolate.

7.3.19 Increasing construction site security

Construction firms could be obliged to provide a specific safety policy for their construction sites to reduce the number of road accidents at the work zones. Road workzone related safety measures should be developed and applied to mitigate the adverse safety effects on workers and road users. Measures to reduce such accidents could include using more message signs to warn motorists, scheduling work when traffic is lighter and putting specific barriers between workers and the cars and trucks driving past.

Many measures may increase safety at road works: e.g. temporary traffic control with temporary speed limits, traffic signals, temporary road markings and flagging. Safety measures at road works are at least as important at night, especially as a result of reduced visibility and because the speed levels can be higher than during the day.

Selected assessment	B/C-ratio	Source
Securing of highway construction sites in Switzerland	7.0	VESIPO (2002)

In the Swiss proposal studied within the VESIPO program, construction firms have to provide a specific safety concept for every construction site. This concept must be approved by a safety audit. According to the concept, the realisation of the concept must be approved by the responsible

Figure 32: Construction site; source: DVR

Figure 33: Lorry carrying dangerous goods; source: DVR

accident commission. The main part of the costs for technical and organizational safety measures at the construction site have to be borne by the construction firms themselves.

7.4 Accident prevention and performance monitoring: centralised management of dangerous goods transport

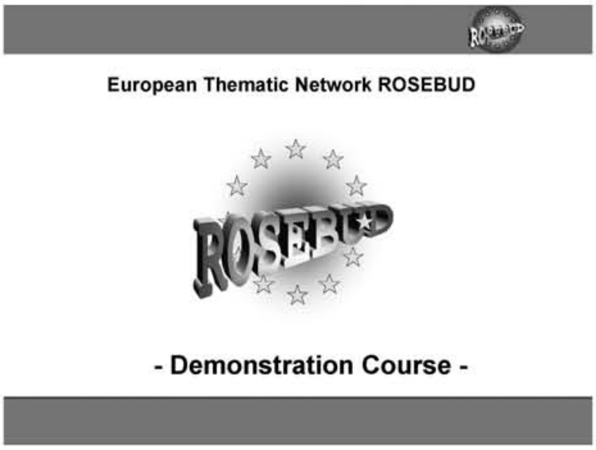
If a truck carrying dangerous freight is involved in a road accident, an additional risk occurs, if the freight escapes as a consequence of the accident. Centralised management of the transport of hazardous freight could reduce the dangers. It could comprise procedures to permit, notify and monitor dangerous or hazardous freight transport, controlled by a centralised management unit.

In Switzerland the centralised management of dangerous or hazardous freight transport includes a variety of procedures including: compulsory registration of all dangerous freight transports; information and automatic assignment of the mode, the time and the route of transport; the transport containers have to be equipped with devices to transmit automatically freight, vehicle and location data; automatic GPS tracing of all dangerous or hazardous freight transports; automatic control facilities to monitor all hazardous freight movements and transport permissions; and centralised management division to prevent cumulative risks and to observe risky freight transports locally and temporarily.

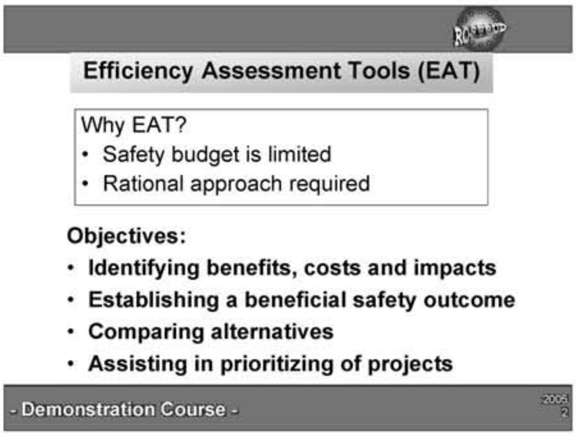
8 Demonstration course

The following PowerPoint presentation is available on the ROSEBUD homepage www.rosebud-eu.org and can be downloaded and used free of charge. The main purpose is to prepare the presentation of efficiency assessment results, to support the recipients with the necessary knowledge. Everyone using this presentation may – and is strongly encouraged to – adopt it for his own purpose, specifically considering the professional experience and educational background of the audience. However, this presentation was designed to suit for most of the possible recipients. This contains the possibility to adopt the depth of knowledge transported by adopting the comments given presenting each single slide.

Further, the example used is a quite critical one which contains a lot of problems which may be addressed in the presentation. In the annex the reader will find the full description of the measure and the economic evaluation of it. The presenter may also use other examples, but only results from state-of-the-art efficiency assessment studies should be selected for this purpose.

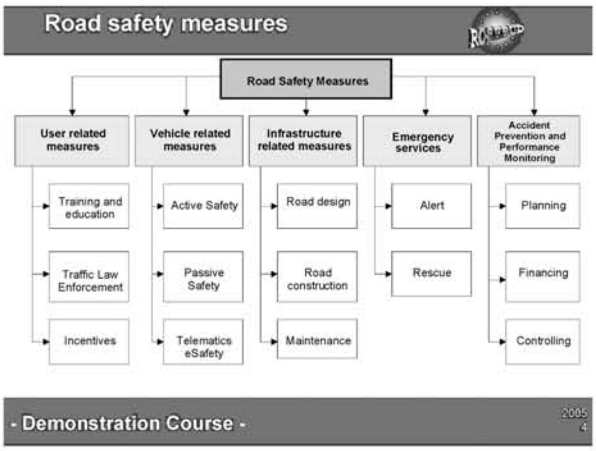


Page 1: Front page
Efficiency assessment (EA) and efficiency assessment tools (EAT) shall support the decision making process in political decisions on road safety measures. They should serve as an objective means of setting priorities. This incorporates both to support the introduction of useful (i.e. efficient) measures and to prevent the introduction of measures which are not useful from the road safety point of view.



Page 2: Efficiency Assessment Tools (EAT)
The core topic of EA is to get the best value for the money spent. It may also be used the other way round, such that for a certain safety target set, EA is used to support finding the cheapest solution. This means, comparing different road safety measures by means of public economic costs (keeping in mind the questions, who pays and who benefits).

Page 3: Road Safety in Europe (EU15).
This sheet point out the importance of road safety measures at the European level referring to the European road safety target of reducing the number of fatalities by 50% until 2010.



Page 4: Road Safety Measures
This sheet systematically lists all fields of road safety work. It may support decisions, if measures are taken in one of the fields, where only little has been done in the past. It may also support measures which address more than one of the fields.
It is a good overview of the various approaches to reduce road deaths and injuries.

Efficiency assessment

- **The aim of the assessment is to identify the most efficient measures.**
- **This will enable the society to allocate the resources to the most beneficial use.**

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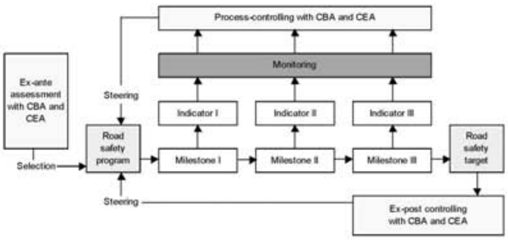
Page 5: Efficiency assessment
Decisions should be taken aiming at efficient strategies. The decisionmaker should commit to aim at the best value for money to prevent as many accidents, deaths and injuries as possible for a given budget. EA supports him with the information he needs for such decisions.

EAT in the decision making process



Possible scheme of a systematic evaluation of road safety activities

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Page 6: EAT in the decision making process
All of the following steps provide decision-makers with information to steer their road safety activities.
Controlling I: Implementation plan and reality should be compared at successive milestones. (Identifying problems to implementation.)
Controlling II: Target variables and indicators should be defined and the expected effects should be compared with the results reached in reality. At this step, measures with unsatisfactory results or (unintended) side-effects should be identified.
Controlling III: Comparison of ex-ante and ex-post CBAs and CEAs should be made. This step should identify the efficiency or inefficiency of road safety activities.

Efficiency assessment can help

- Efficiency assessment = a systematic assessment of the improvement in road safety that can be realised by means of various road safety measures
- Two main forms of efficiency assessment:
  - Cost-effectiveness analysis (CEA)
  - Cost-benefit analysis (CBA)

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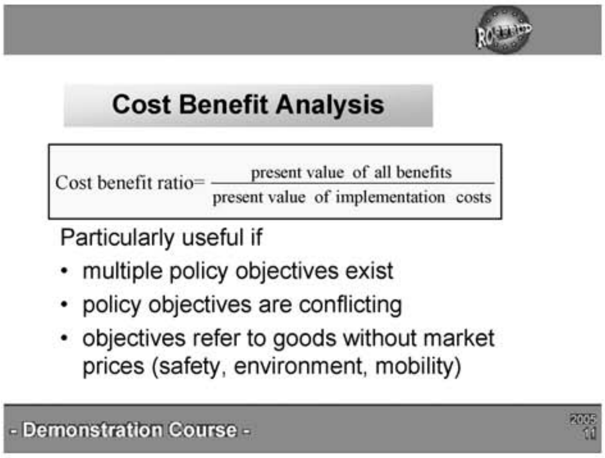
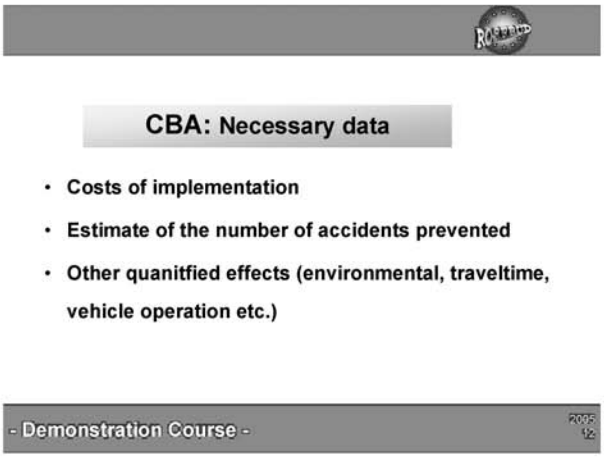
Page 7: EA can help...
In many cases, there are many different ways to solve a specific road safety problem. EA shall support to make the best choice.
There are also other methods (e.g. multi criteria analysis), but CEA and CBA are most commonly used, since they have the best relation between necessary efforts and usability of results.

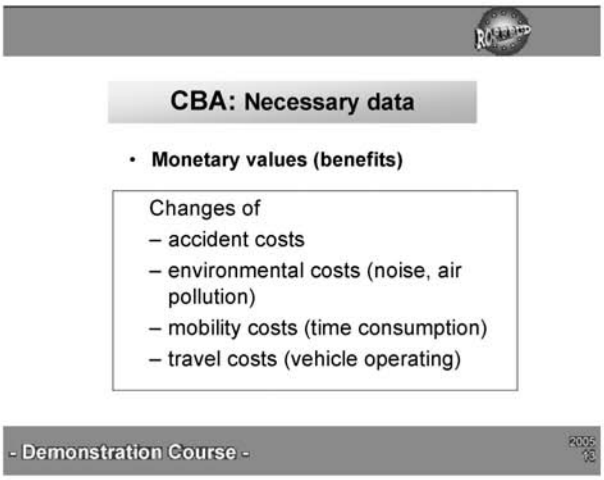
Main elements of efficiency assessment • A list of road safety measures • An estimate of the effects of these measures on accidents or injuries • An estimate of the costs of the measures • For cost-benefit analysis, monetary valuation of impacts is needed - Demonstration Course - 2005 8	Page 8: Main elements of efficiency assessment For CEA an efficiency threshold may be defined (maximum cost per life saved), by CBA a single measure may also be judged whether it is effective or not. Establishing reliable estimates for safety effects is the most difficult task. There may be information how such estimates may be established, e.g. by using results from similar measures, from equal measures at other locations, using accident prediction models or other methods. The main parts of the costs are investment, operation and maintenance.
Cost Effectiveness Analysis $\text{Cost Effectiveness} = \frac{\text{Number of accidents prevented}}{\text{Costs of implementation}}$ **Necessary data** • **Implementation costs** • **Estimate of the number of accidents prevented** - Demonstration Course - 2005 9	Page 9: Cost Effectiveness Analysis The typical results are presented as a ranking of measures by costs per accident prevented of costs per life saved. Start implementing measures bottom down in this list until the available financial resources are completely spent or until the safety target is reached.
Cost-effectiveness analysis • Pros: – A simple technique which focuses on safety effects – Does not require monetary valuation of safety • Cons: – Can only be used for ranking measures – Does not consider tradeoffs against other policy objectives – It is not possible to consider different accidents consequences (severe and slight injuries, property damages) - Demonstration Course - 2005 10	Page 10: Cost Effectiveness Analysis CEA does not require monetary valuation of all other effects, results can be found much quicker. Ranking of measures is the most common purpose, but defining a threshold for maximum cost per life saved, it may also be used to assess single measures. Environmental issues, time consumption, and mobility costs are neglected. In some cases safety measures would be rejected by a CEA ranking, but be very efficient when assessed by CBA (e.g. railroad crossings have a high impact on travel time for rail and road as well, so they are frequently cost-beneficial, but not cost-effective. Even if the number of accidents is selected as the safety parameter, CEA will hardly mirror the complete range of impacts. It is also possible to introduce some form of weighting the severity of casualties when conducting a CEA, by using such methods as Qaly(quality of life-years saved) but this can become quite complicated and may not save much effort compared with a full CBA study.



Page 11: Cost Benefit Analysis
Policy objectives could be e.g. environmental interests or influencing modal split. Most of the measures, where there are no conflicting policy objectives, are more easily assessed.
Experts could give an overview, how the monetary valuation of goods without market prices is carried out.



Page 12: Necessary data
It is crucial to determine, which effects occur when implementing a measure. Some effects might not be considered in a CBA due to certain reasons, but a state-of-the-art CBA should include all the relevant parameters. Implementation costs include all costs associated with implementing a measure. This includes theinitial cost of the measure and all costs associated with mainaining and operating the measure- all discounted to a common date. This also applies to CEA



Page 13: Necessary data
All the quantified impacts have to be transferred to economic values in a CBA. For this purpose, costs per unit (e.g. Euro per ton CO_2, average cost per one severe injury) need to be determined for all the relevant parameters. These valuations should be prepared as exact as possible considering the time and location of the measure. If they are not available, values from other countries or European figures may be used. With regard to accident costs, these generally include medical costs, production losses, material costs, settlement costs and human losses. For the evaluation of all costs and benefits associated with a project, a common time frame and a discount rate have to be selected, through which all costs and benefits can be equated.

Cost-benefit analysis

- Pros:
  - Considers all relevant policy impacts
  - Enables a direct comparison of costs and benefits
- Cons:
  - Monetary valuation e.g. of human life and quality is controversial and difficult, but inevitable
  - Not all effects can be assessed (e.g. distributional effects)

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Page 14: Cost-benefit analysis
The most important advantage of a CBA is that it shows the total impact on public economy and therefore is able to determine whether a road safety measure in term of public economy is worth the money or not. Monetary valuations of human life and injuries are on the one hand difficult to calculate, , can publicly and politically sometimes create difficulties and are not always accepted. Mainly distributional effects are addressed here, which cannot be assessed in a CBA.

CBA: basic rules of the game

- Consumer sovereignty is respected
- Maximum efficiency (Pareto-optimality) in resource allocation is sought
- The existing distribution of income is taken as given

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Page 15: Basic rules of the game
The application of CBA is based on economic principles: consumer sovereignty and pareto-optimality. The distributional effects of the implementation of the measure is not part of the assessment.

Section Control Kaisermühlen Tunnel

Site overview

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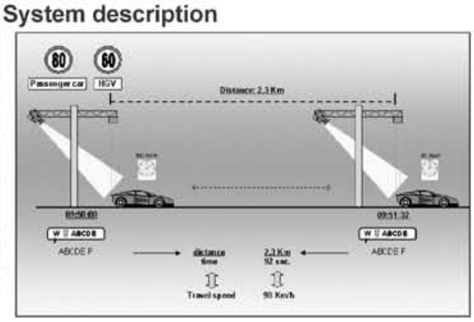
Page 16: Example Kaisermühlen Tunnel
"Section Control" (SC) is an automatic device for speed enforcement, not based on measuring speed at a certain spot, such as "conventional" measures like radar and laser guns. This device is installed in a highway tunnel in the city of Vienna, three lanes in each direction, speed limit 60 km/h for trucks over 7.5 t and 80 km/h for all others.

Section Control Kaisermühlen Tunnel

System description



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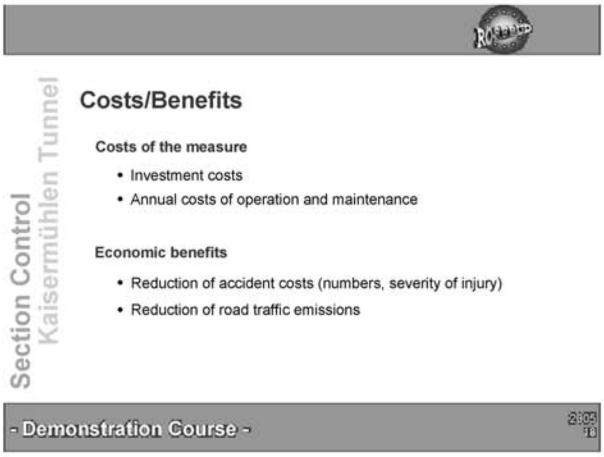
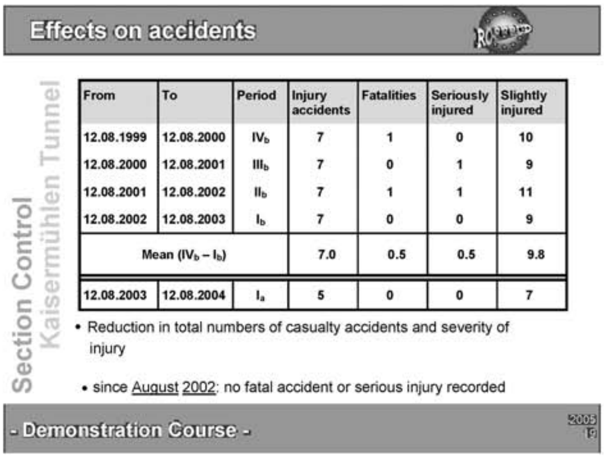
Page 17: System description
The vehicle runs through a radar curtain, which detects its size (i.e. the relevant speed limit) and a photo is taken from behind. The licence plate is detected automatically. After 2.5 km an equal device is installed. The licence plates are compared, and if they are equal, using passage time and distance, the average speed is calculated. If the speed is over the limit, photos and data are transferred to the relevant authorities, else the data is deleted immediately.

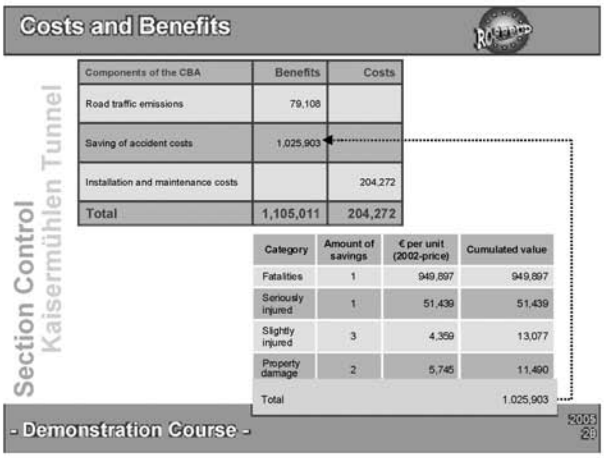


Page 18: Costs and Benefits of the measure
The costs of one such device are 1.5 Mio. Euro approximately. Due to technical reasons, the life-span is 10 years. The average speed of vehicles decreased by about 5 to 10 km/h depending on the time gap to the introduction of SC. The reduction of fuel consumption and exhaust gases was assessed using this speed difference. It was decided not to consider increased time use for passing the tunnel, because advantages collected illegally (by driving over the speed limit) shall not be considered. Also, the fines were not considered as benefits. Noise impacts of reduced speed may be disregarded due to the fact that the whole range affected is in a tunnel.



From	To	Period	Injury accidents	Fatalities	Seriously injured	Slightly injured
12.08.1999	12.08.2000	IV_b	7	1	0	10
12.08.2000	12.08.2001	III_b	7	0	1	9
12.08.2001	12.08.2002	II_b	7	1	1	11
12.08.2002	12.08.2003	I_b	7	0	0	9
Mean ($IV_b - I_b$)			7.0	0.5	0.5	9.8
12.08.2003	12.08.2004	I_a	5	0	0	7

Page 19: Effects on accidents
The total numbers of injuries and fatalities were quite low, which is not a very good basis for a stable assessment. The local accident rates need to be considered if Section Control is implemented somewhere else.



Components of the CBA	Benefits	Costs
Road traffic emissions	79,108	
Saving of accident costs	1,025,903	
Installation and maintenance costs		204,272
Total	1,105,011	204,272

Category	Amount of savings	€ per unit (2002-price)	Cumulated value
Fatalities	1	949,897	949,897
Seriously injured	1	51,439	51,439
Slightly injured	3	4,359	13,077
Property damage	2	5,745	11,490
Total			1,025,903

Page 20: Costs and Benefits
The values for injuries and fatalities in Austria were calculated in 1997 based on data from 1993 and transferred to 2002 prices. The Austrian values are based on a non-behavioural model and therefore quite low by international comparison.

Cost-Benefit Ratio (CBR)

Section Control
Kaisermühlen Tunnel

$$CBR = \frac{\sum \text{Benefits}}{\sum \text{Costs}} = \frac{1{,}105{,}011}{204{,}272} = \mathbf{5.4}$$

⇒ ROSEBUD (WP1): **CBR > 3** are ranked „**excellent**"

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Page 21: Cost-benefit ratio
On an annual basis, the costs and benefits are calculated as a cost benefit ratio.
A detailed description of the assessment of this measure can be found in the annex of this document.

Recent analyses of road safety policy

- There is a large potential for improving road safety
- Only a part of this potential will be realised if current policies are continued
- If priorities for road safety measures were based on cost-benefit analyses, large gains in safety could be realised

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Page 22: Analysis of road safety policy
Studies in Sweden and Norway have shown that only a small share of road casualties will be avoided if current road safety policies are maintained. A cost-effective prioritising in road safety policy could at least triple the number of accident and casualties prevented at the same cost.

Efficiency analysis in context

- Not all inefficient policy priorities can be eliminated by doing efficiency analysis
- A systematic use of efficiency analysis can, however, help achieving targets more efficiently

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Page 23: EA in context
Frequently, decisions on road safety measures incorporate issues like employment. Constraints deriving from environmental considerations are frequently difficult to overcome by using EA.

Do policy makers value efficiency analysis?

- Yes, cost-effectiveness analysis is regarded as useful
- Opinions differ more with respect to cost-benefit analysis
- The techniques are continuously being improved – making them more relevant for policy makers

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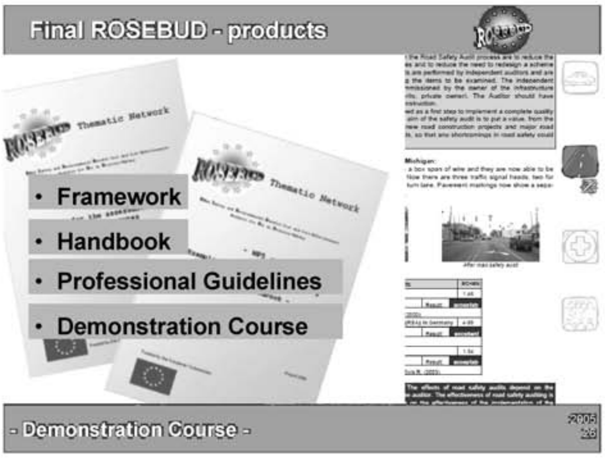
Page 24: Value of EA
These are the results from a broad survey conducted among decision makers carried out in ROSEBUD WP2

Page 25: Final remarks
The assessment of road safety measures should not only be a single process at a certain stage in the process (normally at the beginning) or only to create a single programme. The application of CBAs and CEAs allows the results of systematic monitoring of road safety activities to be assessed (an example of application is described in page 6 of this Demonstration Course)



Page 26: Final products
All of the mentioned ROSEBUD products are available on the ROSEBUD homepage: *www.rosebud-eu.org*.

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Annex I: Description of the assessed measure “Section Control”

Automatic speed enforcement in the Kaisermühlen Tunnel (Vienna, A22 motorway); by Christian STEFAN; Austian Road Safety Board (KfV), Austria; WP4 Report (2005)

The Kaisermühlen Tunnel is an urban tunnel with separate tubes for each direction of traffic. More than 90,000 vehicles use this part of the A22 motorway everyday; about 10% are heavy goods vehicles (HGV). Due to a nearby tank lot, the proportion of HGVs carrying flammable liquids (e.g. motor spirits, diesel oil) is extremely high. The tunnel offers 3-4 lanes per direction with entrance and exit ramps within the tunnel.

The Austrian highway operator (ASFINAG) introduced a new instrument of traffic surveillance to reduce accidents and traffic delays in the Kaisermühlen Tunnel on one of Vienna’s most frequented motorways (A22) in August 2003. This so-called Section Control does not measure speed at a certain point in space and time, but calculates the average speed by means of passage time in a defined area. The aim is to force drivers not only to slow down at certain points of stationary speed control (e.g. automatic speed cameras), but also adhere to the speed limit over the entire distance. It also provides live monitoring of traffic flow behaviour and thus contributes to harmonizing traffic flow.

The system consists of two facilities, one for each driving direction. Vehicle detection is carried out optically. A video system placed above the road on gantries (one camera above each of the three lanes) takes two pictures of each passing vehicle, one at the beginning of the tunnel and one at the end.

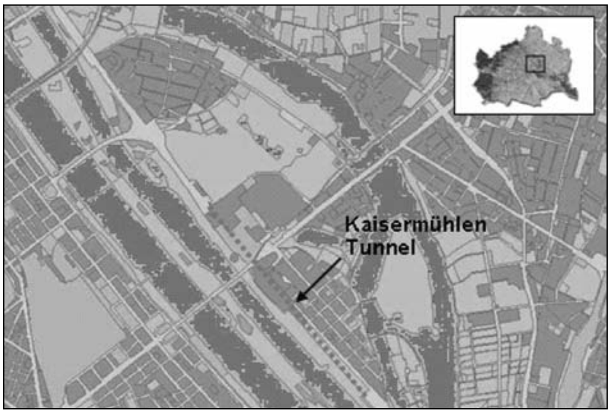

Figure 34: Site overview of the Section Control in the Kaisermühlen Tunnel

These photographs provide details of the event (passage time, use of lane) and the license plate number. Furthermore a laser scanner installed adjacent to the video system is programmed to differentiate between passenger cars and lorries (HGVs), which is fundamental to keep different speed limits under surveillance.

At the entrance and exit of the Kaisermühlen Tunnel, laser scanners are installed to obtain the required data. The system continually looks for two matching licence plates – if a match is found, the average speed is calculated and if it exceeds a defined level, an image of the licence plate is transmitted to the traffic supervision department.

This information is used to establish the owner of the vehicle via the national motor vehicle and driver’s licence registration database. Data of vehicles not exceeding the pre-set speed limit (plus a certain tolerance) are deleted immediately afterward. Only aggregated data are kept for statistical reasons.

KAISERMÜHLEN TUNNEL	
Road classification	Urban motorway (A22)
Type of road	Tunnel with two tubes
Number of lanes per direction	3-4
Width per lane	3.5m
Length	2.3km
Speed limit	Passenger cars, buses, motorcycles: 80km/h
Heavy Goods Vehicles (>7, t): 60 km/h	
Daily traffic (2003[28])	91,915 vehicles/24hours
Amount of heavy goods vehicles (HGV)	10.0%

Table 5: Road characteristics of the Kaisermühlen Tunnel (source: Vienna Municipal Department 34, calculations of KuSS)

28 Computed data by means of a linear regression model. Vehicle data related from the automatic counting station have been inadequate due to false HGV readings in one direction.

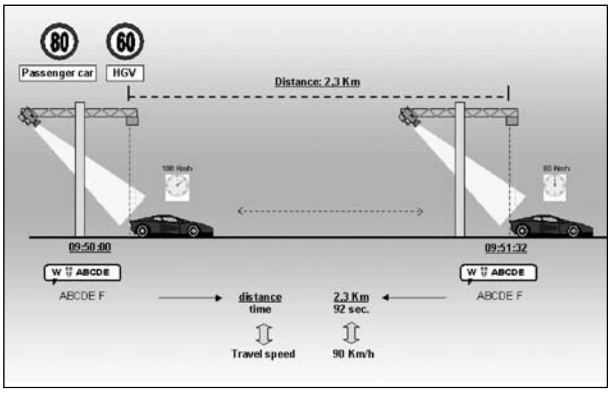

Figure 35: Scheme of Section Control in the Kaisermühlen Tunnel (Source: Vienna Municipal Department 34)

The Section Control system is designed to operate with speeds up to 250km/h and a maximum traffic flow of 2 vehicles per second and lane. Vehicle detection is independent of the position of a vehicle on or between lanes. There is no necessity for pavement installations (like inductive loops) or disruption of the traffic flow.

The target accident group of this measure consists of accidents occurring in the Kaisermühlen Tunnel.

The survey concentrates on injury accidents because data for material damage accidents could not be collected without enormous strains on budget and working hours.

Thus, the cost-benefit ratio computed in the following chapters underestimates the real impacts on accidents to a certain extent. This should be kept in mind, whenever Section Control systems are considered for further use in traffic safety programmes.

The main task of Section Control is the measurement of average speed of motor vehicles for the purpose of speed control and traffic enforcement.

Objectives

- Monitoring different speed limits that apply to different vehicle classes.
- Harmonization of traffic flow (reduction of "stop-and-go" traffic or congestion during peak hours).
- Surveillance of closed lanes (in combination with route information and management systems).

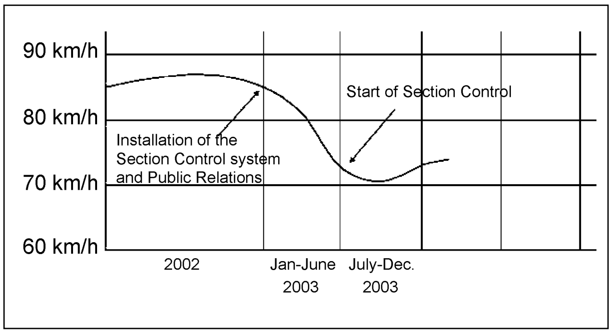

Figure 36: Effect of Section Control on average vehicle speed (Source: Vienna Municipal Department 34)

	Passenger cars	
	Before	After
Daytime	85km/h	75km/h
Night time	95km/h	75km/h
	HGV	
	Before	After
Daytime	70km/h	55km/h
Night time	75km/h	55km/h

Table 6: Average speed of passenger cars and lorries before and after implementation of Section Control (Source: estimations of KuSS in cooperation with local police services)

- Detection of wrong-way drivers ("ghost cars").
- Image triggering (including alarm release) for vehicles exceeding height limits.
- Detection of stolen vehicles.
- Traffic surveillance (for the tunnel operator).
- Statistical data (traffic speed, loads, headways).
- Impact of Section Control on average speed.

In 2003 more than 35% of fatal accidents on roads in Austria occurred because of inappropriate speed. In its first year of operation, a reduction in average speed by more than 10km/h was recorded.

Traditional mobile and stationary speed surveillance (in use before the Section Control started operating) showed the average speed of all vehicles to be 85km/h, whereas this value decreased to about 70km/h shortly after the introduction of the measure.

Further speed measurements carried out after a 6-month period revealed that average speed on this road section has levelled off to 75km/h due to the fact that drivers tend to follow regulations in a very strict manner right after their implementation, but less some time afterwards due to unintended behavioural adaptations ("kangaroo effect").

Drivers started acting in accordance with the speed limit as soon as technical installations were established and reports about this new system of speed control appeared in the media.

Costs of the measure

Investment costs for the Section Control in the Kaisermühlen Tunnel add up to € 1,200,000 (2003 price)[29]. Annual costs of operation and maintenance are about € 60,000.[30]

The Section Control system has a 10-year service life, beginning in 2003. After that period, software problems and missing spare parts for the hardware are expected to affect full operation of the system. Investment costs are incorporated in the form of an annual capital cost assuming a 4% interest rate in real terms.

For the sake of comparability, all costs were converted to their 2002-price level. Total annual costs for operating the Section Control add up to € 204,272 per year.

The "Handbook of Emission Factors for Road Transport" provides emission factors in g/km for all current vehicle types (e.g. passenger cars, light duty vehicles), each divided into different categories for a variety of traffic situations. The following parameters have been used:

- type of emission: hot emissions, cold start emissions, evaporation;
- vehicle type: passenger car – heavy goods vehicle (HGV);

	1,000 EURO (2003-price)	1,000 EURO (2002-price)		
Expense factors	Costs	Costs	Annual capital costs [n=10,4 % p.a.]	Total annual costs
Investment costs	1,200	1,178.8	145.3	204.3
Annual main-tenance costs	60	58.94		

Table 7: Total annual costs of Section Control in the Kaisermühlen Tunnel (source: Vienna Municipal Department 34, own calculations)

Air pollution	Unit of valuation	Value per unit		
		DM (1995)[32]	NOK (1995)[33]	€ (2002)
CO	Tons of NO_x-Equivalent[34]	1700		974.64
NO_x	kg of NO_x		115	14.90
SO_2	kg of SO_2		37	4.79
Particle (PM_{10})	kg of PM_{10}		1,800	233.27
VOC	kg of VOC		15	1.94
CO_2	Tons of CO_2		220	28.51

Table 8: Valuation of environmental impacts for use in cost-benefit analyses (Source: own calculations)

- estimated changes in composition of the vehicle fleet (2003-2013);
- air pollutants (CO, NO_x, SO_2, PM_{10}, VOC) and carbon dioxide (CO_2);
- type of road: urban motorway;
- time of day: daytime/night time.

TheTables 7 and 8 give values for both air pollutants and CO_2 as the most important greenhouse gas emitted by road traffic[31] and information about the annual costs.

For the Kaisermühlen Tunnel, the boost in vehicle technology, along with a lower average speed due to Section Control, results in more than 12,000 tons of saved CO_2 emissions, having a discounted monetary value of more than € 280,000.[35]

Expected changes can be seen in Table 9, which states above all a constant decrease in saved nitrogen oxide emissions because of improvements in vehicle technology.

[29] Construction work of gantries, cables and data lines to the Section Control server are included in this price.

[30] Covering a service contract of 4 service cycles per year plus additional repairs if the system starts malfunctioning

[31] To arrive at 2002 prices, German Mark (DM) and Norwegian Krona (NOK) were first converted into Austrian Shillings (ATS) and then brought to a 2002 price level by using official inflation rates. Values of traffic emissions were finally converted to € by multiplication with 0.07267.

[32] EWS, 1997, page 41

[33] ELVIK, 1999, page 24

[34] Conversion factor: 1 ton of CO = 0.003 tons of NO_x-Equivalent (EWS, 1997, page 41)

[35] Nitrogen oxide emissions are among the most harmful of all air pollutants. Thus, various nitrogen oxide catalytic converters have been developed which will help to reduce emissions of NO_x significantly over the next 10 years.

	Changes in road traffic emissions (t)	Discounted value of traffic emissions in € (2002-price)
CO	-14.9	-137
NO_x	-39.0	-431,639
SO_2	-0.4	-1,552
Particle (PM_{10})	-0.5	-87,029
VOC	+7.3	+11,247
CO_2	-12,879.6	-281,973
Accumulated value		-791.084
Monetary value of saved emissions per year		-79,108

Table 9: Monetary value of saved emissions due to Section Control (accumulated value 2003-2013; source: Austrian Umweltbundesamt, own calculations)

In the year 2003 nearly 6 tons of NO_x were saved through Section Control.

This value will decrease to one ton of NO_x in 2013. Calculated over the economic lifetime of the Section Control system, savings in NO_x emissions amount to a value of more than € 430,000.

Volatile organic compounds (VOC), in combination with nitrogen oxides, are responsible for ground level ozone and smog. VOC are primarily produced when fuels are incompletely combusted. Looking at the VOC traffic emissions in the period under observation, an increase of one ton in 2003 and slightly less in the following years has been calculated. This is due to the fact that most vehicle

From	To	Period	Injury accidents	Fatalities	Seriously injured	Slightly injured
12.08.1999	12.08.2000	IV_b	7	1	0	10
12.08.2000	12.08.2001	III_b	7	0	1	9
12.08.2001	12.08.2002	II_b	7	1	1	11
12.08.2002	12.08.2003	I_b	7	0	0	9
12.08.2003	12.08.2004	I_a	5	0	0	7
Mean (IV_b – I_b)			7.0	0.5	0.5	9.8

Table 10: Injury accidents before and after the implementation of Section Control

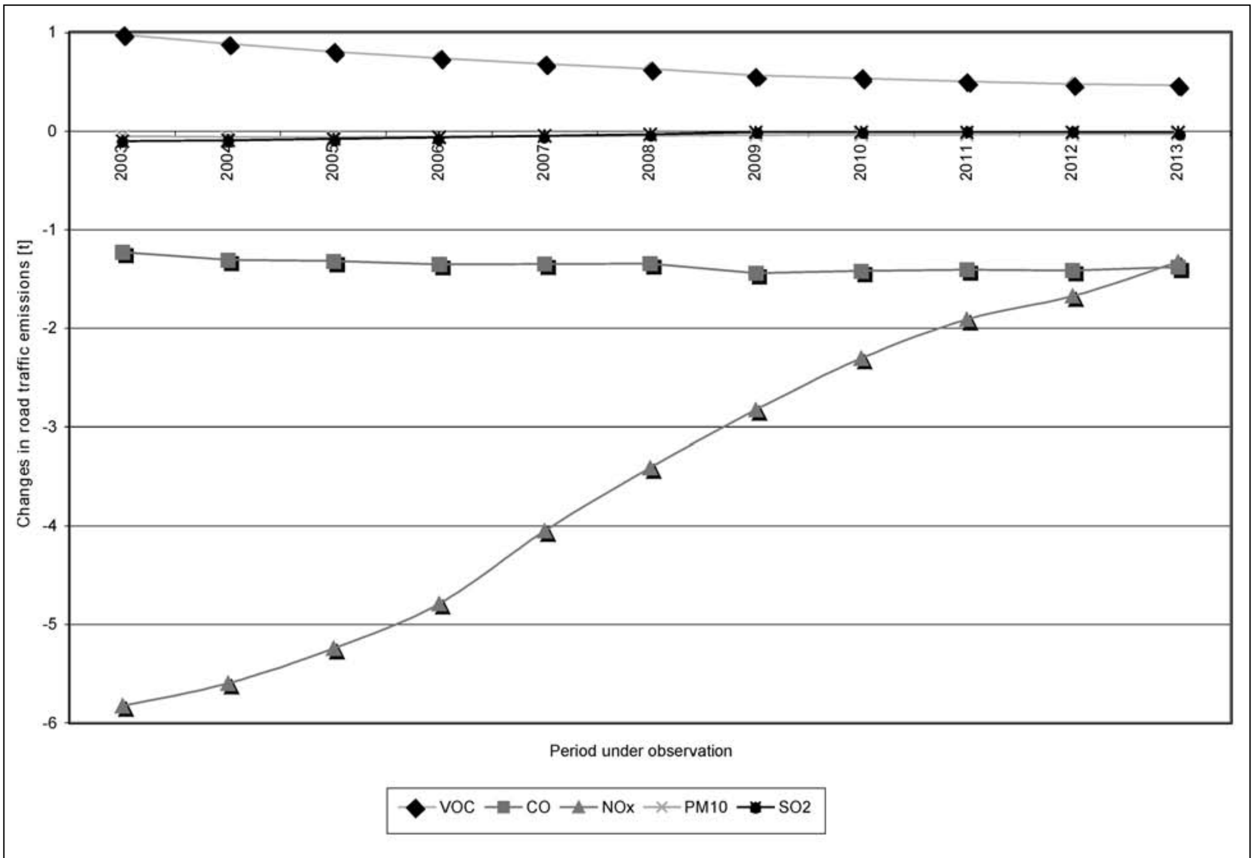

Figure 37: Changes in the emission of air pollutants due to Section Control

engines have their lowest VOC output between 80 and 100km/h. A decrease in average speed to 75km/h (passenger cars) or 55km/h (HGV) amounts to an increase of VOC emissions.

In its first year of operation, a positive impact of Section Control concerning accidents in the Kaisermühlen Tunnel was observed. Apart from the reduction in total numbers of casualty accidents, the severity of injury was also positively affected.

In a four-year period prior to the start of the Section Control system (I_b – IV_b), one fatality, one person severely and 10 slightly injured have been recorded on average every year. Since August 2003 no fatal or severely injured road user was observed in the Kaisermühlen Tunnel, while the number of slightly injured drivers decreased to a total of 7 in the after-period.

To properly quantify the safety effect of Section Control, a simple before/after comparison of accidents is not suitable. It is necessary to compare the situation with Section Control ("after") with the anticipated situation that would have occurred without Section Control.

Traffic performance in the before period (I_b – IV_b) increased in a linear manner, while in the after-period (I_a) a slight drop in vehicle-km was observed. This phenomenon is due to the fact that traffic capacity on this road section has apparently reached its limit. Without further investments in additional lanes or route information and management systems, a further increase in daily traffic is unlikely. Because numbers of fatal and serious injuries are too low to produce meaningful results, these two categories were combined for further calculations. Furthermore, some effects of serious injuries on the quality of life (e.g. lifelong paraplegia) deem it necessary to ascribe these victims the same weight as fatalities.

The corrected "before" value (number of accidents, fatalities or injured people without treatment) results from multiplying the average number of accidents (per million vehicle-km) with the traffic performance in the "after" period (I_a). The ratio of "after" and (corrected) "before" values constitutes the actual safety effect of the measure.

The analysis also controls for general trends in the number of accidents by using the total number of accidents on motorways in the "before" and "after" period as a comparison group. The mean number of comparison group accidents in the before period was 2,485 and 2,540 in the "after" period. Thus, the number of comparison group accidents is sufficiently large to be only minimally influenced by random fluctuations. The effect of Section Control

Period	Traffic performance [million vehicle-km]	Accident rate	Rate of fatal and serious injuries	Rate of slight injuries
IV_b	67.6	0.10	0.015	0.15
III_b	70.3	0.10	0,014	0.13
II_b	72.2	0.10	0,028	0.15
I_b	74.8	0.09	0,000	0.12
I_a	74.5	0.07	0,000	0.09
Mean (IV_b - I_b)		0.10	0.014	0.14
Standard deviation (IV_b - I_b)		0.004	0.011	0.015

Table 11: Traffic performance and accident rates [per million vehicle-km] in the Kaisermühlen Tunnel

	Corrected before value	After value	Ratio[36]
Injury accidents	7	5	0.71
Fatal and serious injuries	1	0	0.00
Slightly injured	10	7	0.70

Table 12: Corrected before and after values of accident severity due to Section Control

[36] Slightly different numbers due to round-off errors in the computation of the ratio

From	To	Period	Injury accidents	Fatalities	Seriously injured	Slightly injured
12.08.1999	12.08.2000	IV_b	2,535	134	1,218	2,847
12.08.2000	12.08.2001	III_b	2,468	165	1,255	2,703
12.08.2001	12.08.2002	II_b	2,402	121	1,173	2,663
12.08.2002	12.08.2003	I_b	2,534	124	1,133	2,819
12.08.2003	12.08.2004	I_a	2,440	108	1,165	2,642
Mean (IV_b – I_b)			2,485	136	1,195	2,758

Table 13: Injury accidents and severity of casualties on Austrian motorways in the before/after period

on the number of accidents (or fatalities or injured road users) was estimated as follows:

Safety effect [%] = $1 - [X_a/E(m)_b]/[C_a/C_b]$

where:

X_a = recorded number of accidents in the "after" period

$E(m)_b$ = expected number of accidents (correct before value) in the "before" period

C_a = number of comparison group accidents in the "after" period

C_b = number of comparison group accidents in the "before" period

	Odds ratio	Safety effect [%]
Injury accidents	0.69	-30.5
Fatal and serious injuries	0.34	-66.4
Slightly injured	0.72	-28.4

Table 14: Safety effect of Section Control on accident severity

	Percentage change in the number of accidents	
Accident severity	Best estimate	95% confidence interval
Injury accidents	-31	(-35; -26)
Fatal and serious injuries	-66	(-82; +143)
Slightly injured	-28	(-39; -13)

Table 15: Best estimate and confidence interval of the safety effect of Section Control on accidents

Category	Amount of savings	€ per unit (2002-price)	Cumulated value
Fatalities	1	949,897	949,897
Seriously injured	1	51,439	51,439
Slightly injured	3	4,359	13,077
Property damage	2	5,745	11,490
Total			1,025,903

Table 16: Valuation of savings in the number of accidents and severity of injury due to Section Control

	Vehicles passing the Section Control (Mio)	Fines		
		Passenger cars	HGV	All vehicles
Heading south (A23)	13,45	19,162	951	20,113
Heading north	15,97	19,558	1,210	20,768
Total	29,42	38,720	2,161	40,881

Table 17: Speed violations and charges in the Kaisermühlen Tunnel (source: Federal Ministry of the Interior, own calculations)

Statistical inference draws conclusions about a population based on sample data. It also provides a statement, expressed in the language of probability, of how much confidence we can place in the conclusions. The different values for the safety effect acts as estimators of the (unknown) population parameter. The purpose of a confidence interval is to estimate this parameter with an indication of how accurate the estimate is and how confident we are that the result is correct. Any confidence interval consists of two parts: an interval computed from the data and a confidence level. The confidence level states the probability that the method will give a correct answer. That is, if you use a 95% confidence interval, the probability that the true value is out of this interval is only 0.05.

The following tables show estimates and 95% confidence intervals of the safety effects of Section Control on accidents. Computing the Odds Ratio, if any value out of 4 numbers involved in the evaluation is zero a correction must be applied, i.e. 0.5 should be added to each number.[37]

Table 17 gives an economic valuation of savings in the number of accidents and severity of injury due to Section Control. The original values were obtained from a study on economic costs of accidents[38]. Figures were then converted into EURO (€) and brought to a 2002 price level by using official inflation rates. As can be seen from the bottom line of the table, the safety effect of the Section Control system amounts to annual savings of more than 1 million €.

In the period under observation (13.09.2003-27.08.2004), more than 29 million vehicles passed through the Kaisermühlen Tunnel and about 40,000 drivers were charged because of excessive speeding. That is, only 0.14% or every seven hundredth driver, does not follow speed regulations on this road section and drives too fast. The top speed of a vehicle heading north was 175 km/h and 154 km/h heading south. About 5% (2,161) of all fines issued were acquired by HGVs. Keeping in mind that more than 10% of daily traffic is due to

[37] FLEISS, 1981, p. 64

[38] Bundesministerium für Wissenschaft und Verkehr, 1997, p. 136-141

HGVs, a possible explanation for this phenomenon can be found in the high proportion of foreign vehicles among lorries. Due to the fact that mutual recognition of financial penalties has only been established with Germany and Switzerland, most of the foreign speed violators cannot be prosecuted.

At the Tampere European Council (15 and 16 October 1999), the Heads of State or Government of the EU member states and the President of the Commission agreed that mutual recognition of criminal and financial matters should be a cornerstone of judicial cooperation within the European Union. Thus, France, the United Kingdom and Sweden initiated the adoption of a Council Framework Decision that enables member states to execute criminal and financial offences against citizens of other member states. Although this proposal is far from reaching legal status due to objections from several countries, it can be expected to pass legislation within the next 3-5 years. Obtaining fines from foreign speed violators should then be possible and benefits will be maximized.

According to Austrian law[39] 80% of the fines from speed violations belong to the operator of the infrastructure, which (in case of the Section Control) is the Austrian highway operator (ASFINAG). The remaining 20% are used to cover the maintenance costs of the system experienced by the Federal Ministry of the Interior.

Table 18 gives fines for different levels of speeding. Drivers exceeding the speed limit by more than 50 km/h have their driving licences revoked. During the observation period, this happened in 46 cases.

The cost-benefit Analysis is based on the principle of economic efficiency, i.e. to estimate if a measure is worth being implemented, the benefits and costs of the treatment are computed and brought into relationship. The benefit term includes all positive (monetary) effects of the measure. In the case of Section Control, benefits consist of reductions in accidents and road traffic emissions. Revenues from speed violators were omitted in the calculation of the cost-benefit ratio because of the fact that in an economic point of view, it is irrelevant if the money belongs to consumers buying goods and therefore increasing their personal benefits or the highway operator that uses the fines for additional safety campaigns. The cost-benefit ratio will be the same at both events.

Different benefits are added to obtain a total benefit. The cost term on the other hand denotes implementation and maintenance costs.

Combining the benefits and costs calculated in the previous chapters, a net present value of all benefits (without fines from speeders) of € 1,105,011 and costs of € 204,272 is obtained.

These values correspond to a cost/benefit ratio of 5.4. According to analyses of safety measures in Work Package 1 of ROSEBUD[40], measures with a CBR larger than 3 are ranked “excellent”.

This survey concentrates on injury accidents because data for material damage accidents could not be collected without enormous strains on budget and working hours. Thus, the cost-benefit ratio computed underestimates the real effects to a certain extent. This should be kept in mind whenever Section Control systems are considered for further use in traffic safety programs.

With the instrument of cost-benefit analysis, it is possible to incorporate various effects of this safety

km/h	Fine	Violators	Revenues due to speed violation
0 – 9	€ 21	16,176	339,696
10 – 19	€ 42	22,048	926,016
20 – 29	€ 56	2083	116,648
30 – 39	€ 70	409	28,630
40 – 50	€ 140	119	16,660
Total		40,881	1,427,650

Table 18: Revenues due to excessive speeding in the Kaisermühlen Tunnel (source: Federal Ministry of the Interior, own calculations)

Components of the CBA	Benefits	Costs
Road traffic emissions	79,108	
Accident costs	1,025,903	
Installation and maintenance costs		204,272
Total	1,105,011	204,272

Table 19: Present value of benefits and costs in € (2002-price) due to Section Control

[39] StVO, Article 100, Paragraph No.10

[40] Road Safety and Environmental Benefit-Cost and Cost-Effectiveness Analysis for Use in Decision-making. ROSEBUD is a thematic network funded by the European Commission to support users of efficiency assessment tools at all levels of government.

measure into the evaluation process, i.e. not only reductions in casualty accidents and severity of injuries, but also impacts on the environment, such as road traffic emissions. A major problem of road traffic, which has been neglected due to the special situation of the Kaisermühlen Tunnel, is traffic noise.

Regional governments in Austria have already expressed their intention to use Section Control as a means to reduce traffic noise in residential areas. Such an application of Section Control will raise the cost-benefit ratio even more.

Annex II: Valuation of impacts in CBA

Country	Fatality cost	Serious injury cost	Slight injury cost	Valuation method[a]
Czech Rep.	263	91	10	Non-behavioural
Hungary	276	25	3	Non-behavioural
Germany	1,257	86	4	Non-behavioural
France	1,500	150	22	N/A
Netherlands	1,741	256	38	Behavioural
Finland	1,934	261	50	Behavioural
Switzerland	1,912	169	18	Behavioural
Sweden	1,954	349	20	Behavioural
UK	2,107	237	18	Behavioural
Norway	3,016	474	41	Behavioural

[a] Behavioural methods are founded on neo-classical theory, while non-behavioural are not,
Sources: BLAEIJ et al. (2004), KOŇÁREK (2004), HOLLÓ (2004), HÖHNSCHEID (1998), DTT (2004), METSÄRANTA and KALLIOINEN (2004), ELVIK (2004)

Table 20: Official values of prevented fatalities/injuries (€ 1000). 2002-prices

Country	Working	Non-working		Valuation method [b]
	Business	Commuting	Others	
France	11.1	10.0	5.5	N/A
Netherlands	28.09	8.35	5.56	Behavioural
Finland	24.08	4.07	4.07	N/A
Switzerland	56.79	11.36	5.68	N/A
Sweden [a]	20.84	4.24	3.37	Behavioural
UK	32.39	6.95	6.95	Behavioural
Norway [a]	20.71	6.00	5.57	Behavioural
USA	22.59	10.20	10.20	Behavioural

[a] Swedish and Norwegian values are given for the case of shorter trips (less than 50km) for car drivers.
[b] The opportunity cost approach using wage rates may be classified as a behavioural method – it is the behavioural assumption that is at stake, not the individual-based viewpoint. However, for non-working trips, the individuals' valuation of time is difficult to get hold of without applying stated preference methods involving specific comparisons, choices, and trade-offs where time is one of several travel attributes.
Sources: BLAEIJ et al. (2004), DTT (2004), METSÄRANTA and KALLIOINEN (2004)

Table 21: Official values of reduced time use (€). 2002-prices

Country	NO_x	VOC	PM_{10}	SO_2	CO_2 [a]
Germany [b]	0.405				181 - 227
France					100
Netherlands	6.71	6.71	21.4		64
Switzerland	5.11		15.3		96.5
Sweden [c]	6.92	3.46		2.34	89.3
Norway [d]	5.14 - 10.27	5.14 - 10.27	0 - 265	2.80 - 10.90	58
USA [e]	6.82 (15.0)	3.42 (14.1)	9.20 (5.20)	4.11 (10.1)	42

[a] € per ton
[b] Official value per NO_x equivalent
[c] Official values for regional air pollution effects
[d] Interval from rural to urban; in the PM_{10} case from 'other built-up' to city
[e] Damage cost values, with social expenditures in brackets
Sources: BLAEIJ et al. (2004), DTT (2004)

Table 22: Official and recommended values of reduced air pollution (€ per Kg). 2002-prices

Country	Unit of valuation			
	Per person affected per year	Per dB(A) change per person affected per year	Per vehicle km	Per dB(A) change in house prices
Germany		50		
Netherlands		21		
France	156			0.4 – 1.1%
UK		15		0.08 – 2.30%
Finland	959			
Denmark [a]	3,316			
Sweden [b]	463	71		
Norway [c]	1,000 – 1,170		0.01 – 0.09	
Switzerland		22		

[a] Official values are given per dwelling/household highly annoyed (NAVRUD 2002). The numbers per person highly annoyed is obtained by dividing by average household size (2.1). It should be noted that values for highly annoyed are generally higher than for affected (comprising highly annoyed plus somewhat annoyed).

[b] A graded monetary scale based on dB(A) level is applied, whereby a reduction to 50dB(A) from a starting point of 51 dB(A) has a value of €16, and a reduction from 75dB(A) to 50dB(A) has a value of €1,771. €463 is simply the average of the graded scale, and €71 is the average per dB(A) change.

[c] Interval for persons affected per year is due to different values for different noise sources (road, rail, air), while the interval per vehicle km goes from small cars to heavy cars.

Sources: BLAEIJ et al. (2004), NAVRUD (2002), ELVIK (1999), DTT (2004), METSÄRANTA and KALLIOINEN (2004)

Table 23: Recommended values of reduced noise. € 2002-prices

Main impact	Subcategories	Vehicle type, road user etc.	Unit of valuation
SAFETY	Road Crashes	All (estimatedreal casesof injury)	Fatality
			Serious injury
			Slight injury
			Property damage
MOBILITY	Travel time	Pedestrian	Person/hour
		Cyclist	Person/hour
		Car occupant	Person/hour
		Bus passenger	Person/hour
TRAVEL COST	Vehicle Operating Cost	Car	Km/travel
		Single truck	Km/travel
		Truck/trailer	Km/travel
		Bus	Km/travel
ENVIRONMENT	Traffic noise	Small cars	Km/travel
		Heavy cars	Km/travel
	Air pollution	CO	Kg of CO
		NO_x	Kg of NO_x
		VOC	Kg of VOC
		SO_2	Kg of SO_2
		PM_{10}	Kg of PM_{10}
	Global warming	CO_2	1 000kg of CO_2

Table 24: Categorisation of impacts for use in cost-benefit analyses

Schriftenreihe

Berichte der Bundesanstalt für Straßenwesen

Unterreihe „Mensch und Sicherheit“

2001

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Vollrath, Löbmann, Krüger, Schöch, Widera, Mettke € 19,50

M 133: **Kongressbericht 2001 der Deutschen Gesellschaft für Verkehrsmedizin e. V.** € 26,00

M 134: **Ältere Menschen im künftigen Sicherheitssystem Straße/Fahrzeug/Mensch**
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2002

M 135: **Nutzung von Inline-Skates im Straßenverkehr**
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Assing € 15,00

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