The use of efficiency assessment tools: solutions to barriers

Shalom Hakkert & Paul Wesemann (eds.)

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Workpackage 3 of the European research project ROSEBUD

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- WP 3 -

The Use of Efficiency Assessment Tools: Solutions to Barriers

Public

ROSEBUD

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

Contract No: GTC2/2000/33020

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Summary

In road safety, as in most other fields, efficiency is an important criterion in political and professional decision making. Tools are available to help choose the policy which gives the highest return on investments. ROSEBUD (Road Safety and Environmental Benefit-Cost and Cost-Effectiveness Analysis for Use in Decision-Making) is a thematic network funded by the European Commission. It is meant to support users at all levels of government in judging the efficiency of road safety measures by making use of Efficiency Assessment Tools (EATs) like Cost Benefit Analysis (CBA) and Cost Effectiveness Analysis (CEA). A CBA is meant to answer the integral efficiency question and investigates the social output of a measure or a policy. The monetized value of all effects is compared with the implementation costs of the measure. The CEA is used for the partial efficiency question and estimates the numbers of the casualties saved per invested euro.

Policies and decisions are often based on other grounds than effectiveness and efficiency. Workpackage 2 of ROSEBUD identified three groups of barriers that were reason for not using CBAs and CEAs: fundamental barriers, institutional barriers, and technical barriers. A total of 28 individual barriers were found and fitted into these three groups of barriers. A large number of barriers are beyond the scope of ROSEBUD. They either are of a philosophical nature, or they are central elements in a certain system of political decision making. This study, Workpackage 3, looked at the remaining barriers and tried to find practical solutions to overcome them, and to improve the use of EATs. These barriers are:

- a lack of generally accepted evaluation techniques;
- inadequate treatment of uncertainties;
- disputable values of parameters in the analysis (e.g. discount rates);
- inadequate methods to deal with distributional effects;
- lack of knowledge of relevant impacts;
- absence of impartial, institutionalized, quality checks on CBAs;
- wrong timing of CBA-information in the decision making process;
- costs of CBA;
- CBA-information does not come from a reliable source (e.g. monopoly position of CBA conductors);
- wrong form of the CBA information (text or figures, tables, diagrams, understandable language, way of offering the information, transparency and accessibility of conclusions);
- prejudices among governors and civil servants because of little knowledge about CBAs.

This study arrived at a number of solutions which can lead to an increased use of EATs for making road safety policies and decisions.

Best practice guidelines

Public authorities on the national and EU level can improve the quality and uniformity (comparability) of efficiency assessment studies by establishing 'best practice' guidelines for the methods and techniques. The guidelines can provide some examples of best practice solutions. Examples are: a sensitive type of analysis with scenarios (optimistic, realistic, pessimistic) to handle uncertainties and careful descriptions of the distribution of costs and/or benefits among the various groups that are affected by a measure. They are informal guidelines with no obligation.

Creating and maintaining a database

To stimulate the application of more uniform and reliable values of safety effects in the EU, it would be useful to establish a database with typical values of the effects, based on international experience. The database should give general values of safety effects on initial steps of CBA/CEA and could assist in comparisons of local effects observed. The database should be accessible to a European network of experts.

System of quality control

The quality of efficiency assessments can be improved by the introduction of impartial quality control. This can be achieved by the introduction of a board for impartial quality control. Another instrument to improve the quality of CBAs might be the stimulation of a competitive market for institutes executing CBAs, and certifying institutes that are highly specialized in these types of analyses. A system of impartial quality control should be developed as a follow-up to the ROSEBUD project.

Support and structure cooperation

It is necessary to support and structure the process of close cooperation between decision makers and analysts by introducing an informal professional code for analysts. Decision makers must be trained and educated. 'Tips and tricks' will be provided for understandable reporting on the results of CBAs and CEAs .

Legal embedding

It is still felt to be too early to generally recommend a legally binding CBA for road safety measures. However, the use of CBA in decision making can be stimulated by legal embedding of this assessment tool in decision making processes where large road investments are involved. In those countries where such an obligation does already exist for large investments in infrastructural projects, it should be included as part of the procedure. The EC could introduce a similar obligation at the EU level.

Contents

1. Introduction

Charlotte Bax and Paul Wesemann (SWOV)

1.1. Motivation and approach

Budgets for road safety policies and activities are not infinite. Politicians and civil servants have to decide about the best possible use of these budgets. They often use the same criteria when deciding about policies and budgets. Suitability and lawfulness or legitimacy are traditionally important criteria for a good policy. Furthermore, considerations of justice will also influence the policy and therefore the spending of the budgets. Recently, efficiency is often mentioned as a criterion for a good policy. To judge the efficiency of an intended policy, efficiency assessment tools (EATs) are available to simplify this task and to choose the policy with the highest return per Euro. Efficiency assessment tools in this case mean especially Cost Benefit Analyses (CBAs) and Cost Effectiveness Analyses (CEAs). A CBA is meant to answer the integral efficiency question and investigates the social output of a measure or a policy. The CEA is used for the partial efficiency question and investigates the casualties saved.

Despite all these criteria, policies are often based on other grounds than effectiveness and efficiency. In Workpackage 2 of ROSEBUD reasons for the non-use of CBAs and CEAs were studied. These barriers to the use of EATs were divided into groups. First of all some fundamental barriers, rejections of the principles of EATs were found. Second, there appeared to be institutional settings which hindered the use of EATs, especially in the organization of the decision making. Some technical barriers, related to methodological issues concerning EAT were found and last, barriers related to the implementation of policies were looked at.

In this third Workpackage of ROSEBUD, the aim is to find solutions for the barriers established in the previous reports. Some barriers will, by their nature, not be solvable, and are considered to be absolute barriers for example the fundamental barriers. Others lend themselves for recommendations about methodology of EATs or about the decision making processes of national and regional governments and are considered to be relative barriers. This first chapter indicates which barriers will be handled and which direction is chosen. But first, an introduction is given to the subject of decision makers. Who are they, on which levels can we find them, and do they differ in the various countries? Since they are the main users of EAT in policy making, it is important to have a clear vision on the concept 'decision maker'. The chapter closes with a reading guide for the report.

This report will be of special interest for experts, more than for political and professional decision makers. The report forms the basis to work out practical solutions, guidelines, tools, and recommendations for further actions in the following Workpackages of ROSEBUD, numbers 4 and 5. In the last chapter of this report we will indicate which recommendations in this report are practical enough to be directly used by the people in the field and which issues need to be worked out, either in the next workpackages or as a follow-up of ROSEBUD by the EC.

1.2. Types of decision makers

Decision makers are the ones who most frequently use the outcomes of CBAs and CEAs. Political scientists distinguish between several types and levels of decision makers. First, a distinction can be made between political and professional decision makers. The political decision makers consist, on the one hand, of the chosen representatives of the people (for example the Parliament) and, on the other hand, of administrators such as ministers and other members of government. Professional decision makers can be distinguished on different hierarchical levels, such as high level civil servants, middle level and low level (or executive) civil servants. These types of decision makers can be present on various levels of the government. We can distinguish the national, provincial (or regional), and local level within the countries, and the European level above the separate countries. Besides these decision makers, there are other parties which use the results of CBAs and CEAs and take decisions about the spending of budgets, often on limited areas. These parties are for instance NGOs (non-governmental organisations), such as PRI-members, the Driver or Vehicle License Centres, and research institutes. Police and the public prosecutors are also relevant parties, but they are a part of the government.

Not every decision maker decides about all possible road safety issues and measures. To make an inventory of the types of decision makers and their power to decide on certain measures, a short questionnaire was sent to the WP 2 and 3 partners of the ROSEBUD consortium: Norway, the Czech Republic, Hungary, Israel, Italy, Germany and the Netherlands. The results of the questionnaire are presented in *Table 1.1* and discussed below.

Concluding it can be said that the decisions about infrastructural measures (construction and maintenance) are made on all three levels of the government. Education is mostly a matter of the national and local level, but in some countries the regions, NGOs and the police also contribute to the decisions. Enforcement is decided upon by the national government and by the public prosecutor, and sometimes the police and the provinces. Regulation is typically an issues which is covered by the national government, although in some countries the local and regional government and the police contribute. In most countries research and data collection and distribution is a matter for research institutes, national government, NGOs and sometimes the police. The above shows that in all countries the national government is the one that decides on most issues, although a fair amount of decentralization happens at the lower governmental levels, especially on the issues of education and infrastructure. Enforcement and regulation is mostly a task of the police and the national government. Decision makers outside the governmental structure usually take decisions about education and research or data collection and data distribution.

In this Workpackage- WP 3, research and recommendations will thus mostly be focussed on the national decision level, but in each chapter attention will also be paid to the regional and local levels.

	Infrastructural measures	Education	Enforcement	Regulation	Research & Data
Norway	All governmental levels	National/local government and NGOs	National govern-ment, public prosecutor, police	National and local government	National and regional govern-ment, research institutes, and NGOs
The Nether-lands	All governmental levels	National/local government and NGOs	National govern-ment, public prosecutor, police	National government	National and regional govern-ment, research institutes and NGOs
Germany	All governmental levels	All governmental levels, police, and NGOs	National government and public prosecutor	National and regional government	All governmental levels, NGOs, police, and research institutes
The Czech Republic	All governmental levels	All governmental levels, police, and NGOs	Regional govern-ment and police	National government	National and local government, NGOs, research institutes, and police
Hungary	National and local government	National govern-ment and police	National govern-ment, police and License institutes	National govern-ment	National government, NGOs, police, and research institutes
Israel	All governmental levels	National govern-ment, driver education centers	National govern-ment, police	National government and public prosecutor	National govern-ment, police, research and statistical institutes
Italy	All governmental levels	All governmental levels, Driver License institute, NGOs	National govern-ment, public prosecutor, police	National government, Vehicle License institute	National and local government, research institutes

Table 1.1. *Types of decision making deciding on groups of road safety measures.*

1.3. Barriers and solutions

The Workpackage 2 report 'Barriers to the use of efficiency assessment tools in road safety policy' searched for a large amount of possible barriers through literature research and questionnaires in seven countries. As indicated above, the barriers are divided into fundamental, institutional, and technical barriers. In this section the barriers will be mentioned very briefly. Also is indicated which barriers will be discusseded in the Workpackage 3 report and an explanation is given for not dicussing some of the barriers. A more extended description and explanation of the barriers is given in the above mentioned WP 2 report.

Fundamental barriers:
1. rejecting principles of welfare economics;
2. rejecting efficiency as the most relevant criterion for priority setting;
3. rejecting the idea of monetary valuation of risk reductions;

This type of barriers cannot be evened in WP 3. This is a matter of conviction which can not be changed easily. However, for barrier 3 sometimes CEA could be used and accepted as an alternative for CBA.

Institutional barriers:

4. lack of consensus on relevant policy objectives;
5. formulation of policy objectives inconsistent with EAT;
6. priority given to policy objectives unsuitable for EAT;
7. the rationality of horse trading;
8. the rationality of political opportunism;
9. non-funded mandates and excessive delegation of authority;
10. abundance of resources;
11. rigidity of reallocation mechanisms;
12. social dilemmas;
13. lack of power;
14. vested interests in road safety measures;
15. lack of incentives to implement efficient road safety measures;
16. absence of impartial (institutionalized) quality check on CBAs;
17. a lack of generally accepted evaluation techniques;
18. wrong form of CBA-information (text or figures, tables, diagrams, understandable language, way of offering the information, transparency and accessibility of conclusions);
19. wrong timing of CBA-information in the decision making process;
20. CBA-information doesn't come from a reliable source (e.g. monopoly position of CBA conductors);
21. prejudices among governors and civil servants because of little knowledge about CBAs;
22. costs of CBA;

Barriers 4 - 14 are beyond the scope of ROSEBUD; changing them would require that the system of political decision making be changed. Barrier 15 is not mentioned in the data of the interviews on the national level and therefore proposed to be left out. For barrier 16 - 22, possible solutions were found in the results of the WP 2 interviews.

Technical barriers:

23. lack of knowledge of relevant impacts;
24. inadequate monetary valuation of relevant impacts;
25. indivisibilities;
26. inadequate treatment of uncertainty
27. disputable values of parameters in the analysis (e.g. discount rates)
28. inadequate methods to deal with distributional effects.

Barrier 24 is included in barrier 17. Barrier 25 was not mentioned explicitly in the interview data and is therefore left out of the list of solutions. Lack of knowledge of the costs of measures is not mentioned in the interviews and therefore not listed as a barrier. Barriers 23 and 26 can be seen as complementary; the less the knowledge of relevant impacts, the more uncertain the outcomes of the CBA will be, and vice versa. Lack of knowledge can be influenced only to a certain degree: if new research is needed there will be no solution in the short term for barrier 23. If no adequate method is found to deal with distributional effects, it will be concluded that barrier 28 cannot be influenced; but first one should investigate possible methods to deal with distributional effects. The rest of the barriers will be handled in this report.

1.4. **Contents of the following chapters**

It is the task of WP 3 to develop practical tools in order to improve the use of EATs. First of all these tools should make it possible to sort out the situations where fundamental and other absolute barriers are present. And secondly they should support decision makers and analysts to overcome the other (relative) barriers. The report is written in the form of a guide for performing an efficiency assessment. This guide aims at a better use of EAT´s by solving a large number of barriers. Thus it fulfils some necessary conditions for increasing the efficiency of road safety policymaking. However, one should be realistic and acknowledge that these will not be sufficient conditions. Beside considerations of efficiency, other arguments are also used in policy making especially in the political domain, even when the situations with fundamental barriers have been sorted out . These political arguments are included in the barriers 7 (Rationality of horse trading), 8 (Rationality of political opportunism), 12 (Social dilemmas), and 14 (Vested interests in road safety measures). In theory, one should try to sort out the situations with these barriers as well but that seems practically impossible. Decision makers are not always aware of these considerations beforehand, or even if they are aware of them, they are not easily going to confess to them.

In this section, the division of the chapters of the report is discussed and it is indicated which barriers will be handled in the chapters.

Chapter 2 deals with the methodology of Efficiency Assessment. This presents the knowledge that is widely shared and not disputed among the EAT experts. Special issues are: uncertainties, distributional effects, basic data (discount rates, value of a statistical life (VOSL), values for travel time and environmental externalities, etc). The following barriers will be discussed:

- a lack of generally accepted evaluation techniques;
- inadequate treatment of uncertainty;
- disputable values of parameters in the analysis (e.g. discount rates);
- inadequate methods to deal with distributional effects.

Chapter 3 handles the availability of knowledge and data. The question will be answered which knowledge and data are required in order to perform a CBA/CEA (amount, quality) and to what extent these are available (what has been researched, which data has been collected; how and where this information can be found). This will cover implementation costs of traffic safety measures, their safety effects, and side-effects on travel time and the environment. Suggestions to overcome the lack of information are made. The following barriers will be dealt with:

- lack of knowledge of relevant impacts;
- inadequate treatment of uncertainty;
- inadequate methods to deal with distributional effects.

In *Chapter 4*, the optimising of the process of Efficiency Assessment will be discussed. First will be considered which method is best chosen for certain types of policies. Furthermore, the possible help of computerized assessment tools and the required thoroughness of the analysis will be handled. Last, the position of the EAT in the decision making process and

the quality control of the EAT will be discussed. The barriers which will be treated are:
- absence of impartial (institutionalized) quality checks on CBAs;
- wrong timing of CBA-information in the decision making process;
- costs of CBA;
- CBA-information doesn't come from a reliable source (e.g. monopoly position of CBA conductors).

In *Chapter 5* the creation of conditions for the use of CBA/CEA is handled. First the presentation form of CBA results is discussed and proposals are made to improve this. Second, the information, education & training for (various types of) decision makers is considered: what should the various decision makers know about CBAs and how can this be achieved. The following barriers will be discussed:
- wrong form of the CBA-information (text or figures, tables, diagrams, understandable language, way of offering the information, transparency and accessibility of conclusions);
- prejudices among governors and civil servants because of little knowledge about CBAs.

2. A state of the art of the efficiency assessment methodology

Rune Elvik and Knut Veisten (TØI), Paul Wesemann (SWOV)

2.1. Introduction

This chapter describes the two main methods for efficiency assessment. These are:
- cost-effectiveness analysis (CEA);
- cost-benefit analysis (CBA).

First the theoretical principles of CBA and CEA will be explained, referring to the mainstream (neo classical) welfare economics (*Section 2.2*).
Next the technical framework of efficiency assessment with these two main methods will be dealt with (*Section 2.3*). The stepwise procedure of defining and evaluating project alternatives is illustrated, followed by some specific features of CEA and CBA.
Section 2.4 treats the methods and its outcomes of valuation of all relevant impacts of road safety policy: safety, time, pollution and noise.
Section 2.5 and *2.6* deal with the problems of uncertainty and equity aspects of CBA based road safety policy.
The chapter is rounded off with conclusions.

A CEA is an analysis in which the objective is to find the cheapest way of realising a certain policy objective. In CEA only one policy objective is considered. Also in a CBA one will search for the cheapest way to reach policy objectives, but these costs are weighed against monetized benefits. Thus, a CBA shall indicate what measure, or combination of measures, provides the largest difference between benefits and costs.

2.2. Theoretical principles of CBA and CEA

CBA and CEA have a foundation in mainstream (neo-classical) economic theory, whereby economic values are recognised as expressions of individual/household preferences. The demand of consumers is assigned the leading role in deciding the availability of goods and services, generally without any judgment or corrections against those who demonstrate higher willingness to pay for Modern Talking than for Beethoven, choose a feeble Budweiser-copy instead of a real Budwar-Budweiser, or rank speed and mobility above safety. There is no bad taste in mainstream economics - only tastes. I.e., the 'sovereign consumer' principle is fundamental. The diversity of preferences/tastes for marketable commodities set prices in interaction with the commodity producers. The thesis for a 'perfect' (free) market says that price levels are given from the point where marginal demand, or marginal willingness to pay, equals marginal supply. These prices are taken as the best indicators of economic value for *private* goods. The competition in free markets also assures that a largest possible quantity is available for a lowest possible price (Varian, 1992).

Road safety can be regarded as a good with a mix of *private* and *public* aspects (Elvik, 1993, Waller, 1986). As individuals we can choose to buy travel modes or equipment that is considered 'safe' (or to increase safety compared to alternatives). When driving four-wheelers or two-wheelers, or when walking, we can individually choose between risky, high-speed behaviour or choose the more cautious behaviour. However, the infrastructure that enables the transport and the various regulations, requirements and traffic controls have clear public good aspects. The safety of the infrastructure cannot be portioned out to individual road-users - it is (for most applications) a *non-exclusive* good - it cannot be denied or sold to the road users (Hanley et al., 1997). Further, the safety of the infrastructure may be regarded as less *congestible* (more *non-rival*) than infrastructure itself. My personal use of the infrastructure, e.g., by occupying some space by driving my car, may in some well-known situations reduce the ability for other road-users to 'consume' the same infrastructure (tailbacks, *rivalry*). But my 'consumption' of the safety standards of the infrastructure and the safety regulations and the traffic control may not reduce other road-users' 'consumption' of the same goods. If provided at a given level, this public safety level of infrastructure, regulations, and control is more or less equally available for all road users.

- Economic value:
  Consumers'/individuals' willingness to pay for a given quantity/quality - cost of providing this quantity/quality = consumer surplus.
- Individual rationality and utility maximisation:
  Individuals are assumed to know their own best and, if informed about all options and given the chance to choose, they will generally choose what is best for them.
- Consumer sovereignty:
  Individuals' preferences/tastes/wants and choices are not morally judged but accepted *prima facie*, given that they comply with the institutional base (law) and do not hamper/deteriorate other individuals' choices.

Box 2.1. *Common features of neo-classical economic values*.

A fundamental question of economics over the last century (at least since Pigou, 1920) has been how to estimate the economic value of public goods. In the case where economic value cannot be derived directly from market prices, some other procedure has to be established. Within the neoclassical tradition the methods applied to value public goods can be classified in *revealed preference* (RP) methods and *stated preference* (SP) methods. RP methods apply a linkage between the public good and a market good, and assume that individuals reveal their valuation of the public good through their demand for the market good, i.e., a similar notion as market prices. A relevant transport example is the *travel cost* method, that is based on the assumption that the cost people incur (out-of-pocket market-based costs for the journey plus time costs) to reach a recreation site of a given quality (the public good) represents the 'price' of access to the site and its environmental services. Number of trips to the site will be inversely related to the travel cost, so by sampling individuals with different travel costs, a demand curve can be estimated, and the value of access to the site can be calculated as the consumer surplus (the area between the demand curve and the price curve). Another relevant RP method is the *hedonic pricing* method. Traffic noise and air pollution from motor vehicles, and also the barrier effect of roads, influence the total residence value. A dwelling may be seen as a collection of characteristics, some of which are tangible, like floor space and number of rooms, while some are more intangible, like status value, sound landscape, and air quality. With a rich data set of dwelling prices and possibility to identify the dwelling characteristics, it is possible to estimate how much total dwelling price would increase from a given reduction in air pollution or noise. SP methods, on the other hand, ask individuals to state either the value directly or to choose between options that have different costs. This approach enables the valuation of recreation site access and site quality improvements and environmental improvements around dwellings. It also enables the valuation of public goods that are not tied to market goods (Mitchell & Carson, 1989; Blaeij et al., 2004).

- From individual valuation to social valuation:
  CBA mimics the assumed individual valuation and choice for society, weighing benefits based on willingness to pay and consumer surplus against costs, including a monetary valuation of public goods.
- Policy guidance from CBA:
  If benefits are higher than costs for a given project/measure, the project/measure is economically profitable. The project with highest benefit-cost difference is the most profitable.
- CBA in the institutional context:
  Leave general issues of distribution to politics; if benefits are higher than costs -there is a potential for “winners” to compensate “losers”. CBA must accommodate fundamental institutional constraints (law); individual benefits of law-violating acts are not counted, while nuisance/dissipation of some individuals’ welfare should be monetary calculated as societal costs.

Box 2.2. *Cost-benefit analysis (CBA).*

CEA and CBA represent tools for public economic choice -applying economic values that are founded on the same individual tastes that are assumed to form the free markets. Thus, it can involve both market prices and estimated public good values from RP or SP methods.

- CEA versus CBA:
  CEA can be regarded as a simplified CBA where not all effects are monetised. E.g., instead of monetary benefits of safety measures, one calculates only physical impacts (injury reduction etc) and compares the costs of alternative measures to reach a given policy goal.
- Policy guidance from CEA:
  CEA provides a ranking of measures to obtain a fixed policy goal with the least costly measure first.

Box 2.3. *Cost-effectiveness analysis (CEA).*

The fundamental difference between CEA and CBA is that:
- CEA takes a political objective as point of departure and aims to find the combination of measures to obtain this objective that has the lowest

economic cost. Thus, it is designed to finding the economically most effective solution to a given objective.
- CBA is also guided by political objectives, but instead of interpreting the specific objective as absolute CBA evaluates the economic benefits and costs of this objective (and related objectives). Thus, it aims to find if a proposed objective is economically efficient at all and how efficient it is (and if alterations in the objective could make it more efficient).

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

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

2.3. Technical framework of efficiency assessment

This section explains further the technique of efficiency assessment. First of all, the main steps of such an analysis are discussed in a general section: describing the project alternatives, determining the duration of effectiveness of the alternatives and the time horizon for the analysis, calculating the return on investments in the project alternatives, the scale level, and multi actor analysis (*2.3.1.4*). Then, for a number of these steps, the specific features of the cost-effectiveness analysis (*2.3.2*) and the cost-benefit analysis (*2.3.3*) will be dealt with.

2.3.1. *General framework*

2.3.1.1. The description of the project alternatives

In a cost-benefit analysis, the welfare effects are determined. To do this, the situation with the measure (project alternative) is compared with the situation without the measure (null alternative). These two situations are compared during a longer period of time. The null alternative, therefore, is not the same as the current situation, but assumes that autonomous developments occur independently from the measure. These include, for example, population growth or other demographical and economic developments. A distinction can thus be made between autonomous effects and project effects. This is shown in *Figure 2.1* below.

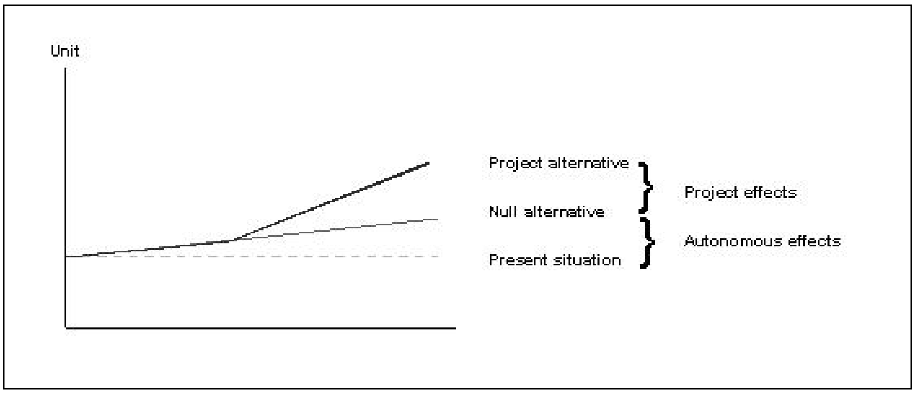

Figure 2.1*. The null alternative.*

The null alternative

The definition of the null alternative is crucial for the cost-benefit analysis. There is the danger of severely overestimating the profit of the proposed project if the null alternative is given too low a value. Generally speaking, the null effect is described as 'a combination of the best application of the available investment means and the best possible other solution for the problem that we wish to solve in the project'. What are also referred to in this context as *opportunity costs*; the benefits missed if the project is carried out, because the production factors to be used for the project, no longer deliver the benefit that they should generate in the null alternative.

As, in practice, it is practically impossible to determine the best alternative application, one often suffices with the choice of the 'norm yield' in the form of a social discount rate. This discount rate is used to calculate the future costs and benefits back to the investment year. In some countries, the national government has prescribed a real discount rate for government investments as norm for the yield of an alternative investment. The European Commission uses a social discount rate of 5% for large investment projects (EC, 2003).

For the description of the null alternative, one further suffices with the situation that occurs when carrying out the *determined* policy. This contains the policy plans that have been approved and, for which, financing is determined.

To describe the economic and demographic developments and the traffic and transport prognoses based on them (such as the increase in traffic and the change in modal split), concurrence can be employed with the longer-term scenarios that most member countries construct periodically for this.

A special point of attention in road safety projects is that, in the null alternative, an assumption must be made for the autonomous crash rate change in traffic. If it can be argued that this decrease is (practically) the same size as the traffic increase, these two influence factors cancel each other out. However, it is often more realistic to estimate the crash rate decrease, if need be by using a margin (two null alternatives).

The project alternative

The project alternative describes the situation that occurs if the measure is introduced. Of course, this alternative depends on the measures or measure packages that are judged. The project alternative can, for example, be the situation that occurs after introducing crash recorders in cars, using retro-reflecting material on lorries, introducing a practical driving test for mopedists, or a combination of these measures. Chapter 3 deals with the possible road safety measures and their effects according to various studies.

2.3.1.2. The time elements

Time horizon and duration of effectiveness

The project alternative and the null alternative are compared with each other during a longer period. Because of this, the time horizon influences the results of the cost-benefit analysis. In the case of infrastructural projects, this period is assumed to be 30 years.

This time horizon can, for non-infrastructural road safety measures, be shortened to 20 years, seeing as the duration of effectiveness of these measures is shorter than the life span of infrastructure. This increases the practical utility because, after all, effects are easier to estimate up to 2020 than 2030.

The advantage of giving all measures the same time horizon is that the *absolute* costs and benefits are mutually comparable. In addition, different road safety measures with the same time horizon are easy to compare or compared with other measures (in other fields). If, for the study, only the cost-benefit *ratio* is important and all effects remain constant during the period, the time horizon of measures does not have to be the same. We will consider further the various measures of efficiency in *Section 3.3* about cost-benefit analysis.

If the duration of effectiveness of a measure is shorter than the time horizon (for example, for measures aimed at vehicles and behaviour), the investment will take place at more times during the time horizon or the effects will decrease.

Discount rate and price level

All effects in the cost-benefit analysis are discounted to the first investment year. This means that effects that occur later weigh less heavily than effects that occur sooner. This weighed summation of effects during a period of time is called the *present value* of an effect. In order to calculate the present value, the discount rate is used. In the EU Guide to Cost-Benefit Analysis of Investment Projects (EC, 2003) a social discount rate of 5% is determined. This means that effects from a second year are multiplied by 1/(1.05)^2 from the third year with 1/(1.05)^3 etc.

This method of calculating present values also implies the effects during the time horizon of the cost-benefit analysis being expressed in real prices, i.e. without correcting for inflation. Thus, use is made of only one price level in which all prices are expressed. In general, the most recent year for which the inflation percentages are known is chosen as price level. The ‘old’ prices have to be raised to the chosen price level by using an inflation correction. After this, only real price rises may be used in the cost-benefit analysis.

2.3.1.3. The scale level

A cost-benefit analysis can be carried out at various levels. It is possible to carry out one for a country, for a specific region within a country, or for Europe. During the last few years, there has been more and more interest for regional and European cost-benefit analyses.

It is important to determine the right scale level for a cost-benefit analysis: regional managers are mainly interested in the regional effects of road safety measures, whereas national managers -if any additional budgets are needed- want more insight in the effects at a national level. The method for calculating the effects does not differ for the various scale levels. The only things that change are, of course, the input data and the area for which the results apply.

A number of different results are possible; a positive effect of the investments for one region can, for example, have negative effects for the neighbouring region, resulting in a lower profit level nationally. This phenomenon is called redistribution and is explained in the example below.

Example of scale level

Suppose, for example, the region A wants to invest in tackling an unsafe crossroads on the exit road of a motorway. The balance of costs and benefits for this region is +10 because of a road safety and accessibility improvement and a decrease in emissions. Region B also profits from the redesigned exit road because, in the case of a crash, there is no more rat run traffic through region B (+2). Some of the traffic from region B even uses a new route across the redesigned crossroads, but does travel through region C.
The traffic increase in region C results in social costs (-3). A regional cost-benefit analysis for region A results in +10. The effects in the other regions are, on balance, -1. A redistribution of the economic effects has a net effect in the three regions of +9, that is the balance of costs and benefits at the national level. To get a clear picture of the whole project, the calculation of effects can be performed at different scale levels.

Region A	Region B	Region C
+10	+2	-3

National balance +9

Figure 2.2. *Diagram of scale levels in cost-benefit analyses.*

It should be added that in economics the national level has had prominence. Further, if projects have effects outside the region or the nation, the correct procedure according to economics is to subsequently increase the area for project assessment, notwithstanding budget considerations (Trumbull 1990).

2.3.1.4. Multi actor analysis

In a social cost-benefit analysis, all relevant effects for society as a whole are brought into picture. In this, it does not matter for which party the effects apply. This means that not only are the financial, business effects examined, but also matters such as emissions, safety, and congestion. In addition, it means that if the costs of the one are the benefits of the other, these effects disappear from the cost-benefit analysis. A good example of this are the taxes; these are costs for industry and income for government.

To actually introduce measures, it is often essential to assign the effects of the cost-benefit analysis to the actors involved. In this way, each actor gets a picture of his costs and benefits, which is necessary for support. After all, if the balance of costs and benefits for an individual party is negative, this party will not be inclined to support the measure. This analysis is an important impulse for a financial analysis (per actor) that gives insight into the budgetary consequences and, perhaps, into the compensatory measures.

2.3.2. *Performing cost-effectiveness analysis*

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

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

In order to estimate the cost-effectiveness of a road safety measure, the following information is needed:
- an estimate of the effectiveness of the safety measure in terms of the number of crashes it can be expected to prevent per unit implemented of the measure;
- a definition of suitable units of implementation for the measure;
- an estimate of the costs of implementing one unit of the measure;
- a method for converting all costs of implementation to an annual basis (in order to make measures with different time spans comparable).

The crashes that are affected by a safety measure will be referred to as target crashes. In order to estimate the number of crashes prevented per unit implemented of a safety measure, it is necessary to:
- identify target crashes (which may, in the case of general measures like speed limits, include all crashes);
- estimate the number of target crashes expected to occur per year for a typical unit of implementation;
- estimate the percentage effect of the safety measure on target crashes. This defines the numerator of the cost-effectiveness ratio of a safety measure.

The various challenges and problems in estimating the effectiveness of a measure are presented and discussed in *Chapter 3*. To estimate the denominator, the first step is to define a suitable unit of implementation of the measure. In the case of infrastructure measures, the appropriate unit will often be one junction or one kilometre of road. In the case of area-wide or more general measures, a suitable unit may be a typical area or a certain category of roads. In the case of vehicle safety measures, one vehicle will often be a suitable unit of implementation, or, in the case of legislation introducing a certain safety measure on vehicles, the percentage of vehicles equipped with this safety feature or complying with the requirement. As far as education and training is concerned, the number of trained pupils according to a certain training scheme may be a useful unit of implementation. The unit cost will be the cost of training one pupil. It is difficult to define a meaningful unit of implementation for public information. It seems reasonable, however, to rely on the assumption that the effects of public information depend on the total volume of information. In that case, there is no need for counting units of implementation; effects are related directly to the total costs, rather than the unit costs. For police enforcement, the number of man-hours of enforcement per kilometre of road per year may be a suitable unit of implementation.

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

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

a. Estimate effectiveness of relevant safety measure in terms of the number of (target) 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 into campaign of a specific type.

b. Estimate the costs of implementing one unit of the measures.

c. Convert all costs of implementation and effects to present time basis (or an annual basis) by discounting.

Box 2.4. *CEA of road saefty measures*.

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

- It is generally easier to calculate the cost-effectiveness of a safety measure than to calculate its cost-benefit ratio. Calculating cost-effectiveness requires knowledge about safety effects and costs of

implementation only. To calculate cost-benefit ratios one needs more information, concerning, for example, crash costs and the effects of a safety measure on mobility.
- Cost-effectiveness highlights the safety effects of measures. A cost-benefit ratio, on the other hand, is determined not just by safety effects but also by the effects of a measure on mobility and on environmental factors.
- Cost-effectiveness does not require the use of crash costs. Crash costs can be difficult to estimate and the estimates are often controversial.

The major shortcomings include the following:
- The cost-effectiveness criterion cannot be used to compare safety effects for different levels of crash severity. Some safety measures (e.g., road lighting and speed limits) have different percentage effects for crashes of different degrees of severity. For such measures, there will be different cost-effectiveness ratios for each level of crash severity. These different ratios cannot be compared without assigning weights to the different levels of crash severity. In cost-benefit analysis, such weights are assigned by means of the unit costs per crash or injury for each level of crash or injury severity.
- The cost-effectiveness criterion cannot be used to trade off safety against other policy objectives. The criterion does not say at what level of cost-effectiveness a measure becomes too expensive. Cost-effectiveness cannot, in other words, be used to determine the level of a safety programme that maximises welfare in an economic sense of that term.
- The cost-effectiveness criterion disregards the effects of safety measures on mobility and the environment. In practice, however, these effects are often important and in some cases decisive for the introduction of a certain measure.

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

2.3.3. *Performing cost-benefit analysis*

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

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

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

The benefit cost ratio is defined as:

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

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

The internal rate of return is defined as the interest rate that makes the net present value equal to zero. The internal rate of return is compared to some critical rate (e.g., a long-term market interest rate); if it is greater than this rate, then the project is 'good'.[1]

a. Estimate effectiveness of relevant safety measure in terms of the number of (target) 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 into campaign of a specific type.

b. Estimate indirect effects of the relevant measures on, e.g., mobility, noise and air pollution.

c. Estimate the costs of implementing one unit of the measures.

d. Estimate the benefits of relevant measures, including monetary value of reduced expected number of accidents and all other (indirect) effects of the measures.

e. Convert all costs of implementation and benefits to present time basis (or an annual basis) by discounting.

Box 2.5. *CBA of road safety measures.*

One of the greatest problems in cost-benefit analysis is to obtain valid and reliable monetary valuations of all relevant impacts. This objective is rarely, if ever, fully realised. It is therefore often relevant to carry out a cost-effectiveness analysis in addition to, or instead of, a cost-benefit analysis.

Cost-benefit analysis is particularly useful in those areas of policy making where:

- there are multiple policy objectives (e.g., both safety, environment and mobility);
- the objectives are partly conflicting (which is well-known in the case of safety or environment versus mobility);

[1] If our task is to choose among two or more mutually exclusive projects, then we should choose the one with the highest net present value. The cost-benefit ratio may be manipulated by changing classifications of costs and benefits, and thus alter the ranking of mutually exclusive projects, but changes in the calculated cost-benefit ratio will not affect a decision about whether the project is worthwhile. For a quick comparison of several projects of different sizes the cost-benefit ratio may be most handy, and in most applications this information will just be confirmed with the net present value. However, with only cost-benefit ratios the scale is lost – it doesn't show if the projects and net benefit are big or small. The internal rate of return shares the limitations mentioned for the cost-benefit ratio and adds another more serious limitation: the internal rate of return will identify correctly the 'desirable projects' only if the net benefit stream is 'conventional', that is, if net benefits start negative and then turn positive and stay positive. Notwithstanding, for most common applications the net present value, the benefit-cost ratio and the internal rate of return will provide the same result (Gramlich, 1994; Hanley & Spash, 1993; Hanley et al., 1997).

- the objectives refer to goods that do not have market prices (which actually is the case for aspects of both safety, environment and mobility).

It is perhaps useful to divide the application of CBA for road safety measures into 'maxi-CBA' and 'mini-CBA'. The maxi-CBAis to be understood as a complete analysis involving best available inputs and estimations of costs and benefits. The mini-CBA, on the other hand, would involve a simpler 'at the back of the envelope' estimation of main costs and benefits. Indeed the elaboration of CBA is not standardized in neither maxi nor mini -various circumstances and elements will govern the thoroughness of any scientific analysis. However, it may be helpful to regard mini-CBA as a relevant approach to preliminary assessments of road safety measures -isolated or within infrastructure development - or even at a regional/local level where resources are not available for elaborated analysis. For a mini-CBA one could apply known average values, both for effects and economic valuations, instead of going for the more elaborate estimation of case-specific effects and €. As part of the mini-CBA it can be possible to work with approximate data on the cost of measures, estimated from expert knowledge. A mini-CBA should be able to be executed within a few weeks or even days (Buck Consultants, 2002).

A maxi-CBA, on the contrary, should be more of a state-of-the-art analysis: it will be more complete (covering all relevant effects) and the estimations of costs and effects will make use of all available information, taking into account all circumstances of the case. This will be more time-consuming and costly then for a mini-CBA. It would serve as confirmation after a measure has passed the first selection phase. A maxi-CBA would be aspired at for the larger infrastructure and safety projects (EC, 1997; Nellthorp et al., 2001).

The methods and techniques for a maxi-CBA are well known from the literature and have been applied frequently. A standard for a mini-CBA still has to be developed. It is recommended that this method is tested in WP 4 in a number of cases; the results and experiences should be documented and disseminated by WP 5.

2.4. Valuation of impacts of road safety policy in CBA

2.4.1. *Valuation of safety impacts in CBA*

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

There are a few basic principles of valuation of non-marketed goods in cost-benefit analysis. Foremost among these is the principle that the valuation of a good should be based on the willingness-to-pay of the potential purchasers of the good. In order to estimate the willingness-to-pay for a non-marketed good (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 choose between various options that provide different amounts of the good. There is a host of methodological pitfalls in such SP studies. It would go beyond the scope of this chapter to discuss these difficulties in detail (Elvik, 1993; Kidholm, 1995; Schwab-Christe & Soguel, 1995; Mitchell & Carson, 1989).

Road crash costs represent an important item in cost-benefit analyses of road safety measures. In the early 1990s a detailed survey of practice in estimating road crash costs in EU countries and other countries was made by an international group of experts as part of the COST-research programme established by the European Union (Alfaro et al., 1994). The report contained recommendations with respect to the cost items that ought to be included in estimates of road crash costs and with respect to the methods for estimating the various cost items.

Five major cost items were identified:
1. medical costs;
2. costs of lost productive capacity (lost output);
3. valuation of lost quality of life (loss of welfare due to crashes);
4. costs of property damage;
5. administrative costs.

In addition one may include the cost of traffic delays (Elvik, 2004). The relative shares of these five elements will differ between fatalities and the various degrees of injuries, and it will also differ between countries' official valuations (Blaeij et al., 2004). As an average of all crash costs in Norway, based on registered crashes (also including crashes with no injury), it was estimated that lost quality of life represented 43%, lost productivity and property damage 22% each, administrative costs 10%, and medical costs (only) 4% (Elvik et al., 1997). These five major cost elements can be divided into two main groups. The first group includes cost items 1, 2, 4, and 5. The other group consists of cost item 3, the valuation of lost quality of life. Whereas market prices normally exist for the four former cost elements (although both labour prices and other cost elements in the health sector etc may be distorted), this is obviously not the case for the valuation of lost quality of life. It is only recently, which means during the latest ten or fifteen years, that any motorized country has tried to estimate the monetary value of lost quality of life. This has been accomplished by both RP methods, e.g., finding implicit valuation of crash risk in job choice related to salary (Viscusi and Aldy, 2003), and by SP methods whereby individuals have hypothetically chosen among options involving crash risks and payments/compensations (Persson, 2004). The other four cost items, that can be related to actual transactions in markets or public accounts, have been estimated in many motorized countries for a long time, starting in the 1950s in the United States, the United Kingdom and Sweden. Today, all the highly motorized countries try to estimate these costs, but the cost items included, and the methods used in estimating them, still differs between countries.

De Blaeij et al., (2004) present values of saved lives and limbs applied in various European countries.[2] They make a fundamental distinction between *behavioural methods*, founded on neo-classical theory whereby economic value is taken to be determined from the (actual or intended) behaviour of utility-maximising individuals, and *non-behavioural methods*. With the behavioural approach economic values are regarded as reflecting individuals' willingness to pay for specific quantities/qualities of market goods (given from prices) and public goods (estimated from RP or SP methods). Thus, the elements of society's total fatality/injury cost/value are based on market prices (property, labour), market-adjusted distorted prices (public hospitals, public administration), implicit willingness to pay revealed in adjacent/similar markets (fatality risk valued by 'safety consumption'/'risky jobs/activities'), or explicit willingness to pay stated in constructed markets (fatality risk valuation assessed by comparisons in surveys). Although not out-of-pocket money, the loss of life quality element visualises the fact that we are willing to pay something to reduce the risk of pain and grief caused by damage and death, beyond the costs of medical expenses and reduced income-earning ability. The behavioural approach basing value on willingness to pay is also advised by Nellthorp et al. (2001) in their valuation conventions for the EU project UNITE.
With a non-behavioural (non-neoclassical) approach nearly the same elements will enter the estimated costs of injury/fatality. However, these value elements are not necessarily taken to reflect individuals' willingness-to-pay. The included elements will rather reflect costs from the viewpoint of business (lost output / wealth creation and administration, e.g., insurance) and the public sector (medical costs and administration). With non-behavioural approaches values are normally taken (directly) from market prices (that may be distorted) and from public accounts. Individual-based valuation of lost quality of life is disregarded. It is rather intended to include further losses in wealth creation that is not reflected in the (labour) market, i.e., housework and 'black economy' activity (Höhnscheid, 1998). *Table 2.1* presents the current official values for the prevention of fatalities and injuries.

Country	Fatality cost	Serious injury cost	Slight injury cost	Valuation method[a]
Czech Republic	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] Bahavioural methods are founded on neo-classical theory, while non-behavioural are not.

Table 2.1. *Official values of prevented fatalities/injuries (€ 1000); 2002-prices (Sources: Blaeij et al.,2004; Koňárek, 2004; Holló, 2004; Höhnscheid, 1998; DTT, 2004; Metsäranta & Kallioinen, 2004; Elvik, 2004).*

[2] The study by Blaeij et al. (2004) is fruit of a sub-contract to the Vrije Universiteit Amsterdam under Workpackage 2 (WP 2) of the Thematic Network ROSEBUD.

As can be seen from *Table 2.1*, the official injury and fatality do vary between the sampled countries. Comparing Germany with other North-Western-European countries, those applying behavioural methods give larger economic weight to crash risk reductions. Lost quality of life, i.e., the welfare loss (that is not tangible from direct transactions in markets or from public spending) represents the domineering share in the values/costs reported from the countries that apply behavioural methods. It typically varies between 50% and 90% of total value.

Looking only at fatality valuation, Sælensminde (2001; 2003) performed a literature study of official economic valuations of a traffic crash fatality in several countries, mostly from the OECD area (including the countries presented in Blaeij et al., 2004). Adding values from the Czech Republic (Koňárek 2004) and applying the values from Blaeij et al. (2004), *Figure 2.3* shows official economic valuations in € 2002-prices from 23 countries.

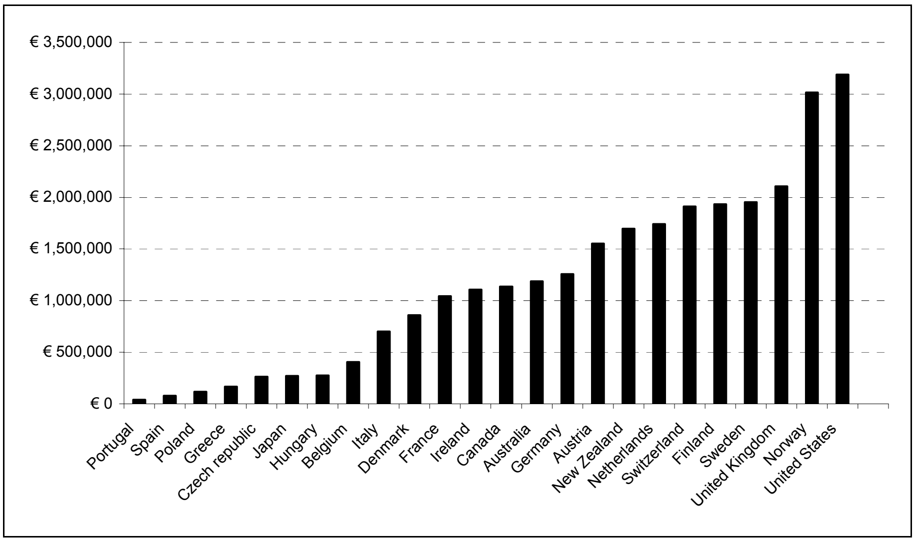

Figure 2.3. *Official monetary valuation of the prevention of a road crash fatality in € at 2002-prices in 23 countries (Sources: Sælensminde,2001; 2003; Blaeij et al., 2004; Elvik,2004; Koňárek, 2004; DTT, 2004; Metsäranta & Kallioinen, 2004. Sælensminde transformed values in local currencies to 1999-€ (and 1999-USD), and these estimates have been multiplied with a CPI of 1.065 to obtain a 2002-€ estimate. Blaeij et al. provide values in 2002-€ (see Table 1). It should also be noted that these various national values are not of identical date, thus some of these (especially those in the lower end) may have been fundamentally revised).*

The five countries with highest fatality valuation, including Norway, UK and Sweden, all apply behavioural valuation methods with willingness-to-pay based values. As indicated, Germany applies a non-behavioural approach. E.g., Italy applies another non-behavioural approach using court-based indemnities to set the monetary values. The Southern European countries with lowest fatality valuations base their numbers on insurance payments (Sælensminde, 2001, 2003), but it has not been ascertained if some of these countries have changed their valuation approach recently. A change from non-behavioural to behavioural approach, with an increased weight on individuals' own expressed valuation of quality of life, will most probably lead to increased estimates. When road crash costs were revised in Norway in the early nineties, including a valuation of lost quality of life in the crash costs, the cost of a fatality was quintupled (Elvik, 1993).

Although basically 'a € is a €' in any country, what a € can buy does differ. Those countries with high valuations also tend to be high-cost countries. A way to provide figures that take relative cost levels into account is to apply a purchase-power-parity (PPP) indicator to adjust the '€ from exchange rates' approach in *Figure 2.3*. *Figure 2.4* shows the same official monetary valuation of the prevention of a road crash fatality where the € at 2002-prices are PPP-adjusted.

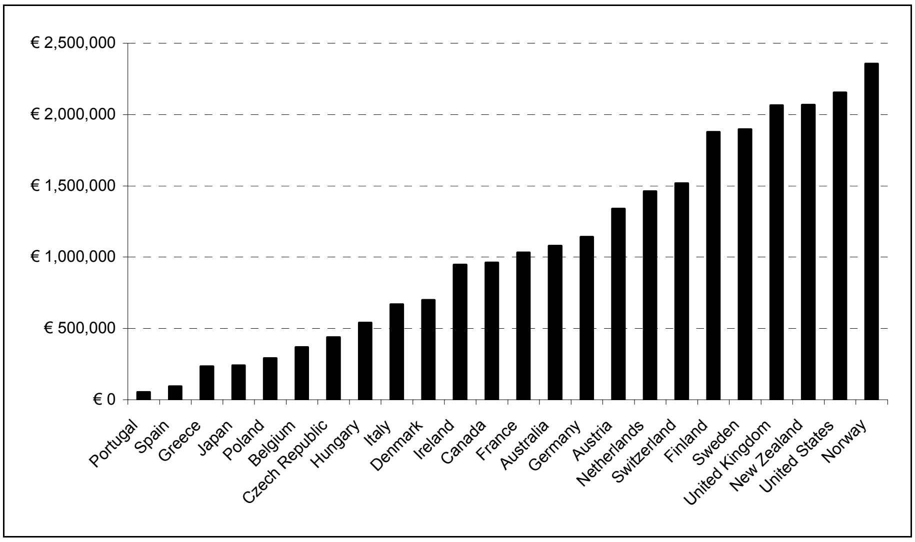

Figure 2.4. *Official monetary valuation of the prevention of a road crash fatality in 23 countries, € at 2002-prices adjusted to purchasing power parity (PPP) (Sources: Sælensminde, 2001; 2003; Blaeij et al., 2004; Elvik, 2004; Koňárek, 2004; DTT, 2004; Metsäranta & Kallioinen, 2004).*

Actually, the PPP-adjustment generally closes the gap between countries with high fatality valuations and those with lower. However, the ranking from highest to lowest is only slightly affected.

2.4.2. *Valuation of time in CBA*

As far as the valuation of other impacts of measures is concerned, a distinction should principally be made between measures that affect travel demand (traffic volume) and measures that do not affect travel demand (see Appendix). In what follows, we will disregard effects on travel demand, which implicitly assumes that the safety measure under consideration does not affect travel demand.

However, although (overall) travel demand is not affected, mobility and travel time may well be altered by road safety measures. The value of time use is to a certain extent difficult to estimate. Except for wage rates mirroring time costs in labour (and other time costs from business), there is no market value of the time for commuting and time spent travelling to leisure activities. Still, the estimated time values for non-work (non-business) travel may weigh heavily in the benefit component in a CBA of infrastructure improvement, or in the cost component of road safety measures that reduce mobility. As indicated, time has been valued according to an opportunity cost approach, whereby the individuals are assumed to value time according to what they could earn by working an additional unit of time (that is, according to their wage rate). Additionally one could also consider a disutility cost, a willingness to pay to reduce the discomfort and boredom in travelling, a disutility generally increasing by trip length (Blaeij et al., 2004). The complicating issues arise from both the assumption of how individuals perceive the opportunity cost of time, which is at least partly related to the trip purpose, if it is business, commuting or recreational travel. Disutility aspects may also be related to trip purpose, as well as transportation mode and other issues. The official costs/values for the use of time in various European countries have also been summarized by Blaeij et al. (2004), presented in *Table 2.2.*

Country	Working	Non-working		Valuation method[b]
	Business	Commuting	Others	
Germany	4.12	4.12	4.12	Non-behavioural
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 50 km) 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.

Table 2.2 *Official values of reduced time use (€). 2002-prices (Sources: Blaeij et al., 2004; DTT, 2004; Metsäranta & Kallioinen, 2004).*

In the sampled countries the share of non-working time value to working time value differ between approximately ½ in the US and approximately 15% (average of 'commuting' and 'others') in Switzerland.

2.4.3. *Valuation of pollution and noise in CBA*

Official costs/values for pollution hardly exist in Europe. Currently, only Sweden and Germany have official values for air pollution (and noise and climate change). In Table 2.3, the presented values of some air pollutants from transport in various European countries are therefore mostly recommended values (Blaeij et al., 2004).

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.

Table 2.3. *Official and recommended values of reduced air pollution (€ per Kg). 2002-prices (Sources: Tables 4.3.1 and 4.3.2 in Blaeij et al., 2004; DTT, 2004).*

A specific complication for the valuation of pollution is the assessment of effects on individuals, i.e., the need for establishing dose-response relationships (how many are affected, how much, and with what type of consequences). Air pollution effects will to some extent be intangible for individuals - they must be informed about effects to be able to value any reduction. Some of the negative effects manifest themselves only on a long-term scale. Obviously, the value per kg emission must be adjusted according to some scale that indicates how many are affected (rural or city, etc). Alternatively (with better dose-response functions), a value/cost of air pollution -as for noise- could be given according to numbers affected and level of exposure.

For noise valuation different units of measurement makes comparison between countries somewhat more tedious (Blaeij et al., 2004; Navrud 2002). Three main approaches are either € per dB(A) or per X% (e.g., 20% or 50%) change per person affected/annoyed ('highly annoyed' plus 'somewhat annoyed') per year, or the percentage change in house prices per dB(A). The first valuation approaches are based on SP methods, while the house price approach is based on a RP method (hedonic pricing). Only changes above some threshold level, normally 50 or 55 dB(A), is valued. Values of noise reductions can also be stated in terms of reduced vehicle km. This may provide an easier computing of economic effects from altered noise effects due to infrastructure/safety measures (Elvik 1999). *Table 2.4* provides noise values from some European countries.

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			04-1.1%
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 50 dB(A) from a starting point of 51 dB(A) has a value of €16, and a reduction from 75 dB(A) to 50 dB(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.

Table 2.4. *Recommended values of reduced noise. € 2002-prices (Sources: Blaeij et al., 2004; Navrud, 2002; Elvik, 1999; DTT, 2004; Metsäranta & Kallioinen, 2004).*

2.4.4. *Including 'all' relevant impacts of road safety policy in CBA*

Various aspects of transport, not only road safety, are complicated to value. We may be fairly certain that individuals trade-off such aspects and effects, also against money, but getting 'the right values for the right levels' still pose challenges. But, rather than digging further into alternative approaches from the literature, we will provide an overall set of illustrative valuations of impacts to be included in cost-benefit analyses. The valuations given in *Table 2.5* are based on Elvik (1998, 2004) and Mysen et al. (1998).

Main impact	Subcategories	Vehicle type, road user etc.	Unit of valuation	Value per unit (€-2002)
Safety	Road crashes	All (estimated real cases of injury	Fatality	3,015,988
			Serious injury	474,403
			Slight injury	41,421
Mobility	Travel time	Pedestrian	Person/hour	11.36
		Cyclist	Person/hour	9.19
		Car occupant	Person/hour	7.47
		Bus passenger	Person/hour	5.45
Travel cost	Vehicle operating cost	Car	Km/travel	0.13
		Single truck	Km/travel	0.35
		Truck/trailer	Km/travel	0.51
		Bus	Km/travel	0.62
Environment (urban)	Traffic noise	Small cars	Km/travel	0.02
		Heavy cars	Km/travel	0.18
	Air pollution	CO_2	1000 kg of CO_2	58
		NO_x	Kg of NO_x	10.27
		VOC	Kg of VOC	10.27
		SO_2	Kg of SO_2	10.90
		PM_{10}	Kg of PM_{10}	265

Table 2.5*. Valuation of impacts for use in cost-benefit analysis. € 2002-prices (Source: Elvik, 1999, 2004).*

Regarding the safety values in *Table 2.5* in Norway the injury classes would also comprise 'critical injury'. Elvik (1999, 2004) also provides alternative (higher) cost estimates per police reported case adjusted for incomplete crash reporting. More detailed estimates have been made for various road user groups (Elvik 1998), according to which the mean cost of an injury crash is lower for cyclists than for motorists. The cost of a pedestrian crash is, however, higher than the cost of an crash involving motor vehicles only. *Table 2.5* provides an alternative time valuation, compared to Table 2.5, with a split on transportation mode (instead of trip purpose). The values of travel time for pedestrians and cyclists are preliminary estimates based on the WALCYNG-project (Stangeby, 1997). Also travel costs per vehicle type are included in *Table 2.5*. The air pollution costs in *Table 2.5* represent the upper values of the intervals given in *Table 2.3* relevant for urban areas. Although extensive, this list of valuations which has been used in cost-benefit analyses in Norway, is far from complete. It does not include a valuation of insecurity or other elements of costs for pedestrians and cyclists. Further, values of travel time and vehicle-operating costs for mopeds and motorcycles are not included in *Table 2.5*.

It should be noted some safety measures, especially those that enhance bicycling or restrain car driving, simultaneously imply environmental improvements (Sælensminde 2002). However, one may also find some safety measures that may have adverse environmental effects, e.g., road salting (Amundsen and Kolbenstvedt, 2003).

The effects on land use and business development of improving road infrastructure represent a topic of long-standing controversy (Gramlich, 1994). The current majority opinion among economists is that what is often termed 'regional impacts' are captured by the change in consumers' surplus for induced traffic attributable to road improvements (see appendix). Hence, to add to this a valuation of growth in employment or the creation of new firms would constitute double counting of benefits. In the same way, one could argue that the benefits to shopkeepers of creating pedestrian streets is included in the generalized costs of walking, at least to the extent that a drop in these costs fully reflects the benefits to pedestrians of getting rid of cars.[3]

2.5. Uncertainty

There are numerous sources of uncertainty in the estimated effects of road safety programmes. Elvik & Amundsen (2000) 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.

At the current state of knowledge it is not possible to meaningfully quantify all these sources of uncertainty. Following a discussion of each source of uncertainty, Elvik & Amundsen (2000) conclude the following with respect to the possibility of quantifying the sources:

[3] An issue that we have leaped is the valuation at consumer prices (the 'quality of life' part of fatality/injury costs, non-working time costs and some environmental costs) versus the valuation at factor prices (infrastructure and operating costs, working time costs, the transaction parts of fatality/injury costs). Nellthorp et al. (2001) provide adjustments to put all CBA items in factor cost units, simply by dividing the consumer prices by $(1+\tau)$, where τ is the indirect taxation of consumer expenditures.

Source of uncertainty	Possibility of qualification
1. Which crashes or injuries are affected	In principle, quantification is possible; in practice this is rarely considered
2. Random variation in count of crashes or injuries	Can easily be quantified by relying on the Poisson probability law
3. Incomplete crash reporting	In principle quantification is possible; in practice it is usually disregarded
4. Random variation in effects of road safety measures	Can be quantified by relying on confidence intervals for estimates of effect
5. Unknown systematic variation in effects of road safety measures	As long the sources of systematic variation remain unknown, it is difficult to account for them
6. Modification of effects when several road safety measures are combined	Too little is known about it to quantify this source of uncertainty
7. Uncertain monetary valuation of road safety	Part of the uncertainty can be quantified; part of it is not of a statistical nature
8. Uncertain duration of effects	Very difficult to quantify at the current state of knowledge

In traditional normative decision theory, a distinction is made between four cases, depending on how well known the potential consequences of a decision are:

- decisions under certainty: all consequences are known with certainty;
- decisions under risk: all consequences are known and their probability of occurrence can be estimated;
- decisions under uncertainty: all consequences are known, but their probability of occurrence is unknown;
- decisions under ignorance: not all consequences are known, nor can their probabilities of occurrence be estimated.

Decisions made about road safety measures represent a mixed case. Some of the consequences of these decisions are fairly well known, others are less well known, and some may not be known at all. This means that it is rather difficult to adequately describe the uncertainty inherent in such decisions.One rarely sees any attempt to discuss, let alone quantify uncertainty, in formal efficiency assessment. This is regrettable. In some cases, uncertainty will be so great that it ought to be considered explicitly when decisions are made.

Consider, as an example, the following two road safety measures:

Measure A	Measure B
Best estimate of benefit cost-ratio: 2.0	Best estimate of cost-benefit ratio: 1.5
95% prediction interval for cost-benefit ratio: 0.5-3.5	95% prediction interval for cost benefit ratio: 1.2-1.8

In this case, a decision maker disregarding uncertainty would opt for measure A. A decision maker who considered uncertainty might want to prefer measure B, since it gives an assurance that benefits will be greater than costs. In that case, an explicit consideration of uncertainty would lead to a different choice from that based strictly on the best estimate of the cost-benefit ratio.

Following this example, a practical way to deal with uncertainties is to present/construct three scenarios: A 'golden mean' 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.

2.6. Equity aspects of CBA-based road safety policy

It is often held that efficiency-based policies, applying CBA and the potential Pareto criterion, will have adverse effects on equity. So what about equity effects of CBA-promoted policies that affect road safety? Is it relevant to expect that the implementation of economically efficient safety measures will involve any alteration of distribution and rights? Many of those vociferous in media and public opinion try to limit the equity issue to a claimed unfairness of any policy affecting a more or less erroneously identified group (car drivers, outskirts, business). Most economists seemingly limit the issue to the distribution of wealth or income. Also for equity related to safety policies, it is deemed necessary to assess if some equity aspects are more important than others. We will shortly discuss the following equity aspects:
- basic institutional and legal equity;
- distributional equity;
- 'equity-masked privileges'.

Basic institutional and legal equity principles should be assessed first. Boulding (1978) terms 'equal treatment for equal cases' the fundamental principle of equity. The well-known 'equality before the law' is closely related to this fundamental principle. But, also the 'polluter-pays-principle' applied in environmental policy may be related to this fundamental equity: Everybody is equally responsible for both direct and indirect (external) effects of behaviour and consumption, and should pay the full cost of it, be it bread, or use of infrastructure. There is an analogy to road safety, in that the basic equality right must be related to everybody’s fundamental right to life and limb (that trump the right to mobility). And if road safety measures imply costs to car drivers or other road users, it seems equitably correct according to the principle that those who cause the cost should pay for it. Thus far, the economic efficiency criterion (consumers pay a given price set from marginal demand/benefit and marginal supply/cost – paying provided that benefits exceed costs) may not be in conflict with basic fairness (that those who cause a threat to basic right should, indiscriminately, be responsible for restoring the seized right).

Rawls (1973) would probably see the basic equity aspects as 'distribution of primary goods' (political conditions and principal economic and social institutions). However, the distributional equity focussed by economists have especially been related to effects on the distribution of utility or resources, say, income. In standard CBA benefits and costs are calculated without regard to the resulting distribution and without attempting to include different marginal utility of income between individuals or households or segments (it is set equal for all). However, the social desirability of a policy (the calculated net present value) could clearly be affected by a different approach to weighing individual gains and losses (Halvorsen, 2002). One could imagine that a road safety measure had adverse effects on income distribution. E.g., the wealthiest could be better off with the measure ('winners') -paying relatively little (in fees, time loss, etc) for a highly valued public good (safety), while the poorest could be worse off- paying relatively much for a not so highly valued good. Still, for safety one could also very well consider another type of distribution -the distribution of risk, e.g., to which extent risk is equally distributed between transport modes and how economically efficient safety policies may affect this distribution.

It is not obvious that any claim of unfair effects of a (road safety) policy merits to be considered among the equity effects. Implementation of some (road safety) policies may alter distribution in such a way that the basic equity aspects are re-established. Thus, the claimed unfairness may in some cases be denoted a defence of an 'equity-masked privilege'. Based on the principle that economic values and prices should reflect all economic impacts, generally implying that external effects should be internalized in the price ('the polluter pays principle'), it can be asserted that also road users should pay for the external effects they may cause on safety, environment and congestion in the infrastructure. An equity assessment should involve some ranking of what is most important. Losing the privilege to have road pricing equal to zero, or to buy fuel at a price that does not internalize environmental effects, or to avoid a fee (or other punishment) for dangerous driving may not be ranked higher than gaining the rights to cleaner air, reduced noise, or safer transport.

Neo-classical economics, which holds the theoretical fundament of CBA, has confined itself with the potential Pareto principle, pushing the issue about implications on basic rights and income out of the analysis. Yet, economists are free to at least include a registration of equity effects in the CBA.

2.7. Conclusions

In this chapter we have sketched the two main methods among efficiency assessment tools, cost-effectiveness analysis (CEA) and cost-benefit analysis (CBA). We provided an overview of the theoretical principles, the technical framework for the application of these methods and we entered into details on the valuation of all impacts of road safety measures: safety, travel time, pollution and noise. The chapter is rounded off with a discussion on uncertainties and equity aspects.

The sections on the theoretical principles and the technical framework of CBA and CEA reflect generally held views among economists, founded in neo-classical welfare economics. Since CBA is the most complex and extensive of the two, we have provided some extra sections on the additional items and challenges in CBA. While CEA is limited to somewhat one-dimensional cost calculations of a given measure, CBA should principally embrace benefits and costs of all direct and indirect impacts, on both market goods and non-market goods. CBA fundamentally requires a behavioural approach, founded in neo-classical economics where economic value rests on individuals' willingness to pay. CBA forces the decision makers (households, civil servants, politicians) to face the tough trade-off between mobility, travel costs, environment and safety. Its legitimacy is well founded in people's own preferences and choices. Therein lays the efficiency argument itself, and this argument alone may actually conduce towards much higher road safety efforts (Elvik, 2003). Theoretical consistency therefore requires that the valuation of safety and eventual side impacts of road safety measures will be based on individuals' willingness to pay or so-called behavioural methods. Recent developments show that these methods are accepted and applied by more and more countries. It is hoped that this development will continue. The international comparability of values would be improved as well, although in this case equal values are not guaranteed by uniformity of methods between countries. On the contrary, it is to be expected that application of the same method will produce different values in each country. As a consequence it will not make sense to strive after European values.

The issues of uncertainties and equity aspects are generally acknowledged. But at the same time it is acknowledged that neo-classical welfare economics does not provide theoretically sound solutions for these problems. Nevertheless it is generally felt that they should be considered explicitly.
A sensitivity type of analysis with scenarios (optimistic, realistic, pessimistic) could be performed in order to handle uncertainties.
Equity refers to the distribution of costs and/or benefits among the various groups that are affected by the measure (e.g. which income or risk groups are going to pay for the implementation costs and which will receive the safety benefits). At the least these distributional effects should be described carefully, including the distribution of wealth or risks among these groups at the outset. Neo-classical theory offers no solution to integrate this information in the CBA so they are left to the discretionary power of the decision maker.

3. Knowledge and data

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3.1. Introduction

This chapter deals with knowledge and data elements, which are required in order to perform an efficiency assessment (CBA/ CEA) of a safety-related measure. In order to estimate the cost-effectiveness of a road safety measure, basically, two information elements are needed (e.g. Elvik, 1997a):

1. an estimate of the effectiveness of the safety measure in terms of the number of crashes (injuries, fatalities) it can be expected to prevent;
2. an estimate of the implementation costs of the measure.

The number of crashes the measure is expected to prevent, is a function of the number of crashes affected at the treated site (area, population) and the safety effect of the treatment. The crashes affected by a safety measure present a target crash group[4]. The safety effect of a treatment is defined as the expected reduction in target crashes following the implementation of the treatment. The effect is usually given in the form of a percentage (e.g. Elvik et al, 1997; Ogden, 1996).

If a cost-benefit analysis is applied, then, besides the above components, the monetary values of the measures benefits are also required. The monetary values imply, first of all, crash costs and, depending on the range of other effects considered, may also include costs of travel time, vehicle operating costs, costs of air pollution, costs of traffic noise, etc. Besides, in order to make the costs and benefits comparable (as well as for a comparison of different measures), a conversion of the values to a certain time reference is required. Such an action needs a definition of the economic frame, i.e. a number of information elements (life span, discount rate, etc), which are common for the performance of economic estimates. The monetary values of crashes and the economic parameters, which are recommended for the efficiency assessment of safety-related measures, are discussed in *Chapter 2*.

The data and knowledge components of CBA/CEA to be discussed in this chapter are:

- safety effects of measures;
- number of crashes affected by measures;
- implementation costs of measures;
- side-effects.

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[4] Depending on the type of safety measure it can also be a target injury group, target driver population, etc. Further discussion in this chapter will be in terms of *crashes* whereas, depending on safety measures considered, the interpretation can be in different forms of crash units, e.g. injuries, drivers involved, vehicles involved, etc.

3.2. **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 is the evaluation studies, which accompanied the treatments in the past.

The most common form of a safety effect is the percentage of crash reduction following the treatment (sometimes, it is also called the crash reduction factor). The quality of the efficiency assessment of a safety measure (i.e. a prediction of the crash reduction 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 there exist data (values of crash reduction factors) relative to the type of measure considered, applied on a certain type of sites?
- validity of data: were the effect values estimated properly, i.e. accounting for confounding factors that may have influenced the results measured?
- variability of the effect: having a range of results for similar treatments, what is the best estimate of the effect to be applied?
- 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 changes, depending on traffic volumes?

3.2.1. *Availability of values*

The safety effect of a measure is available if the estimates of both the average value and the confidence interval of the effect are known. The statement is relevant, where both the type of measure and the type of sites for which the estimates are available, correspond to those for which the CBA/CEA is performed.

One should remember that both in the case of a single evaluation of a safety effect and in searching for values available, it is important to provide a proper definition for each measure, the safety effect of which is estimated. Pure presentation of safety effects is not sufficient for practical purposes; a precise description of intervention should accompany any published value of the safety effect (Workshop, 2004).

The main source of evidence on safety effects is the observational before-and-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 (WP 1, 2003). Those, mostly, provide theoretical values of the effects based on known relationships between risk factors and crashes.

The structure of safety measures can be presented as follows (WP 1, 2003):

- user-related measures (training and education; traffic law; incentives and enforcement);
- vehicle-related measures (active safety, passive safety, telematics);

– infrastructure-related measures (road design; road construction; maintenance);
– organization (planning; financing; controlling);
– rescue services (alert, rescue).

Screening the results of the evaluation studies reviewed (WP 1, 2003) revealed that, in most cases (groups 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 crashes are less direct, permitting, at times, only qualitative evaluations.

For group 2, in the case of passive safety (e.g. use of seatbelts or airbags), the effects of the measures can be quantified by means of statistical observation of reality. In general, as in 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 effect 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 crash 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, 1997a):
– to document the effects based on a meta-analysis;
– to document the effects based on traditional literature surveys;
– to provide for theoretical effects based on known relationships between risk factors and crashes.

a. The effects based on meta-analysis

The recommended way to summarize the results of studies is by means of a qualitative meta-analysis. The technique provides both the weighted estimate of the mean effect and a confidence interval for the estimate (a 95% confidence interval is common). The meta-analyses of the evaluation studies served as a firm basis for the Norwegian Traffic Safety Handbook (Elvik et al., 1997), which is known today as the most comprehensive and reliable source of international experience on this issue. The illustrations of the technique and the results of the analyses can be found in papers, e.g. Elvik (1995), Elvik (1997), Elvik (2001).

In the Norwegian Handbook, the treatments are arranged in 124 groups, which concern road and traffic conditions, vehicle improvements, road users' behaviour, organizational measures, etc. Within each group, estimates are presented for several treatment subtypes, various conditions, and target crash groups. *Tables 3.1* and *3.2* present some examples of safety effects associated with police enforcement.

Injury level	Per cent change in number of crashes		
	Crash types affected	Best estimate	95% confidence interval
All	All types of crashes	-2	(-4;-1)
Fatal crashes	All types of crashes	-14	(-20;-8)
Injury crashes	All types of crashes	-6	(-9;-4)
Material-damage-only (MDO) crashes	All types of crashes	+1	(-1;+3)

Table 3.1. *Best estimates of the effects on crashes of manual/stationary speed enforcement.(Examples of safety effects based on meta-analysis) (Source: Elvik et al., 1997; Table 8.1.3 (based on 17 references).*

Injury level	Per cent change in number of crashes		
	Crash types affected	Best estimate	95% confidence interval
Controls of alcohol concentration in the blood			
All	All	-3.7	(-4.2;-3.2)
Fatal crashes	All	-9	(-11;-6)
Injury crashes	All	-7.1	(-7.6;-6.6)
Fatal and injury crashes	Night-time/ single crashes	-7	(-9;-5)
Fatal and injury crashes	Daytime crashes	-12	(15;-9)
All	Crashes in urban areas	-3	(-4;-2)
All	Crashes in rural areas	-2.6	(-4.5;-0.6)
All	Pedestrian crashes	0	(-3;+2)
Driver license suspension only			
All	All	-18	(-19;-16)
Treatment / rehabilitation as an alternative to driver license suspension			
All	All	+28	(+21;+36)
Injury crashes	All	+15	(-1;+35)
Material-damage-only crashes	All	+41	(+18;+70)
Treatment only			
All	Alcohol related crashes	-27	(-86;+274)
Penalty, driver license suspension, imprisonment (collective effect)			
All	All	-4	(-5;-3)
Changing punishment: From imprisonment to fine			
All	All	-4	(-5;-3)
Fatal crashes	All	-19	(-24;-14)
Injury crashes	All	-3	(-4;-2)

Table 3.2. *Effects on crashes of drink-driving enforcement, driver license suspension, sunctions/ punishment and treatment/ rehabilitation measures. (Examples of safety effects based on meta-analysis). (Source: Elvik et al., 1997; Table 8.4.1 (based on 39 references).*

b. The effects based on traditional literature surveys

For safety measures, for which the results of meta-analysis are not yet available, the evidence of safety effects can be attained by a traditional literature survey. Such a survey can also be devoted to results observed in a specific region or at certain groups of sites, which sometimes, enables a more detailed consideration of the effect values and, as a result, better fitting of the available knowledge to the cases considered for CBA/CEA.
Some examples of reviews of safety effects on road infrastructure improvements are:

- Travers Morgan (1992): a review of more than 200 studies from Australia, US, and other countries, with a detailed classification of treatments and crash groups considered. A range of safety effect values was produced for each treatment type;
- Ogden (1994), Ogden (1996) provide a summary of effectiveness of traffic engineering measures as appears in the Australian literature. Another summary of values recommended for application is given in RTA (1995) but this time in the form of series of values associated with different crash types (as defined by the local crash codes).

One should remember that, similar to the meta-analysis, a systematic consideration of safety effects within a literature survey also requires a definition of treatment types, sites (areas, populations) of treatment and target crash groups. For example, in an Israeli study of safety effects of road infrastructure improvements (Gitelman et al., 2001), a literature survey of the effects was carried out. To develop summary values of the effects, a database was established which classified the treatment categories and demonstrated the estimates from different literature sources. Using this database, summary values were developed for each treatment category or for a group of categories. In total, some 250 values of safety effects for infrastructure improvements were provided and served as a 'default' input to CBA. The summary safety effects were subdivided into two sets, for 'rural' and 'urban' areas, whereas the measures considered are further subdivided into 'junction' and 'section' treatments, and then into topic subgroups, e.g. 'cross-section', 'medians', 'roadside hazards', 'marking and signing', etc. Such a structure of the database enables the measures to be easily identified, in accordance with the type of site considered. Examples of the values are given in *Table 3.3.*

Subgroup of treatments Treatment type (Area[1)])	Safety effect – percent change in total injury crashes
Junction	
Introducing traffic signals* (All)	-20
Minor realignment (All)	-15
Improved visibility conditions (All)	-3
Introducing stop signs* (All)	-30
Cross-section profile	
Passing lanes for heavy vehicles (R)	-20
Widening lanes (All)	-25
Constructing shoulders (R)	-20
Major realignment (R)	-30
Upgrading road in densely populated area (U)	-7
Road-side hazards	
Attenuaters on fixed objects (R)	-69
Road side safety barriers (R)	-40
Removing obstacles (R)	-20
Medians	
Installation of barriers** (R)	-6
Widening median (R)	-15
Introducing median (R)	-4
Introducing median*** (U)	-7
Marking and signing	
Rumble strip on shoulders (R)	-15
Raised pavement marking (R)	-15
General improvement (U)	-25
Raised marking of dividing line (U)	-10
Traffic calming (U)	
Road humps	-48
30 km/h speed limit zone	-27
Residential yard	-25
Pedestrians (U)	
Pedestrian fences	-20
Refuge at pedestrian crossing	-15

[1] R – rural area, U – urban area, All – both areas
There are separate values for: *different junction conditions, **different barrier types, and ***different road types

Table 3.3. *Summary values of safety effects of road infrastructure improvements. (Examples of values coming from a traditional literature survey*) *(Source: Gitelman, Hakkert et al (2001)*

For each safety measure, for which effects are based on traditional literature surveys, a judgmental confidence interval (not based on statistical estimation) is still recommended, because it is essential for a sensitivity analysis of the CBA/CEA results. Such an interval is based on the range of results obtained in the evaluation studies or is intended to encompass the range of most of the values.

The aggregated values of safety effects, which are suitable for global estimates, can be found in publications on large-scale safety programs. For example, *Table 3.4*, which is reproduced from Elvik (1997a), provides estimates for the most applicable safety measures as these were considered for the Dutch road safety plan. (To be accurate we should mention that part of the values in *Table 3.4* came from meta-analyses of evaluation studies.)

Screening the results of the evaluation studies revealed (WP 1, 2003) that comprehensive efficiency analyses of large numbers of road safety measures were carried out in the USA, Switzerland, Norway, and Sweden. For the USA, Tengs et al. (1995) estimated the cost-effectiveness of five hundred interventions, based on a comprehensive literature search; in the Swiss road safety programme VESIPO (VESIPO, 2002), 77 road safety measures were assessed; recent analyses of the cost-effective road safety policies for Norway and Sweden referred to 132 and 139 measures, accordingly (Elvik, 2001a; Elvik, 2003). It is reasonable to expect that in each project, the safety effect values were estimated for the safety measures considered and these databases can be of help for future applications by CBA/CEA experts.

A recent publication by ETSC (2003) gives examples of the application of focused literature surveys to provide for safety effects of the measures considered. For instance, considering the effects of compulsory Daytime Running Lights (DRL) in the EU, two meta-analysis studies were available: a study by SWOV (Koornstra et al, 1997) and a study by TØI (Elvik, 1996). The TØI-study concluded that the DRLs introduction would lead to a 10%-15% reduction in the number of multiparty daytime crashes, whereas the SWOV-study expected a 12.4% reduction. The latter found furthermore that the amount of injured persons decreased by 20%, and that the effect on fatalities would be even higher – a 24.6% reduction. The ETSC (2003) took a conservative approach by assuming the effect of DRL on fatalities to be 20%.

Measure	Area of application	Percent change in number of target injury accidents		
		Lower 95%	Best estimate	Upper 95%
Cycle lanes	Urban arterial roads	-35	-30	-25
Roundabouts	Three arm junctions	-40	-30	-20
	Four arm junctions	-50	-40	-30
Blackspot treatment	Each blackspot	-40	-30	-20
Truck lanes	Rural multilane roads	-30	-20	-10
New road lighting	All unlit roads	-33	-30	-25
Upgrading road lighting	Lit roads	-25	-15	-5
Shoulder rumble strips	Rural roads	-45	-25	-5
More 30 km/h zones	Urban access roads	-30	-25	-20
Reduced speed limit	80 km/h to 60 km/h	-25	-20	-15
Junction speed limit	80 km/h to 60 km/h	-30	-25	-20
Speed reduction at pedestrian crossings	Pedestrian crossings on busy roads	-60	-33	0
Ugrading pedestrian crossings	Application of refuges and fences	-25	-15	-5
Mopeds off cycle tracks	Prohibition	-60	-50	-40
Daytime running lights	Law requiring use (*)	-15	-12	-10
High mounted brake lights	Law requiring use (*)	-15	-12	-10
Driver side airbags	Law requiring use (*)	-30	-25	-20
Rear seat belts	Law requiring use (*)	-40	-25	-10
Speed limiters on mopeds	Law requiring use (*)	-20	-15	-5
Child pedestrian training	Training of 6-12 year old children	-25	-15	-5
Increased speed enforcement	Doubling	-10	-5	0
	Trebling	-15	-10	-5
Extending speed cameras	All roads	-25	-20	-15

(*) Estimate refers to intrinsic effect of meaure (effect for each car/user)

Table 3.4. S*afety effects of measures considered for the Dutch road safety plan.* (*Examples of values coming from a traditional literature survey and from meta-analyses).(Source: Elvik, 1997a).*

Theoretical effects

In the case of measures for which no previous evaluation studies are available, the estimate of the expected safety effect must be *hypothetical*. This concerns, for example, the effectiveness of speed limiters in cars. Such devices have not yet been introduced on a wide scale. Their actual safety effects are therefore unknown. Predictions of reductions of crash occurrences can be made on the basis of the effects estimated in speed simulation, utilising the mathematical relationships between speed change and change in crash frequency (Carsten & Tate, 2000).

The empirical relationships between travelling speeds and crashes were established in many studies. One of them, which is widely applied in evaluation studies in the UK, was stated by Finch et al (1994). Finch et al summarized the crash changes associated with the changes in actual travel speeds in different countries (Finland, Denmark, Sweden, Germany, Switzerland, USA) and suggested that an increase (decrease) of 1 kph in average speeds is associated with an increase (decrease) of 3% in injury crashes. Such a 'rule of thumb' served for example for predictions of safety effects associated with new forms of speed humps.

According to the Australian experience, there are examples of evaluation of the potential safety effects from structural improvements in cars. For example, Fildes et al (1995) estimated the likely benefits if Australia were to adopt a new dynamic side-impact regulation for cars. The likely benefits were estimated based on harm reduction analysis. A systematic building block approach was used, which permitted a body region by contact source analysis of benefits, following adoption of the regulations.

The likely body region outcome associated with the new standard was estimated using the test data from USA and European experts' opinions. The calculation of benefits was performed for various body regions and seating positions. The injury reduction analysis was based on trauma patterns provided by the Crash Injury File. The latter was developed in 1991, based on a detailed examination of over 500 real world crashes with results, which were then adjusted to the Australia-wide database.

In a similar way, Fildes, Gigges & Dyte (1997) estimated the potential effect of a new dynamic frontal offset standard for car crash tests. The benefits were estimated based on harm reduction analysis. First, the injury reductions were estimated by an international expert panel of vehicle manufacturers, researchers, and government agencies. In this case, the benefits were expected to be from three sources: a general improvement in structural integrity of cars, a greater use of driver side airbag, and from specific countermeasures to address particular injuries. (A reduction in frontal harm was expected to be of 15%-23%). In the second step, a previously developed National Harm Database was applied. The database provided the estimates of the total annual harm for passenger car occupants, by different body regions. The annual harm benefits from the application of the new standard were estimated based on these national values, within a range of expected reduction in frontal harm (of 15-23%).

As can be seen, in both cases, the estimates of safety effects presented a synthesis of expert judgement and crash statistics.
Even though the estimate of safety effect is hypothetical, the confidence interval of the values should be provided. It is based on the assumptions made in calculating the expected safety effects.

3.2.2. *Correctness of values*

Most of the values of safety effects are provided by before-after comparisons. However, not all the results are correct to the same degree.

Due to the fact that safety studies are observational (non-experimental), there are confounding factors, which influence the crash occurrences and, therefore, should be accounted for in the estimation of a real safety effect of the treatment. There is a general assumption that the more known confounding factors a study controls for, the better becomes the basis for concluding that observed changes in road safety were caused by the treatment rather than by confounders (Elvik, 1997).

The nature of confounding factors, which should be accounted for in the evaluation of safety effect, is explained by Hauer (1997):

- Crashes have a random behaviour, for which it is possible to assume a given distribution of frequency (e.g. Poisson). This means that, in some periods, the values measured on given points of the network can be greater (or less) than the average values expected for those points. If the measurement leads to choosing those points for the treatments, a selection bias occurs and, in the measurements made after the treatments, an effect of decrease of crashes is registered (regression to the mean), independent of the treatments.
- Crashes occur in a setting, which, unlike a laboratory, is not 'controlled'. Therefore, for some types of crashes, some medium-long term trends can be observed, determined by such factors as the improvement of the safety performances, due to various safety features of vehicles or a change in driver habits. If a decreasing crash trend took place in the previous years, the reduction of crashes after the treatment would probably have occurred even without the treatment.
- For the same reason (lack of controlled environment), other external factors can affect the number of crashes registered where a treatment took place; for example, a reduction or an increase in traffic flows might bring about a variation in the number of crashes, independent of the treatment.

Therefore, to properly quantify the effects of a treatment, a simple before/after comparison is not correct. It is necessary to compare the situation with the treatment ('after') with the situation that would have existed had the treatment not been applied. The latter presents a corrected value of a previously observed ('before') situation.

The determination of what situation would have occurred without the treatment is a critical passage of the process and is performed in two steps:

1. determination of the correct *before* value (of crashes);
2. determination of the correct *after* value (of crashes) without the treatment.

The first point accounts for the selection bias; the second one – for the uncontrolled environment.

The Empirical Bayes method constitutes an effective instrument for the first point. A correction of 'before' crash numbers is performed with the help of reference group statistics, for each site in the treatment group. A brief description of the method is given in *Appendix 2 Controlling for regression to the mean.*

For the second point (the corrected value of crashes without the treatment), two basic approaches are possible:

1. using a comparison group - relies on the assumption that changes in the number of crashes in the comparison group correctly predict the changes that would have occurred at the treatment sites in the absence of treatment. The comparison group should be large (to strengthen the significance of the findings), demonstrate a similarity with the treatment group (e.g. from an engineering viewpoint – for the infrastructure improvements), and a high similarity with the treatment group, from the viewpoint of crash changes in the past (Maycock and Summersgill, 1995; Hauer, 1997). The evaluation of the treatment effect is performed by means of the Odds-ratio, where for the 'before' period the 'corrected' crash numbers (from the first evaluation step) are applied (e.g. Elvik, 1997b; Gitelman et al., 2001).
2. the use of multivariate models, which supply the expected number of crashes as a function of a series of physical and traffic parameters of the treatment sites and of general crash trends. The technique of generalized linear models (GLMs), with a Poisson or Negative Binomial distribution for the frequency of crashes, is the most widely accepted today for this purpose. Methods for the development of models can be found in Hauer (1997), Maher & Summersgill (1996), Hakkert, Gitelman et al. (2001), and other papers.

In practice, a correction due to selection bias is not always necessary. For example, a correction is not performed where a large number of sites is treated and they are selected without consideration of previous crash experience (e.g. Griffith, 1999), or where a large-scale safety intervention, such as enforcement and publicity campaign, is evaluated.

In general, selecting studies with safety effects, it is important to examine the quality of the studies' design and to rely more on the findings of those, which satisfy the criteria of correct safety evaluation. Elvik (1995), Elvik (1997), Elvik (2001) and other papers provide examples of such examination, accompanied by a demonstration of differences in safety effects estimated by different groups of studies (whereas the groups of studies are defined by the level of control for confounding factors).

For example, Elvik (1997) performed a meta-analysis of 36 studies, which considered the effects of black-spot treatments. The studies were carried out in Great Britain, Norway, Denmark, Germany, France, USA, Canada and Australia. It was found that the results of many studies depend very much on the confounding factors the studies have controlled for. Whether or not the studies have controlled for regression-to-the-mean in the number of crashes is particularly significant. *Table 3.5* presents the results of studies that have controlled for regression-to-the-mean and general trends in the number of crashes. The results indicate that the treatment of both blackspots and blacksections reduces the number of crashes at the treated sites. In studies which have not controlled for regression-to-the-mean, there was a significantly larger decrease in the number of crashes in some cases than is shown in *Table 3.5* (Elvik 1997). However, in accordance with presently accepted methodology for the evaluation of crash changes (Hauer, 1997), the results of these studies cannot be trusted and are therefore not shown.

Percentage change in number of crashes			
Crash severity	Types of crash affected	Best estimate	95% confidence interval
Blackspot treatment			
Injury crashes	All crashes at the spot	-14	(-31; +7)
Property damage only crashes	All crashes at the spot	+0	(-27; +38)
Blacksection treatment			
Injury crashes	All crashes on section	-44	(-61; -18)
Property damage only crashes	All crashes on section	-16	(-39; +15)

Table 3.5. *Effects on crashes of black spot treatment. (Based on the results of studies which satisfy the criteria of correct safety evaluation) (Source: Elvik, 1997).*

Another way for estimating the safety effect of a treatment is by means of a cross-section analysis. In contrast to before-after comparisons, in this case, the safety level of two groups of sites (e.g. road sections or junctions) is considered for the same time period, whereas the major difference between the sites is seen in a certain engineering characteristic, whose influence on safety performance is estimated. As both groups of sites are similar in most traffic and road characteristics and are exposed to the same general crash trends, if a difference between the crash frequencies was found, it could be attributed to the engineering feature considered. Such an evaluation technique is acceptable when the 'before' period does not exist, i.e. the sites were built with a specific feature, the safety effect of which it is required to quantify. For example, this occurs when residential areas are originally built with elements of traffic calming and a question on the safety effect of these features is raised (Gitelman & Hakkert, 2003).

However, in general, the cross-section analysis has fewer possibilities to account for confounding factors and, therefore, is less recommended for producing safety effects' values (Griffith, 1999a). A principle exception is when the comparison is based on safety performance functions.

A safety performance function (SPF) is a multivariate model, which establishes a relationship between crashes and traffic flows and (optionally) other road characteristics of the road sites considered. Crashes are estimated as numbers per time period, per site. The term SPF was introduced in the North-American literature (e.g. Hauer 1997; Persaud et al 1999). However, the techniques for establishing such relationships were also developed in Europe, especially in the U.K. (Maher and Summersgill, 1996). Actually, SPFs belong to the family of crash prediction models, which are recommended for application at different steps of before-after analysis (see above).

Using SPFs, the value of a safety effect associated with a certain infrastructure feature can be attained, comparing the estimates provided by the models for similar traffic and road conditions, but for groups of sites with and without the feature considered.

3.2.3. *Variability of effects*

As stated previously, the data for forecasting the effects of a treatment are, in many cases, derived from measurements made ex-post on similar treatments. The results obtained for similar treatments frequently present a range of values. It is necessary, therefore, in order to be able to utilise the data in the forecasting phase, to define some average values and the confidence intervals of the estimates[5].

A commonly used method for this is meta-analysis (e.g. Elvik, 1995; Elvik, 2001). The effects estimated for separate studies are combined by means of the log-odds method (Fleiss, 1981). Each estimate is assigned a statistical weight inversely proportional to the variance of the logarithm of the odds ratio.
The estimate of the effect observed at each study *i* (θ_i) is, usually, the odds-ratio of crash numbers observed at treated and comparison sites, in before and after periods. It has the form:

Estimated effect (θ_i) = [X_a/ X_m]/[C_a/ C_b]

where
X_a – the number of crashes observed at the treatment sites in the 'after' period;
X_m – the adjusted number[6] of crashes at the treatment sites in the 'before' period;
C_a – the number of crashes in comparison group sites in the 'after' period;
C_b – the number of crashes in comparison group sites in the 'before' period.

The statistical weight of the estimate by study *i* looks like

$$w_i = \frac{1}{\frac{1}{A^i} + \frac{1}{B^i} + \frac{1}{C^i} + \frac{1}{D^i}}$$

where A, B, C, D are the four numbers of the odds-ratio calculation.

The weighted mean effect (*WME*) based on a set of estimates is

$$WME = \exp\left[\frac{\sum_i w_i \ln(\theta_i)}{\sum_i w_i}\right]$$

with a confidence interval

$$\left(WME \bullet \exp\left(\frac{z_{\frac{\alpha}{2}}}{\sqrt{\sum_i w_i}} \right), WME \bullet \exp\left(\frac{z_{1-\frac{\alpha}{2}}}{\sqrt{\sum_i w_i}} \right) \right)$$

where *exp* is the exponential function, *ln* is the logarithm, α - the confidence level (95 percent is usually accepted).

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[5] A similar situation takes place when we need to combine results from different studies (see *section 3.2.1, a*).
[6] Accounting for a selection bias – see Appendix

The applicable value of the safety effect, i.e. the best estimate of crash reduction associated with the treatment (in percents), is calculated as (1-WME)*100. Examples of weighted mean effects estimated for road infrastructure improvements under Israeli conditions are given in *Table 3.6.*

Treatment type	Estimated effect* (WME)	WME confidence interval	Number of treatment sites in the set	Number of crashes at the treat-ment sites
Road humps and raised marking on #sc	0.718	(0.47, 1.098)	41	71
Pedestrian priority signs on #sc	0.857	(0.755, 0.972)	23	1028
Road #sc construction	1.88	(0.795, 4.448)	10	21
Roundabout	0.405	(0.194, 0.844)	16	26
Mini-roundabout	0.375	(0.154, 0.915)	10	28
Traffic signals at #jn	0.792	(0.608, 1.033)	28	270
Pedestrian islands at unsignalized #jn	0.361	(0.189, 0.688)	17	48
Raised #jn	0.572	(0.214, 1.527)	7	15
Traffic islands at unsignalized #jn	0.701	(0.241, 2.045)	9	11
Minor realignment of signalized #jn (islands, turns)	0.878	(0.595, 1.295)	12	111
Stop sign at #jn	1.009	(0.807, 1.261)	22	332
Pedestrian priority sign at #jn	1.009	(0.848, 1.201)	80	533

* On injury crashes
#sc - section
#jn – junction

Table 3.6*. Examples of safety effects evaluated for urban infrastructure improvements, under Israeli conditions (Source: Gitelman et al., 2001).*

An essential point in the evaluation is a choice between fixed effects and random effects models of meta-analysis. The fixed effects model is based on the assumption that there is only random (and not systematic) variation in findings between the studies or, in other words, heterogeneity of the effects is low. To test the validity of this assumption, the Q-statistic is used (Elvik, 2001). If the test of Q-statistic is significant, then the heterogeneity of the effects is high and a random effects model should be adopted. In this model, the statistical weight assigned to each result is modified to include a component reflecting the systematic variation of estimated effects between the studies. The formulae above demonstrate the evaluation technique within the fixed effects model. The formulae for testing Q-statistic and for correcting the statistical weights, when the studies' heterogeneity is high, can be found in Elvik (2001).

For those cases, where the safety effect refers not to the crash numbers but to crash rates (e.g. the number of crashes per vehicle-kilometer travelled) or to a conditional probability of crashes (e.g. the probability of a fatal crash, given that an crash has occurred), relevant definitions for the odds-ratios and the statistical weights can be found in Elvik (1995).

3.2.4. *Local versus general effects*

As agreed among international experts (Workshop, 2004), the general values of safety effects (i.e. those based on international experience) are acceptable for application, with due care as to the conditions in which they were attained. However, for local applications, a collection of local experience is preferable. The local experience is especially important for measures, which are dependent on cultural differences between the countries (mostly user-related and passive safety measures). Besides, the measure can be similarly effective in different countries (as when it is based on the same physical principles) but being applied differently, thus providing different safety effects. We should also admit that, not rarely, the authorities prefer local values of safety effects over international ones, pointing out the (assumed or established) peculiarity of local conditions, e.g. driver behaviour, road design, climate, etc.

Considering the results of a safety evaluation study, a major question usually arises as to the possibility to combine new findings with those from previous experience. Such a question is quite common because the estimates attained are sometimes insignificant or significant to a certain extent (for example, with p-value<0.10) and from the practical viewpoint, there is a need to accept or ignore the findings. One should also remember that to prove a significance of the effect, which ranges in 10-20%, the size of crash set considered should be of several hundreds (e.g. Griffith, 1999), a condition that frequently cannot be provided for consideration of a specific treatment.

Another problem can be in that the local result is somewhat at odds with the values reported in other countries. For example, the local value of a safety effect may be too high or indicate an increase in crashes whereas crash reductions were generally observed in other countries.

Therefore, sometimes, there is a need to indicate those of the local findings, which are sufficiently strong to serve as a basis for CBA/CEA of the potential projects. For this purpose, some decision rules can be developed as described below.

To examine the local findings on safety effects of road infrastructure improvements, in the Israeli study (Gitelman et al., 2001) two criteria were introduced:

a. significance of the value estimated for local conditions;
b. consistency of the result with the international experience.

For a subdivision of the findings, using the two above criteria, three groups of values (of safety effects) were defined:

I. Values recommended for application (without reservation). This includes findings, which (a) were found significant (p-value < 0.05) and (b) resembled the international results.
II. Values admissible for application (with some reservations). This comprises values which (a) can be seen as significant to a certain extent (p-value < 0.20) and correspond to the range of values which were found in other countries; or (b) were found highly significant for local conditions (p-value < 0.05) but contradict the international findings.
III. Values not recommended for application yet. This includes values, which do not satisfy the demands of groups I and II. Concerning these types of treatment, a follow-up study should be continued, to provide for larger data sets for evaluation and consequently obtain more significant results.

Using the above decision rules, some 20 estimates of safety effects were found as applicable to local conditions and were introduced into the database of the evaluation tool for CBA of road infrastructure improvements that was developed (Gitelman et al., 2001).

In a more regular case, the new value of a safety effect can be combined with the previous experience, using the meta-analysis technique as described in S*ection 3.2.3*.
In principle, there can also be a case of strong preference for local versus international findings. This might happen, for example, where a measure seems to be highly dependent on local (and especially cultural) conditions, where the international experience on the issue is inconsistent, or where the results were obtained in a pilot study, prior to a wide application of the measure in the country.

3.2.5. *Changeability of the effect*

A safety effect is usually given in the form of an average value, suitable for a range of site conditions. As certain relationships exist between traffic volumes and crash frequencies (Hauer, 1997; Persaud et al., 1999), it is reasonable to expect that the safety effect to occur at a specific site will depend on changes which are expected to take place in the traffic volumes. Even recognizing that the safety effect might be not stable but changes, depending on traffic volumes, the average values of safety effects are usually applied, at least at the stage of a 'mini' CBA/CEA. However, when a major change in road infrastructure takes place, e.d. widening or upgrading of a long road section, a more explicit consideration of changes in traffic volumes with a consequent consideration of safety effect is sometimes required.
For such a consideration, safety performance functions can be of help. As introduced in S*ection 3.2.2*, safety performance functions (SPFs) are multivariate models, which establish relationships between crashes and traffic flows and other road characteristics of the road sites considered, i.e. sections or junctions.
Maycock & Summersgill (1995) present the general form of such a model as:

$$A = k\, Q_a^{\alpha}\, Q_b^{\beta} \exp\left[\Sigma\, b_i G_i + \Sigma\, d_j D_j\right]$$

where A is the number of crashes per year,
Q_a, Q_b – traffic volumes (e.g. vehicle and pedestrian flows, at junctions),

G_i – continuous variables presenting road characteristics and traffic control parameters (at junctions),
D_j – categorical variables (1 or 0 values) indicating presence or absence of a certain road design element (e.g. traffic islands at junctions),
k, α, β, b_i, d_j – parameters calibrated for the model.

The dependent variables of the model can be the number of crashes, with different severity levels. Independent variables can be: traffic flows, length of the road segment, width of the lane, width of the shoulder, typology and width of the median, number of intersections per road section, etc. In any case, the expected crash number is a function of the traffic flows considered.

For example, Persaud et al. (1999) calibrated SPFs for typical locations on rural roads in Ontario, Canada. To illustrate, for four-legged signalized intersections (in the years 1988-1993) the SPF has the form:

No. of crashes/year = 0.0005334 x (total entering AADT) exp (0.8776).

For 4-lane freeway in Canada, the SPF was calibrated as follows:

No. of injury crashes = (Section length)(0.0000537)(AADT)exp (1.01786).

Maher & Summersgill (1996) reported on models which were developed by the U.K. Transport Research Laboratory for a range of typical sites such as: 4-arm roundabouts; 3-arm major-minor priority junctions on rural single carriageway roads; 4-arm signalized junctions on urban single carriageway roads; 3-arm major-minor riority jumctions on urban single carriageway roads; rural single carriageway links on English trunk roads; rural dual-carriageway links on the trunk roads, etc.

The effect of a treatment can be estimated as the difference between the typical crash numbers expected for one type of sites (which was relevant in the 'before' period) as opposed to the crash number expected for another type (which exists in the 'after' period), where these values are estimated for the levels of traffic volumes assigned to 'before' and 'after' periods, accordingly.

3.3. Number of crashes affected by the measures

The number of crashes affected by a measure multiplied by a value of the safety effect provides for the number of crashes prevented due to the measure. Considering the number of crashes affected, two basic situations are possible.

1. When a safety measure is chosen for a specific crash site (area, population), the implementation unit is known. The number of crashes affected by a measure depends on two factors: the statistics of crashes observed at the site over the last few years and the target crash group of the measure.
   The target crashes 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 3.7*. The definitions were given by Elvik (1997a), within the framework for a CBA of the Dutch road safety plan.

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 30 km/h roads	All accidents in areas changed into 30 km/h zones
Reduced speed limit on 80 km/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
Extra high mounted brake lights	Rear end collisions
Driver side airbags	Frontal impacts involving cars
Rear seat belts mandatory	Injuries to rear seat occupants in 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

Table 3.7. *Examples for definitions of target accident groups: target accident groups for safety measures for the Dutch road safety plan (Source: Elvik, 1997a).*

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

If, due to practical reasons, an improvement is planned for a site with no crash record in the last period, it is still possible to account for safety benefits, using typical safety records for this type of sites or the estimates provided by safety performance functions (see *Section 3.2.5*).

2. When a safety measure is considered for implementation within a large-scale road safety program, first, a typical 'unit' of implementation should be defined and then, the number of target crashes 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 & Gitelman, 1999). Considering each field of the program's activity, three stages were passed: (1) definition of target crash groups; (2) evaluation of the expected safety effect of the treatments; (3) definition of the implementation scope, which is attainable during the program. Regarding the third stage, two types of activity were defined: national-type (e.g., 'enhancing the use of safety restraints in cars') where potential injury savings were estimated using average nation-wide indices; and a varying-type, 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:
   a) five categories of geographic units, i.e. one-kilometer road sections and junctions in urban and rural areas, accordingly (as potential black-spots), and varying-length rural sections (as candidates for creating forgiving roadside conditions);
   b) 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 crashes that can be prevented by road related measures should be based on crash rates representing the typical level of safety for various categories of road elements and road types (Elvik, 1997a). *Table 3.8* provides an illustration of typical crash rates for roadway elements for the Netherlands.

Two more factors are essential for the evaluation of crash numbers to be saved:

a) the measure can be already 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 hardly result in significant changes in crash records. Similarly, the black-spot treatment measure is widely applied in many European countries; there is some initial level of police enforcement, etc. As a result, the actual safety potential of the measure, for local conditions, should be estimated as lower than a basic one.
b) 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, 2001a).

Type of element	Characteristics of element	Mean AADT	Injury accidents per million vehicle kilometres
Motorway	More than 4 lanes	81,252	0.07
	4 lanes	31,451	0.07
Motor traffic road	With median	16,957	0.15
	Without median	5,877	0.10
Rural highway	Two lanes	18,314	0.27
	Single lane	4,927	0.30
All purpose road	Two lanes	1,396	0.51
	Single lane	314	0.85
Urban arterial	All types	4,471	1.33
Access road	All types	636	0.74
Four arm junction	Unchannelized	1,676	0.32
	Partly channelized	7,446	0.31
	Fully channelized	18,012	0.17
	Signalized	65,549	0.20
Three arm junction	Unchannelized	2,766	0.05
	Partly channelized	10,145	0.10
	Fully channelized	33,750	0.12
	Signalized	39,833	0.08

Table 3.8. *Normal crash rates for roadway elements for the Netherlands (Source: Elvik, 1997a (from: Poppe, 1993).*

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

the number of fatalities (observed) * the average 90%-use of DRL * the 40% of the DRL relevant crashes * the 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 crashes, 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):
a) 3% drink-drivers (in traffic) and 30% alcohol related fatalities;
b) 2% drink-drivers and 40% alcohol related fatalities.

Three forms of safety effect were considered:
1. a 9% reduction in all fatalities (based on the Norwegian Traffic Safety Handbook, see *Table 3.3* above);
2. a 30% decrease in alcohol related fatalities (as was found in Norway, following a tripling of the enforcement level in low frequency RBT areas);
3. 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 2,040-2,500 fatalities, on an annual basis, is expected in the EU.

3.4. 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 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 for the performance of CBA/CEA, especially at the stage of a preliminary evaluation. However, these values are usually not published, which strengthens the uncertainties of the evaluation results.

Research efforts can be undertaken to provide for typical values. For example, developing a tool for evaluation of safety benefits of road related measures, in Israel, the typical costs of road infrastructure improvements were explored (Hakkert et al., 2002). The typical components and typical costs were suggested for: a minor realignment of junction, a roundabout, traffic lights' installation, lighting installation at junction, sealing shoulders, resurfacing on rural roads, etc. For preliminary estimates' performance, the following values were recommended: a typical treatment of one kilometer black-spot section costs 100,000 NIS[7] , a typical treatment of a black-spot junction – 500,000 NIS.

Estimating the Road Safety Plan for the Netherlands, Elvik (1997a) assumed the implementation costs for each safety measure considered; those included both public expenditure and costs to road users and were expressed in Guilders (1993). For example, introducing cycle lanes on an urban arterial has an investment cost of 125,000 guilders and an operating cost of 12,500 guilders, per unit (1 km); roundabout instead of X-junction costs 250,000 guilders; blackspot treatment (at junction) – 50,000 guilders, etc.

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

ETSC (2003) provides detailed specifications of costs of five 'promising' road safety measures for the EU: DRL, RBT (best practice guidelines), 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, present value costs of € 23 billion (for standard low beam headlights) and of €16 billion (for special DR-lamps) were estimated.

For the RBT, the costs include (ETSC, 2003):
- costs of police personnel at the road-side (with 180 days/year, 6 hours/day, 15 tests/hour, i.e. 16,200 tests in one person-year; 100,000 Euro per person-year);
- equipment costs, where each personnel device costs € 750 and 20,000 mouthpieces costing € 0.25 each are needed per year, or 5,750 euro 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).

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

Considering the best practice road safety engineering, examples of low-cost infrastructure-related measures, that have been recently introduced in Norway, were discussed. The implementation costs of these measures are given in *Table 3.9.* The values are typical for Norway and only illustrative for other countries (ETSC, 2003).

[7] NIS – New Israeli Shekel, 1 euro = 5.5 NIS

A study by ICF (2002) also provides implementation costs and estimates the economic benefits from two major safety initiatives in the EU, i.e. better enforcement with respect to a number of important contributors to fatalities in road crashes - speeding, drunk driving, non-use of seat belts, and improved enforcement of existing road safety laws relating to commercial road transport.

Treatment	Mean cost (NOK)	Mean AADT
Pedestrian bridge or underpass	5,990,000	8,765
Converting 3-leg junction to roundabout	5,790,000	9,094
Converting 4-leg junction to roundabout	4,160,000	10,432
Removal of roadside obstacles	310,000	20,133
Minor improvements	5,640,000	3,269
Guard rail along roadside	860,000	10,947
Median guard rail	1,880,000	42,753
Signing of hazardous curves	60,000	1,169
Road lighting	650,000	8,179
Upgrading marked pedestrian crossings	390,000	10,484

Table 3.9. *Examples of costs of road safety engineering measures in Norway. 1 NOK = 0.138 euro (2002). (Source: ETSC, 2003, from Elvik & Rydningen, 2002).*

3.5. Side-effects

Road safety measures can produce three kinds of effects: safety, mobility, and environmental (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 programs for economic evaluations in transport, e.g. BVWP, EWS-97, RAS-W in Germany; TUBA, COBA, NESA in the UK; STEAM in the USA, etc (WP 1, 2003).

As many road safety measures affect the amount and/or speed of travel, they may also have impacts on emission and noise. For example, an increase in the use of fuel, which occurs with DRL, will increase emissions 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 € 0.20 million per year (ETSC, 2003).

A recent study on improvements of the procedure for economic evaluation of transport projects in Israel (Nohal Prat, 1999), recommended the values for inclusion of emissions of air pollutants and noise in CBA (*Table 3.10*). The project was commisioned by the Ministry of National Infrastructures and was carried out by an international team headed by Hague Consulting Group from the Netherlands.

Type of road/ vehicle	Emissions	Noise
Urban:		
Passenger car (petrol)	0.07	0.03
Passenger car (diesel)	0.20	0.03
Lorry (diesel)	1.51	0.09
Bus (diesel)	1.99	0.06
Rail (tram)	0	0.06
Interurban:		
Passenger car (petrol)	0.01	0
Passenger car (diesel)	0.01	0
Lorry (diesel)	0.06	0.01
Bus (diesel)	0.06	0.01
Rail (train)	0	0.01

Table 3.10*. Recommended values per vehicle kilometre for emissions and noise, in Israel, in NIS. 1 NIS=$ 0.25 US (1999). (Source: Nohal Prat, 1999).*

The values for emissions (see *Table 3.10)* include only the health effects, whereas the effects of acidification on buildings and forests and the contribution to the greenhouse effect are incorporated in the quantitative multi-criteria analysis (which is recommended by the same document - Nohal Prat, 1999). As can be seen from *Table 3.7*, the cost of the emissions of a lorry are more than 20 times as high as from a passenger car on petrol. More than half of the damage from lorries comes from the direct emissions of PM10 (typical for diesel engines) and another third from NOx (mainly through the contribution to secondary particulate formation). Because of the high value of emission cost for diesel buses compared to petrol cars, substitution from car to bus is only worthwhile from an air pollution perspective, if the bus is almost full (Nohal Prat, 1999).

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 (*Table 3.11*). These estimates were published by the highway authorities in both countries and are used for CBA of highway-related projects.
In a similar study by Robuste et al (2003), which sought for an optimal speed limit for a Spanish highway, the environmental impacts studied were: toxic emissions, noise pollution and the greenhouse effect (carbon dioxide emission).

The relationship between vehicles, their emissions and travel speeds was taken from the CORINAIR program. In 1999, the total environmental pollution cost for Spain was estimated at € 2,957,953; considering the number of vehicle-kilometers in the same year, an estimate of € 0.73 per vehicle-kilometer was attained (at a speed of 60 kph). As the average vehicle traveling at this speed emits 6.5 g/km, the social cost will be 0.113 €/g emitted. This value enables to establish a relationship between the average speed of vehicle and the associated social costs, stemming from the toxic emissions (Robuste et al, 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 (CO2)	0.37	0.37	1.50	1.50
Emission of 1 kilogram of nitrogen oxide (NOx)	33	66	60	72
Emission of 1 kilogram of volatile organic compounds (VOC)	33	66	30	50
Emission of 1 kilogram of sulphur dioxide (SO2)	18	70	20	118
Emission of 1 kilogram of particulate matter (PM10)	0	1700	0	3343

Table 3.11*. Monetary valuations of environmental impacts of speed choice in Norway and Sweden (national currencies; 1999 price level) (Source: Elvik, 2002).*

To express the noise pollution cost, a formula developed by the French research center CETUR was applied. First, the relationship between the noise emissions produced by a flow of vehicles and the average road speed is established, and then, the noise pressure is converted into the associated costs (Robuste et al., 2003).

Carbon dioxide is a by-product of gasoline combustion; its emission is proportional to the fuel consumption. The emission of 2.59 kg of CO_2 per liter of fuel consumed, was estimated. The associated costs were taken from the cost measures mitigating the greenhouse effect, i.e. 46 €/ton of CO_2 (Robuste et al., 2003).

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 the emissions from a typical stream of vehicles traveling at steady speeds. 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 actually updated, and accomplished by carbon dioxide emission rates, based on Kallberg & Toivanen (1998).

An example of the calculation using the MASTER framework, is presented in *Table 3.12.*

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 3.12*. Air pollutant emission coefficients (average), following the increase of 100 kph speed limit to 130 kph speed limit on rural freeways (Source: Cameron, 2003).*

Air pollution cost estimates were provided as follows (in year 2000 A$):
carbon monoxide - $ 0.002 per kilogram;
hydrocarbons - $ 0.44 per kilogram;
oxides of nitrogen - $1.74 per kilogram;
particulates (PM10) - $ 13.77 per kilogram;
carbon dioxide - $ 0.022 per kilogram.

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

3.6. **Conclusions**

Lack of information on safety effects and costs as well as doubts on the validity of the available values present one of the major practical barriers for the performance of the efficiency assessment of safety related measures.

Summing up the available knowledge and data, the following recommendations can be drawn up to promote the application of efficiency assessment for road safety measures:

<u>The need for a database on safety effect values</u>

1. In different countries, many evaluation studies have been conducted which demonstrated the effects of safety related measures on crashes. In order to make the safety effects available for CBA/CEA applications, there is a need to arrange them on a systematic basis, i.e. relevant data should be retrieved, ordered, screened, and made accessible for CBA/CEA experts.

2. In some countries, such work on systematization of the results of evaluation studies has been performed, i.e. there are databases of values, which are immediately available for application. One of them is the Norwegian Traffic Safety Handbook (Elvik et al., 1997). The majority of values in the Handbook present a summary of international experience that makes it a reliable source of general values of safety effects associated with various safety measures.

3. To stimulate the application of more uniform and well-based values of safety effects in the EU, it would be useful to establish a database with typical values of the effects, based on international experience. The Norwegian Traffic Safety Handbook, in combination with other available sources, can serve as a basis for such a database. The initial part of the database can focus on infrastructure-related measures, as the majority of both available estimates and the requests for application come from this field. Such a database might be open to a European network of experts and provide for general values of safety effects on initial steps of CBA/CEA as well as assist in comparisons of local effects observed. The values of safety effects kept in the database should be regularly updated, in accordance with the last evaluation results in the EU.

4. For local applications, a collection of local experiences is usually preferable. To provide for the local values of safety effects, a systematization of the results of the evaluation studies, which have been performed under local conditions, is required. For example, in Israel, a database on safety effects of road infrastructure improvements was developed in a recent study by Hakkert et al. (2002).

<u>Quality of estimates</u>

5. Each value of a safety effect, which is recommended for application, should be presented in the form of a best estimate (weighted average) and a confidence interval of the effect. It should also be accompanied by a list of the evaluation studies, which supplied the basic estimates of the effects. Such a presentation enables: to perform the efficiency assessment, to measure the level of uncertainty in the efficiency assessment' results, and to systematically update the available values.

6. The values of safety effects, arranged for practical use, should be presented for various groups of crashes, as dictated by severity levels and types of crashes affected.

7. The evaluation studies, results of which are accounted for in producing typical values, should satisfy the criteria of a robust safety evaluation.

8. Since the applicability of the values depends on the correspondence between the countermeasures and the treatment sites (population), which are considered for the efficiency assessment and for which the values of safety effects are available, special attention should be given to a correct and full definition of those components.

<u>Other evaluation components</u>

9. Typical implementation costs could be of help for regular evaluation practices.

10. Considering the implementation scale is essential for a proper cost evaluation (mostly, because the traditional countermeasures have been in use, to a certain extent, for many years). When the exact implementation scenario is unavailable, several sets of assumptions can be developed and estimated.

11. The environmental impacts of safety measures stem from changes in the amount of travel/ fuel consumption and vehicle speeds, following the implementation of the measures. Different studies provided estimates for the amount of emissions per km traveled (for different travel speeds); also, the cost values per unit of emission are available in some countries. Both components enable to account for air pollution impacts of safety related measures. Similar components can be provided for noise pollution effects.

4. Optimizing the process of efficiency assessment

Jutta Schneider (UoC) and Charlotte Bax (SWOV)

4.1. Introduction

The third workpackage of ROSEBUD aims to provide a users' guide with solutions for overcoming the barriers to the application of Efficiency Assessment Tools (EAT) for road safety measures. In the previous chapters of this guidebook a summary of the methodology of such assessment tools has already been given. The availability of knowledge and data to the assessment has also been discussed earlier. The following chapter will deal with the process of efficiency assessment itself and its institutional setting. Optimization potential shall be detected within the single steps of the application of EAT for the evaluation of road safety measures. The following table illustrates where optimization potential can be found.

1.	Defining the type of problem: choosing the method
2.	Computerized assessment tools
3.	Thoroughness of the analysis
4.	Position of CBA in decision making process
5.	Quality control

Table 4.1. *Areas for optimization in the application of EAT.*

Before starting the evaluation, the optimal method for the efficiency assessment has to be chosen. Therefore this chapter will first analyse which EAT will be best for certain types of objectives and policies within the assessment.

In Workpackage 2 it turned out that many interviewees did not feel well enough provided with materials (software, guidelines etc.) to assist them with the assessment. An overview of existing assessment and requirements software tools which can be used as a good assistance tool, will be presented in *Section 4.2*.

The duration and costs of an efficiency assessment can be reduced by performing a less thorough analysis. Requirements and options for doing so, will be itemized in *Section 4.3.*

Decisive for the effect of an efficiency assessment is its timing within the process. The information can come too early or be too late. In some decision making processes less information at a lower cost can be even more effective in terms of actual influence on outcomes and implementations. Therefore the best position of the EAT in the decision making process will be discussed in *Section 4.4*.

Institutionalizing a quality control of EAT can reduce scepticism and mistrust in the results of efficiency assessments. Instruments like the development of a standard methodology for EAT, the establishment of an evaluation board, and possibilities for stimulating a competitive market will be discussed in *Section 4.5*.

Special decision making problems (local and regional decision making, multiple decision makers) and their implications round off this chapter.

4.2. Defining the type of problem: choosing the method

The first step within the evaluation of road safety measures is the formulation and definition of the decision problem and the choice of the adequate evaluation method. As evaluation methods for road safety measures Cost-Benefit Analysis (CBA) and Cost-Effectiveness Analysis (CEA) are primarily considered. In the following the characteristics of these two evaluation tools will be presented briefly:

1. With a Cost-Benefit-Analysis (CBA)[8] the lack of a market for road safety is bridged by the creation of a virtual road safety market. This requires that all relevant cost and benefit categories are measured in monetary terms (which is the main barrier to performing a CBA). The costs and benefits of a measure will then be weighed against each other. The result of a CBA is a cost-benefit ratio:

   $$\frac{\text{Present value of the measure's benefits}}{\text{Present value of the measure's implementation costs}}$$

   When investment leads to a marginal cost-benefit ratio lower than 1, policy makers should stop spending money on that project. The funding of road safety projects will be beneficial as long as any additional money spent results in safety returns which are at least as high as the investment cost.

   CBA is a sophisticated decision tool that requires good knowledge of the methodology and qualification of the performer. But its value largely depends on the data used and the issues captured.

2. In the cost-effectiveness analysis (CEA)[9], the cost of a measure is weighed against its effects. In opposition to the CBA, the effects of a measure are expressed in non-monetary terms (e.g. number of saved lives).
   Resulting from the CEA is a cost-effectiveness-ratio:

   $$\frac{\text{Effects of a measure (e.g. number of saved lives)}}{\text{Implementation costs of a measure}}$$

   The higher the ratio the more effective is a safety measure. A comparison between ratios of various measures can be done to

[8] For the methodology of CBA see also Chapter 2.
[9] For the methodology of CEA see also Chapter 2.

ascertain the *relative* efficiency of the measures e.g. to specify the most efficient measures in a set of measures to realise a pre-defined target (e.g. reduction of casualties in road traffic). But – contrary to a CBA – a CEA cannot ascertain whether a project should be undertaken or not. It cannot estimate the *absolute* efficiency of a measure (e.g. the benefits are higher than the costs of a measure). The most appealing advantage of a CEA is that it requires less theoretical knowledge and qualification for application. It is therefore easier for planners and decision makers to handle such an assessment tool.

In particular cases (e.g. if non-monetary effects and political issues have to be regarded, if measures have to be assessed where the cause-and-effect chain is not clear, if essential data for a monetary assessment is missing) it can be necessary to include other – non-monetary – methods as evaluation tools for decision making. Non-monetary methods are represented e.g. by Multi Attribute Utility Analyses (MAUT). A common argument against the application of non-monetary assessments is the subjectivity of their evaluation. Preferences and moral concepts of the performer will encroach unfiltered into the analysis. To a certain degree this offers the possibility for performers to design the results according to their own interests. Nevertheless in certain cases non-monetary assessment tools can represent an adequate tool for the evaluation of road safety measures or – in combination with monetary assessment tools – they can at least enlarge the analysis by important factors (non-monetary aspects of the assessment). But, as ROSEBUD attaches great importance to the monetary assessment tools, a detailed elaboration of the methodology of non-monetary assessment tools will not be made in this chapter.

The concrete formulation of the decision problem affects to a great extent the choice of an adequate evaluation method. *Specifications and requirements* resulting from the definition of the decision problem have to be taken up by the assessment tool. The choice of the evaluation method has to be aligned with the underlying objectives of the assessment. The following points have to be considered for the evaluation and the selection of the assessment tool:

1. Ranking of options versus test of efficiency: the objective of the evaluation can, on the one hand, be the ranking of measures according to their efficiency and, on the other hand, prove the absolute efficiency of measures. For ranking the measures another evaluation tool than for proving the absolute efficiency of a single measure, is needed. Therefore the objective of the evaluation determines the choice of the evaluation method.

2. Fixed budget versus fixed objective: According to the economic principle, the question arises if a (pre-determined) fixed objective can be reached with a minimum budget or if a pre-determined budget must be utilized to reach the topmost level of goal achievement. If a pre-determined budget for the improvement of road safety measures is given, a method has to be utilized that can quantify the efficiency and make measures comparable to each other, to ensure that the budget is used for the most efficient road safety measures. This implies the application of other evaluation methods than in cases without a budget restriction.

3. Improvement of road safety or aiming for general allocational efficiency: the selection of the evaluation method depends on the measurement for assessment underlying the range of road safety measures. If optimization of road safety is the only objective of the assessment, a method can be chosen that shows the improvement for road safety resulting from the implementation of this measure. But if the allocational efficiency of a measure is decisive, a method has to be chosen that includes all relevant allocational impacts in the evaluation.

4. Achievement of overall political goals versus a rough test of general efficiency: if the implementation of measures for road safety is guided by political interests (e.g. influence of interest groups, subordination of road safety policy under structural and regional policy), the efficiency criterion will be the most important in the assessment. Evaluation methods that are consequently concentrating on efficiency will become less important. The selection of measures is guided mostly by political interests and not by efficiency.

5. Regarding other influencing factors besides efficiency: decisive for the choice of the evaluation method is the importance of other influencing factors besides efficiency (e.g. user acceptance, acceptance in the public, time lags by the implementation of measures, discrimination of certain social groups). If they have to be regarded in the assessment of road safety measures, those evaluation methods will be chosen that can include these factors or can be combined with methods that can include them.

6. Evaluation of single measures versus evaluation of the whole system: measures can be linked to each other and influence each other in the direction and/ or extent of impacts. The implementation of measures can even affect the whole system (e.g. infrastructural measures that affect the road network). If these effects are included in the evaluation of measures, the assessment tool needs to be able to display these impacts.

7. The assessment of road safety measures has to analyse if conflicts of objective or synergies with other policy fields (e.g. environmental policy) can occur. Those effects can be included in the assessment.

8. Collection of impacts: it has to be decided if an assessment tool is used that is able to display all impacts of a measure, or if a method is used that only focuses on several selected impacts in the evaluation. The objective is to make these impacts (and the measures) comparable.

9. When measures have to be compared to each other, it has to be ascertained that the evaluation method can be applied in the same manner for each measure in the range of possible measures for a road safety problem. This implies e.g. that the input data for the evaluation is available in the same quality and extent for every measure. When the evaluation method is selected, this has to be taken into account.

10. The chosen assessment tool has to show clear and well-defined results and (analytical) transparency (i.e. it has to be interpretable, easy to

understand, and with valid contents), so that the results will be sustainable in the political decision making process.

11. The chosen assessment tool has to guarantee that the financial resources provided for the improvement of road safety, will be used in an optimal and efficient way. Important is, therefore, that the chosen assessment tool and the extent of expected impacts of a road safety measure are in due proportion to each other (e.g. trade-off between costs of the assessment tool and impacts of the measures).

The *combination* of the specifications and requirements for the selection of an evaluation method in the decision making process, on the one hand, and the (methodological) characteristics of several assessment tools, on the other, can be found in *Table 4.2*. This table gives support to the selection of applicable evaluation methods for several situations and decision making problems concerning the implementation of road safety measures.

Decision making problem		Applicable assessment tool	Explanation
Form of results	Number of prevented crashes is wanted.	CEA	Within a CEA, the effects of a measure are not expressed in monetary terms. Also a CBA can be used, but the monetary benefits of a measure have to be transformed in the number of crashes prevented.
	Monetary results are wanted.	CBA	The cost-benefit ratio expresses the proportion of costs and benefits for a certain measure. A measure is beneficial if the ratio is higher than 1.
Ranking of options	The most efficient measure within a finite set of measures will be found.	CEA	With a CEA the relative efficiency of a measure can be tested, i.e. the measure with the highest cost efficiency ratio within a finite set of measures.
	Those measures will be found where the benefits are higher than the costs.	CBA	The absolute efficiency can only be tested with a CBA. In those cases where the cost-benefit ratio is higher than 1, a measure is efficient (the benefits are higher than the costs).
	A fixed budget for road safety shall be exploited by the most efficient measures.	CEA	If the only target is to increase road safety, the cost-effectiveness ratios of the measures sets the path to the most efficient set of measures. If the budget has to be filled with those measures that are *absolute* efficient, a CBA has to be used.
Objective of the evaluation	Safety effects will be highlighted.	CEA	The cost-effectiveness ratio of a measure shows its impact on safety. But a CEA cannot be used to compare safety effects for different levels of crash severity. This can only be done within a CBA when crash costs are included in the analysis.
	Multiple policy objectives (environmental issues, social effects) will be regarded.	CBA	Within a CBA multiple policy objectives can be weighed against each other by quantifying them.
	Policy objectives are conflicting.	CBA	Only within a CBA can safety be weighed against other policy objectives, because different policy objectives can be taken into account.

Table 4.2. *Application of assesment tools for several decision making problems concerning the implementation of road safety measures.*

The examples in *Table 4.2* demonstrate the possibilities for the application of monetary assessment tools in decision making. After the suitability of the assessment tools is tested, relative barriers and optimization potential in the use of assessment tools will be identified and analysed next.

Decision making problem		Applicable assessment tool	Explanation
Objective of the evaluation (continued)	Further issues have to be regarded in the assessment, such as user acceptance, discrimination of certain social groups, that are hardly monetary ascertainable	Monetary assessment (CBA) in combination with qualitative assessment (e.g. MAUT)	The methodology of CBA can be extended by further influencing factors. Their impacts have to be quantified and included in algorithms of the analysis. But there are limitations to this approach as regards contents and methodology of the analysis.
Missing data	Measures have to be evaluated where the cause-and-effect chains are not clear (e.g. driver trainings etc.)	Qualitative assessment	If the cause-and-effect chain is not clear and the impacts of a measure cannot or can hardly be estimated, a monetary evaluation will be difficult to do resp. can be done only with great efforts. CBA and CEA therefore have to be eliminated as assessment tools for economical reasons. It can only make qualitative assumptions of the direction and the extent of the impacts of these measures.
	Benefits cannot be quantified.	CEA	If the impacts of a measure are known, but cannot be quantified (e.g. no crash costs), a CEA can be done.

Table 4.3. *Application of assessment tools for several decision making problems concerning the implementation of road safety measures. (continued)*

4.3. Computerized assessment tools

In WP 2 the interviewees were asked to define barriers to the application of monetary evaluation methods for road safety measures. One of the barriers that was mentioned is the complexity of the assessment tools. The interviewees were convinced that in many cases the efforts to conduct a CBA or CEA will not be in due proportion to the benefits of the measures in the evaluation. Thus, in their mind, the application of a monetary evaluation method will not be justified economically. Additionally, the lack of methodological knowledge can be a decisive factor for abstaining from the application of these methods. On the national and regional levels, many interviewees think that the existing tools (e.g. software, guidelines) for the application of the methods are not adequate or accessible. For these reasons, in some cases, monetary evaluation methods will not be used despite the fact that it would generally be possible and economically justified.

To optimize the process of efficiency assessment and extending the application of monetary assessment tools for road safety measures, the barriers have to be eliminated. It has to be the overall objective to find solutions for the problems decision makers are facing (here: complexity of methods, lack of know how). Tools have to be developed that admit or facilitate the application of the assessment methods. Especially software tools can be helpful in this regard. Computerized assessment tools reduce the complexity of the analysis by standardizing the algorithms. Thus the application of CBA or CEA will be simplified.

Two options have to be taken into account when computerized assessment tools are used for optimizing the efficiency assessment. In both cases solutions have to be found for the aforesaid barriers to the application of monetary assessment tools for road safety measures.

1. On the one, hand the suitability of available software tools for the evaluation of road safety measures should be considered. In doing so, the particular requirements for the evaluation of road safety measures have to be considered. It has to be tested, whether the available software tools fulfil these requirements.

2. On the other hand, the requirements for an ideal software tool for the evaluation of road safety measures have to be set up. A new tool could be developed that will meet these particular requirements.

In the first case, usable tools for the application and implementation of monetary assessment methods already exist. But these tools are not used yet for assessing the efficiency. This might originate from a lack of information decision makers are facing: they do not know these tools at all (or if they are available) and they do not know if they are able to fulfil their personal requirements for the evaluation. *Table 3* gives a short overview of existing software tools for the monetary assessment of measures. This table can only display a short extract of existing tools that are frequently used for the assessment. There is a range of additional options beyond the tools mentioned in the table.

Tool	Editor	Year of introduction	Area of application	Contents	Addressee	Information and help	Quality check	Presentation of results
Definite	Institute for Environmental Studies, Vrije Universiteit Amsterdam, NL	1994 (MS-Dos based),	Multiple decision making situations (i.e. infrastructure planning, environmental projects); decision support on a finite set of alternatives	Toolkit of methods: multicriteria methods, CBA, graphical evaluation methods	Professionals with no prior experience of such software and sophisticated users	Easy step menus, information screens and help screens	Test of robustness of results with sensitivity analysis	Report and graphical presentation (results specified by the user), can be edited using MS Word.
MicroBEN-COST	Texas Transportation Institute, Texas A&M University System	1993	Broad spectrum of transport infrastructure planning projects (bypass, new locations, pavement rehabilitation, bridge rehabilitation and replacement)	Main programme for complex economic analysis on the basis of costs and benefits, Update programme for customizing and updating the data set	Decision makers and transport planners	User manual is provided		
TransDec – Transportation Decision Analysis Software	HLB, Decision Economics Inc.	TransDec 2.0 Version has been released in summer 2003	Situations with multiple criteria; allows planners and decision makers to consider factors like noise, lives and pollution that are difficult to attach monetary values to; multiple — and sometimes even conflicting — interests and objectives can be assessed to arrive at the best use of transportation funds, scaled to apply over the range of differently sized urban areas and over the range of variously sized projects.	Beyond a cost-benefit analysis, TransDec analysis includes qualitative effects (such as public concerns like noise and aesthetics), as well as standard quantitative data (such as financial or construction requirements).	Decision makers and transport planners			Models, data and diagrams packaged within a single user-friendly Windows XP and Windows NT-compatible application.
COBA 11	Integrated Transport Economics and Appraisal Division, Department for Transport. Great Britain	2001	The programme is used for the evaluation of trunk road and highway projects in England, Wales and Northern Ireland.	Costs of providing road systems and benefits derived by road users (in terms of time, vehicle costs etc.); results are expressed in terms of monetary valuation.	Local authorities and transport planners involved in the economic evaluation of trunk roads projects.	Provision of a user manual	Check of Input data, error-check, check if observations or traffic model outputs are reasonable.	

Table 4.3. *Inventory of existing computerized assessment tools in Europe/USA.*

Tool	Editor	Year of introduction	Area of application	Contents	Addressee	Information and help	Quality check	Presentation of results
TARVA – Estimation tool for traffic safety effects of road im-provements	Technical Research Centre of Finland (VTT)	1994	Impact analysis of road safety measures, calculation of safety effects of a road improvement programme and the corresponding cost-benefit ratio.	Estimation of safety effects of road improvements, road, traffic and crash data are combined with effects of different safety measures. Information is stored in a database	Finnish National Road Administration (Finnra), easily convertible to any other country.			(various presentation modes)

Table 4.3. *Inventory of existing computerized assessment tools in Europe/USA (continued). (Source: Highway Safety Analysis Software, Version 2.1, URL: www.x32group.com/HSA_Soft.html; HLB, Decision Economics Inc., TransDec – Transit and Highway Investment Decision Support Tool, URL: www.hlbde.com/products/transdec.html; Janssen, R., Herwijnen, M. van & Beinat, E. (2001) DEFINITE for Windows. A system to support decisions on a finite set of alternatives (Software package and user manual), Amsterdam; Peltola, H., Background and principles of the Finnish safety evaluation tool, Tarva, in: Evaluation of Traffic Safety Measures, Proceedings of the 13th ICTCT Workshop, Corfu 2000; Texas Transportation Researcher, Software balances needs and funding, Vol. 34, Nr. 3, 1998, URL: http://tti.tamu.edu; Texas Transportation Researcher, The Road Ahead, Vol. 39, No. 2/2003; UK Department for Transport, COBA 11 User Manual, URL: www.dft.gov.uk; U.S. Department of Transportation, Federal Highway Administration, Traffic Analysis Tools Primer – final report, Washington 2003).*

There is a range of computer programs dealing with monetary evaluations. The examples mentioned above represent only an extract of already existing assessment tools. Common tools as e.g. Definite, MicroBENCOST or TARVA will provide good assistance in the assessment of road safety measures (especially infrastructure related measures). To widen the applicability of computerized assessment tools for road safety measures, enhancements of existing tools should be developed. Additionally existing tools can be used as a knowledge basis for further developments of new tools that focus on road safety measures.

Both, existing tools and new software tools have to fulfil certain requirements. This is to ensure that the software tool provides assistance with the application of monetary assessment tools. Therefore the following points have to be achieved by good software:

- The software has to be easy to use. It must not overextend the user. A long skill adaptation time demands a high readiness of the user to invest time and activity. Thus it complicates the application of monetary assessment tools. A graphic user interface that is clearly and easily arranged (simple menu prompting, visual aids etc.) can help to reduce complexity. It has to be ensured that not only experts but also 'normal users' are able to deal with the tool. A help file is needed to prevent user problems (e.g. searching via catchwords).
- A demo version of the software tool can introduce the user very quickly in the operation. The user’s adjustment to the new programme can be accelerated.
- The software tool has to work with high speed and power. The time exposure of the calculation has to be marginal.
- Via control questions and error checks (e.g. warning signals or opening windows for wrong data input) the quality of the calculation has to be ensured.
- The software should run on all current operating systems.
- The software should contain security barriers. An automatic data-backup should be included in the software. The deletion of data has to be confirmed by the user. Control questions can be included in the programme ('Do you really want to delete?').
- The software should integrate improvements, updates, and new calculation tools via add-on modules. A current programme maintenance has to be installed that provides support for acute bugs. Thus will be assured that the programme can be used for a long time and that the initial costs will amortize.
- The programmer has to be a professional.

These general requirements will mostly be met by the existing software tools mentioned above. But in the assessment of road safety measures special problems occur that will exceed the general requirements. Additional conditions have to be fulfilled by a software tool that will be used for the assessment of road safety measures.

- A multitude of different road safety measures (e.g. infrastructure-related or vehicle-related measures, educational measures) exist. Therefore the software has to be applicable to a broad range of measures.
- The main focus of the software must be the evaluation of road safety measures. Thus it can be assured that characteristics and particularities

of these measures can be taken into account. If the software tool is programmed for other assessments (e.g. road investments, environmental projects etc.), road safety will mostly be treated as a side effect and specialities might not be considered.

- A fall-back level in the software that bridges missing values has to be included. This might be done by a provision of experience values if trustable data is not available (e.g. for impacts).
- The programme should provide a mode of operation that is able to test – during the data input – the trustworthiness of a calculation. It has to be tested if a valid calculation can be guaranteed despite the fact that there occur missing values.
- The software tool must provide different calculating levels. The possibility should exist to do a rough calculation as well as a very detailed cost-benefit analysis. This leaves the option to the user to test the general efficiency of a measure if restrictions in terms of available data, time, or budget for a detailed CBA have to be included.
- A mode of operation can be included in the software tool that – after release by the programmer – stores the calculation automatically in a (online-) database that is accessible for a network of users.
- The results of the calculations have to be presentable in different modes. The programme should be able to display the results in table form and as a graphic data output that gives a quick overview of the main results. The possibility to display the cost-benefit ratio as well as the physical impacts of a measure (e.g. 'cost-benefit-ratio x equals a reduction of y crashes with introduction of this measure') should also be included. This increases the tangibility of the results for non-economists.
- For international use, input and output of the software tool have to be harmonized. The software should include mode operations that convert currencies or distances (e.g. Euros into British Pounds, kilometres into miles) and use the same calculation functions.
- The software tool has to be dynamic. Updates should be started by the tool itself, regarding certain parameters for the calculation (e.g. price indices).

There is no obligation that all these points have to be fulfilled by a single tool to ensure the applicability of an assessment tool or the validity of a calculation. Especially multi-usable assessment tools will only cover a small part of these demands. But the catalogue of requirements can provide useful assistance to the development of a new software tool that will be exclusively designed for assessing road safety measures. To extend the application of monetary assessment tools for the implementation of road safety measures, software tools have to be developed that meet the special requirements of the measures. Therefore it has to be the objective to create an adequate software tool that complies with the qualifications and is able to assess most kinds of road safety measures.

As described above, there are a number of software packages available that enable CBA calculations to be applied to the evaluation of road safety measures. It is suggested that in WP 4 of the ROSEBUD project, which deals with the complete cost-benefit evaluation of a number of road safety measures, to be selected, the application of such a software package be evaluated as part of the process.

4.4. Thoroughness of the analysis

As mentioned before, the interviewees in WP 2 often remarked that the complexity of monetary assessment tools will bar decision makers from applying these methods. When regarding the process of decision making in road safety, it becomes clear that the complexity of efficiency assessment tools will be a very important factor for nót using them. As the determining terms for decision making about the implementation of a measure are time and budget, the complexity of a method can be decisive for its application.

In the application of road safety measures decision makers are often pressed for time. This is caused, on one hand, by the acute call for action (e.g. focal point of crashes) in road safety. Additionally, road safety decisions are often exposed to public pressure. Therefore, support in decision making can only be given by an efficiency test that can be carried out instantly and rapidly. The best assessment tool within a given time budget then must be chosen. For this reason the application of a time-consuming CBA will often be neglected or even avoided for road safety measures.

At the same time, the application of road safety measures faces a financial budget restriction. Especially on the regional or local levels, decision makers generally have only a small budget for road safety measures at their disposal. But also on the National and European level, the financial resources for extensive research and monetary assessment of measures are limited. Not all measures can be assessed extensively by detailed CBAs or CEAs. This is even strengthened by the fact that the application of a CBA or a CEA is very cost-intensive and therefore the small budget for road safety measures will be additionally burdened. For this reason, a selection according to the priority for extensive assessment among the measures has to be carried out. Nevertheless this does not necessarily imply that monetary assessment tools cannot be used at all. There are several possibilities to reduce the effort that has to be made for the application of such tools.

- To some extent the collection of specific data can be substituted by backup-data: if, for example, no information about crash costs for a certain measure is available, experience values and fluctuation margins can be used for a first assessment of the general efficiency of the measure. Physical impacts of measures can be appraised by the formulation of case scenarios.
- Helpful in this context will certainly be the compilation of a data base in which the corresponding data from former analyses is stored. This data will then be at our disposal for future research. This helps to reduce the effort of data-collection.
- Furthermore, the analysis can be simplified if the assessment is done only for a representative section of the total project (typical project section) and only for a reduced project-duration. The results of the assessment for the project section can finally be transferred to the whole project. This reduces enormously the research activities and the efforts that have to be made for the calculation if the assessment would be done for the entire project.

The restrictions mentioned above prompt the question of how thoroughly a monetary assessment of a certain road safety measure has to be done. The reasons for and against a detailed analysis have to be balanced. As seen before, there is a trade-off between the thoroughness of the evaluation and the time and financial budget. It has therefore to be the objective to find the right level of thoroughness for every single measure. Hereby the following factors will be decisive:

- Characteristics of the measures: Do 'small' measures with low costs have to be assessed? In most cases the application of a detailed analysis will not be economically justified. The efforts for the analysis will be too big compared to the impacts. But if a measure is assessed that is of great importance with regard to safety, or that needs a high financial budget, then a detailed assessment is needed to ensure the efficiency in the application of funds.
- Will a new measure be introduced or is a measure where the impacts are well-known being applied? If experience has already been collected concerning the efficiency and adequateness of a certain measure (e.g. by ex-post analyses), this can be used in future assessment.
- A common reason for not applying CBA or CEA is missing data for quantifying the effects of a measure. Missing information about crash cost rates can, for example, hinder the application of a CBA. Only if all relevant data is available, can a detailed monetary assessment be executed.
- The objectives that are underlying the assessment can affect the thoroughness of the analysis. The stronger the opposition by interest groups to the implication of a measure, the more important is a detailed assessment of this measure to ensure that all relevant factors are taken into account. But if it is obvious that there is consensus between the stakeholders and decision makers concerning the efficiency of a measure, it can be more acceptable to reduce the assessment to a rough calculation.
- The point in time where a monetary assessment will be carried out within the planning and implementation period of a measure is decisive: If the assessment is planned as a first check of the general efficiency of a measure within the planning period, often a rough calculation will be sufficient. If needed, the results can be confirmed later on by a detailed analysis in a subsequent stage in the decision making process.
- Last but not least, the time- and cost aspect is also decisive. If such restrictions underlie the decision making process, often only a rough appraisal of efficiency can be done. A certain degree of inexactness has to be accepted to do a monetary assessment of the efficiency of a measure within a designated frame of time and costs.

The factors mentioned above create a decision making framework that helps to determine the right level of thoroughness of the monetary efficiency analysis for certain road safety measures. However, it has to be considered that a detailed analysis generally has to be preferred to a rough calculation. The different possibilities to reduce the complexity of a monetary assessment should rather be regarded as an alternative in those situations where a detailed assessment seems not to be applicable due to the reasons discussed above. This can be essential e.g. at the regional and local decision making level, where a detailed monetary assessment often faces financial budgeting restrictions.

4.5. **Position of the CBA in the decision making process**

In WP 2, two barriers were mentioned concerning the position of a CBA in the decision making process. The first barrier mentioned was a possible wrong timing of the CBA information in the decision making process. The information could be too early to be effective, or (more common) too late. Also the amount of desired information differs per phase of the decision making process. Indirectly, a second barrier appears here: the costs of a CBA are usually considerable. This can hold back policy makers from executing a CBA. In some phases of the decision making process, less information for less costs may be preferred.

4.5.1. *Rational decision making model*

The goal of a CBA is not to replace the decision making, but to deliver clear policy information about costs and effects. A rational or analytical model of a decision making process shows the following phases (March & Olsen, 1976 and May & Wildavsky, 1978):

1. Formulation of the problem the policy has to solve;
2. Gathering information about the problem and possible solutions, including effects and costs;
3. Weighing the possible solutions against each other;
4. Choosing for the best option: most effective and efficient;
5. Implementing the policy;
6. Evaluating: was the policy indeed effective (problem solved?) and efficient (C/B ratio)?
7. If necessary: repeat from 1.

This is a purely rational, somewhat exaggerated, decision making model, an ideal-type. In this model, CBA information fits in the second step: gathering information about possible solutions for a well-formulated problem. In practice policy makers do not always wait with weighing the alternatives until all information is present, and the execution of CBAs takes a lot of time. This means that information is often too late to have an impact on the decision making process. From the interviews in WP 2, the image appeared that policy makers have a need for indicative information at the beginning of the process, to make a first selection of the possible solutions. Then, later on in the process, more thorough information about the selected options is required. This decision making process is still a rational one, but with a loop:

1. Formulation of the problem the policy has to solve;
2. Gathering indicative information about the problem and possible solutions (e.g. the maximal potential effect of a measure), including effects and costs;
3. Weighing the possible solutions against each other;
4. Make a first choice for some 'best options';
5. Gather more thorough information about these options;
6. Choose the best of these options: the most effective and efficient;
7. Implementing the policy;
8. Evaluating: was the policy indeed effective (problem solved?) and efficient (C/B ratio)?
9. If necessary: repeat from 1.

In step 2, a full CBA will cost too much in terms of money and time. A mini-CBA may be a possibility in this case. A mini-CBA may be defined as a quick scan of solutions or directions for a defined problem. The mini-CBA was also mentioned in *Chapter 2*. It is a first analysis of as many solutions as possible. Preferably this analysis is executed before political standpoints have been taken and options have been excluded. In practice, this is not always possible, political standpoints have sometimes already been taken before the CBA has been commissioned. Furthermore, a mini-CBA is characterized by the limited depth, and by the use of 'index numbers'. The availability of relevant index numbers is a condition for the execution of a mini-CBA. A mini-CBA should be able to be executed within a few weeks (Buck Consultants, 2002). One of the limiting factors in the conduct of a full CBA evaluation is that the information on costs of implementing a measure often needs a full engineering assessment. This is time-consuming and costly. As part of the mini-CBA it can be possible to work with approximate data on the cost of measures, estimated from expert knowledge. Such information needs to be confirmed in the second phase full CBA study once the measure goes through to this second phase.

In step 5, a full CBA may then be executed on a few selected options. For the position of the CBA in the decision making process, it is necessary to coordinate the execution and appearance of the CBA study with other studies and reports (obligatory or not), for instance the environmental impact reports. Care must be taken for duplication in the reports, or a bad coordination of the timing. The reports preferably must have the same scope in terms of the reach of the options they investigate and the details of the effects.

4.5.2. *Legal embedding*

In addition to the introduction of the mini-CBA, legal embedding of the CBA is another tool to reinforce the use of CBA in the decision making process. This obligation might be restricted to large projects at the national level, or to projects with possibly severe impacts on safety, environment and/or mobility. Some advantages and disadvantages of an obligatory CBA can be mentioned. The most eye-catching advantage is of course that the need for executing a CBA will increase. Policy makers are forced to consider the outcomes of the CBA. However, some disadvantages are attached to the legal embedding. The obligation to carry out a CBA may slow down the speed of the decision making process, which in most countries already is quite low for infrastructural projects. Furthermore, an obligation to carry out a CBA at a certain phase of the decision making process, makes the process rigid. Coordination with other studies or anticipation of new developments in the process will be harder. Since decision making processes are not as rational as is suggested above, deviations from the rational process constantly occurr, due to political and practical arguments. Legal embedding of CBAs makes it harder to anticipate these changes. Beside these disadvantages, the costs of the decision making process will be higher if a CBA is compulsory. Last but not least, legal embedding of the CBA study does not necessarily motivate the policy makers to pay attention to the outcomes. Sometimes the legal embedding causes irritation, because of the obligatory character. The consequence can be that less attention is paid to the results of the CBA than is desirable.

In some European countries, a CBA is compulsory for large infrastructural projects. This is the case for example in Great Britain, Germany, Italy, and the Netherlands, and recently also in Hungary. Evaluations of this obligation are not available in each of these countries. In Hungary, the obligation is too recent to be able to evaluate the measure. In Italy, a feasibility study is compulsory for all infrastructural initiatives above 20.000 million lira (about 10 million Euro). A CBA is a standard part of this feasibility study. However, evaluation of this obligation shows that the CBA-part of the feasibility study is rarely applied and tends to be done 'according to whether it is convenient' (ECMT, 2004). In the Netherlands, a first evaluation of the guidelines for the application of CBAs in large infrastrucutural projects was made in 2002 (Buck Consults International, 2002). It states that the obligation has a positive effect, it helps to bring more professionalism and transparency in the decision making process. Road safety is a regular part of the CBA, as part of the external costs of roads.

Germany has an intermodal assessment model to compare the costs and benefits of various types of transport (de Jong, 2000). A CBA is part of this assessment model. The methode is standardized and explained in a manual. The method is also used by the federal states (Bundesländer), although they are not obliged to do so. Evaluation shows a great satisfaction in Germany with this instrument. The system has recently been updated (Federal Ministry of Transport, Building and Housing, 2002). In this procedure, the costs of property damage resulting from crashes and the monetary valauations of personal injuries are adapted.

Finally, Great Britain has an obligatory CBA for roads and public transport, which includes environmetal concerns and safety. Sometimes the CBA can not be apllied because of lack of data on the environmental or safety issues. Evaluation shows that the methodological framework is very coherent, but also strict, which makes it very difficult for lower governments to realise their proposals. This is why some lower governments tend to use an alternative methode, the Integrated Transport Studies, which is able to calculate the effects of packages of measures for various policy aspects. The national government has made attempts to integrate the two methodes (de Jong, 2000). So, although the CBA method seems very effective (virtually nor project can pass the decision making without passing the CBA), it is also considered a rigid instrument.

To conclude this section, the following remarks can be made. In the countries where a legal obligation for CBAs on infrastructural projects exists, the experiences and appreciations vary. Moreover, the evaluations did not go into detail concerning the safety effects of CBAs of infrastructural projects. Information about the obligatory use of CBAs for non-infrastructural measures is not available, but it is clear that these evaluations are much more difficult to perform than evaluations of infrastructural measures, due to lack of reliable data about effects. For this reason, and on the basis of the advantages and disadvantages mentioned above, it seems too early to recommend a legally binding EA analysis for road safety measures. However, we would like to suggest that in those countries where legally binding CBAs have to be carried out for large infrastructure projects, the safety aspects should be included as an inherent part of the procedure. This requirement could also be laid down in law. We also suggest that in those decision making processes on infrastructural road safety measures where budgets of the European Union are involved, a CBA should be part of the procedure before allocating the finances.

4.6. **Quality control**

In the interviews in WP 2, some countries (especially the Netherlands) mentioned the absence of impartial (institutionalized) quality control as a barrier for an optimal use of the outcomes of CBAs. Policy makers do not have a clear view on the quality of CBAs and are mostly not able to judge this themselves. In addition to this, policy makers lack understanding of the assumptions and uncertainties in the study. Three main instruments may be mentioned to solve these barriers: developing a standard methodology or procedure for CBAs, installing an evaluation board, and stimulating a competitive market.

4.6.1. *Standard methodology*

By introducing a standard methodology, one may easily develop a set of minimum standards which a CBA should meet. In some countries examples of standards like this already exist, the Netherlands developed guidelines for CBAs on road investments. Preferably, the standard methodology should be a European one. The second chapter of this report may be the start for such a standard methodology.

4.6.2. *Evaluation board*

Roughly spoken, there are two possible forms of an evaluation board: a permanent one or an ad hoc board of experts. Because of the barriers mentioned above, the board should be independent of the institute which carries out the CBA and of the institute which commissioned the CBA. An ad hoc board of experts has the advantages that a tailor-made board can be formed, with experts relevant to the project. The disadvantages of an ad hoc board (or advantages of a permanent board) are larger in number, but do not necessarily carry more weight. A permanent board will give more continuity and consistency in the judgement of CBA studies. This will eventually cause a greater impact of the evaluation. For an ad hoc board, it is harder to keep continuity and consistency, unless one develops a (more or less fixed) evaluation framework. Besides, the acquisition of the ad hoc board can be hard: the question is if experts will take time to participate in such an evaluation board. The quality control of CBAs must have a high profile to attract people to participate, or a compensation must be given.
An evaluation board may be most appropriate for CBAs at the national level and for large projects.

It may be considered if the board of experts should have a national or an international composition. The range of experts is not always big enough in all (forthcoming) European countries to fill an entire board or to circulate experts in the case of an ad hoc board. Using international experts may thus be a solution. A disadvantage of this approach is the speed and the accessibility of the board.

Furthermore, some considerations about the timing of the quality control can be made. An evaluation of the CBA quality can be made at the end of the process, when the CBA report is ready. At that moment, the best overview over the CBA outcomes is available. The evaluation or quality control can also be done during the execution of the CBA, at some predetermined moments. This gives more opportunity to adjust the CBA-process when the quality appears not to be as expected. Quality control during the process will cost more time than an evaluation at the end.

In conclusion, a quality control for CBAs may, as the CBA itself, also be institutionalized. Roughly the same advantages and disadvantages as mentioned above for legal embedding can be seen.

4.6.3. *Competitive market/certification*

A third instrument to improve the quality of CBAs may be the stimulation of a competitive market for institutes executing CBAs. At this moment, CBAs are only carried out by a very limited number of institutes, specialized in CBAs. When the market broadens and more institutes and commercial consultancies have the possibility to carry out a CBA, certification may be a good instrument to guarantee the quality of CBAs.

4.7. **Local and regional decision makers**

Most of the recommendations mentioned above also apply for local and regional decision makers. However, in some ways, decision making on these levels has its own problems and possibilities. In general, we can say that the road safety measures taken at regional and local level are smaller, less complex and more standard than the measures on the national level. Therefore, the costs and time spent for a CBA have to be lower. On the local and regional level, policy can be more tailor-made. On the other hand, the number of employees working on road safety will be lower than at the national level, and the knowledge level will be lower. The regional and local levels also have more direct contact with the public than the national decision level. Therefore, some specific recommendations for regional and local decision makers can be made regarding the position of the CBA in the decision making process, the quality control and the presentation of the results.

First, since local and regional governments will be taking many comparable road safety measures, it seems possible and helpful to prepare a manual about the possible places of a CBA in the decision making process. This helps provinces and municipalities to decide easily on a set of measures without having to re-invent the wheel concerning the process.

To lower the costs and time for a CBA, municipalities and provinces can work with the mini-CBA. In this CBA, index numbers are used to simplify the calculation. It is also possible to make a standardized version of a CBA of a specific measure, in which local authorities only have to fill in some specific parameters for their municipality. In this way, local and regional governments do not need to have much knowledge about the details of the calculation or the technique of CBAs and will still be able to use them for a previously determined set of measures.

Even more then at the national level, it will be important to communicate the results of the CBA to laymen such as local and regional politicians and citizens. The outcomes of the CBA can be simplified even more than mentioned above, by visualizing the results in diagrams, using colours instead of numbers.

Concerning quality control, a standard methodology for CBAs will be the best guarantee for quality. Most CBAs performed by regional and local communities will be too small and too standardized to benefit from an evaluation board. Certification of commercial consultancies, on the other hand, will be very useful for provinces and municipalities who want to hire a subcontractor to be assured of a certain quality level.

4.8. Multiple decision makers

In most cases, there is only one official decision maker who has the formal power to decide on road safety measures. This will often be one of the governmental levels in a country. But this decision maker often will need support to implement the measures. Sometimes, the need for this support is officially laid down in law through an obligation to hear different parties such as other governmental levels and pressure groups. Sometimes, this obligation is not present, but the need is still felt by the decision makers. Although in such a case the decision maker is formally entitled to make whatever decision he likes, in practice he will need other parties to implement the policy and will have to be able to enforce the measures.

To gain support for ones policy, it is important to involve the parties in the policy process which are needed for implementation at an early stage. This includes also (or specifically) possible opponents of the policy. Pressure groups for road safety can not be missed here (Bax, 2003).

Concerning the CBAs, it is important to agree at an early stage on the scope of the CBA and the terms under which it will be performed. This includes the consultation about assumptions, parameters used in the calculation and index numbers. If these topics are not agreed upon, the outcomes of the CBA will not be accepted by the different parties involved. In the case that an agreement on these points is not reached, different CBAs with different assumptions or parameters can be made to clarify the importance of the various assumptions or parameters. The decision as to which assumptions to use will be pushed to the end of the decision making process in which politicians play a larger role. A last item that may be important for the parties involved in the decision making process, are the distributional effects of measures. These can be very different for the various parties. It is therefore important to include these distributional effects in the CBA.

4.9. Conclusions

In this chapter, possible solutions to the issues of relative barriers such as a limited (time) budget, complexity of the assessment, the non-existance of an impartial quality check and the possibility of a wrong timing of the CBA in the decision making process are presented.

A first step to overcome the barriers is defining and formulating the decision problem and choosing an adequate evaluation method. Depending on the form of the results, the ranking of the options, the objective of the evaluation, and eventually missing data a CBA or a CEA can be chosen. To upgrade the quality of a CBA or CEA (standard methodology) and to cut down the costs of executing the method, using a computerized assessment tool can help. An overview of existing tools is presented and the tools are compared on the issues of the area of application, the contents, the target group of the tool, the availability of an information tool and quality control, and on the presentation of the results. Furthermore, a list of requirements for both existing and new computer tools is presented, consisting of general technical requirements (which are met by the existing tools) and specific requirements for road safety measures. An investigation of the existing tools with the special requirements for road safety measures of this list has not been executed, but should be part of the work to be performed in the following ROSEBUD Workpackage 4.

To save money and time, and to reduce the complexity of (especially) the CBAs, the thoroughness of the analysis can be varied by using or developing various forms of CBAs. Backup data can be used instead of specific data for a measure. The compilation of a (European) database will be very helpful in this. A plan or scheme for the development of such a database can be made in one of the following workpackages of ROSEBUD. The CBA can also be restricted to a specific section of the project and the results extended to the project as a whole. Not in all cases a full CBA is necessary. This depends, amongst others, on the characteristics of the measure (big/small measure, well known or new), the objective of the assessment (for example convincing opponents), point of time where the EAT will be done (first check in beginning of decision making process) and the available time and budget of a project. Conducting a mini-CBA as explained in *Chapter 2* should be considered. This will not only save money and time, but can also be a solution for bad timing of the CBA in the decision making process. The mini-CBA can be used at an early stage of the decision making process to make an inventory and first selection of all possible policy options. This way, the CBA information can be available in time. A more thorough analysis can than be done at a later stage in the process. Another way of forcing a CBA at an early stage of the decision making process is to take care of legal embedding of the CBA in certain kinds of decision making processes, such as decisions about large road investments. Pros and cons are mentioned in this chapter. It seems too early to recommend a legally binding CBA for road safety measures in all European countries, although we do recommend that in those decision making processes about infrastructural road safety measures where budgets of the European Union are involved, a CBA should form a part of the procedure before allocating the money. The recommendation of the obligation is restricted to infrastructural measures, because the performance of a CBA is more difficult for non-infrastructural measures, because of lack of reliable data about the effects of the measures. Furthermore, in those countries where legally binding CBAs have to be carried out for large infrastructure projects, the safety aspects should be included as an inherent part of the procedure. To improve the quality and ensure that an impartial quality check is included in the process, the following things can be done. The use of a standard methodology could be an assurance of the quality of a CBA. Furthermore, a permanent or ad-hoc evaluation board could be installed for large CBAs. The pros and cons for both options are mentioned in *Section 4.6*. The following workpackages could experiment with various types of evaluation boards.

To conclude, some remarks are made in this chapter about the situation in which local decision makers or multiple decision makers will perform (or give an order for) a CBA. Most of the recommendations mentioned will be of use for these groups. A manual for the possible (or even best) place of the CBA in the local or regional decision making process can be helpful for municipalities and regions. The use of a mini-CBA or a standardized version of a CBA for a specific measure is recommended. A municipality or region can add or fill in its own parameters. Standards could be developed in future workpackages. In the case of multiple decision makers, it is recommended to include all relevant parties as early as possible in the decision making process. In this way the scope and terms of the CBA can be agreed upon at an early stage.

5. Creating conditions for the use of CBA/CEA

Charlotte Bax and Charles Goldenbeld (SWOV), Péter Holló (KTI)

5.1. Introduction

It is not only important, as mentioned in the previous chapters, that CBAs and CEAs are performed technically correctly; it is as least as important to make sure that the information reaches the decision makers who have to use the outcomes. Two issues are of interest here. First, the presentation of the EAT has to be done in a way that ensures that the subject is understandable and accessible. Thick reports, unclear tables and incomprehensible language are undesirable and counter-productive. Besides, it helps when decision makers are explained the methodology and outcomes of the EAT. In this respect, every kind of decision maker has a demand for different kinds of knowledge. The information can also be offered in various forms for the different kinds of decision maker. In this chapter we will first mention how the presentation of the outcomes of EATs can be handled. After that, the informing, education, and training of (political) decision makers will be dealt with.

5.2. Presentation form of CBA results

In the WP 2 interviews, the question was asked whether another presentation of the outcomes of CBAs could promote the use of these outcomes. About 50% of the respondents answered this question positively. The respondents complained about thick reports, technical language, incomprehensible tables, lack of transparency concerning assumptions and uncertainties, et cetera.

5.2.1. *Presentation of the results*

It is clear that executing a CBA is a difficult and technical process with a lot of calculations which can not easily be explained to non-economists. But as the policy makers are the users of the information and customers, it is important to take efforts to explain the outcomes of CBAs to 'laymen'. One way to do this, is to present the outcomes of a CBA in a different way to different target groups. This way the information is made accessible on various levels. For instance, an executive summary, a main report, and background reports can be made. For politicians it will probably suffice to read the summary, policy makers may need some more information and will use the main report. Both will need information tuned to 'laymen'. The background reports will probably be used by experts. Information for the 'public' (citizens, interest groups, and the media for instance) will also have to be made available. As was mentioned before, the language may not be too technical, jargon should be avoided. It is recommended to let the summary and information for the public be written by a communications expert. Complementary to the report, oral presentations can be given to target groups. Of course digital information in the form of websites or databases can supply a need.

It is important not to treat the CBA as an isolated calculation. By mentioning the context of the study, the outcomes will be better understood. More precisely, one should mention the effects which are specific for this project and refer to the policy goals of the project. This will give policy makers and politicians a referential framework for the outcomes of the CBA. Furthermore, one could clarify what the criteria or matters of dispute are for the decision making. This prevents discussions about minor details of the CBA outcomes which are not vital for the policy making itself. A ranking order may be introduced for these matters of dispute, but it is not the task of a CBA to draw policy conclusions.

Second, it is important to make clear which assumptions have been used in the study. If this is not done, users of the CBA information may become suspicious, because they do not understand the outcomes. The same goes for uncertainties in the study. This should not be done in difficult, technical terms, but by translating the assumptions and uncertainties in different outcomes of the CBA (sensitivity analysis). In this way laymen can get an overview of the parts of the project which are profitable anyhow, the parts which are not profitable in any case, and the parts which might be profitable depending on the assumptions of the researchers, the choices of the policy makers, or uncertainties. It is especially important to clearly explain the parts of the CBA that are in conflict with the policy makers' and politicians' intuition. A communications expert can help to detect these parts.

5.2.2. *Specific writing tips and tricks*

- Start the main report with a summary and start the chapters or even the sections with summaries as well.
- The summary must be written clearly and not contain too much information.
- Plan enough time for writing the summary, use the help of a communications expert if necessary.
- Explain in the summary how the net present value has been calculated, many policy makers and politicians do not know this. For example, a text like this can be added (Koopmans, 2003):
  'The effects are estimated for each of the years 2003 to 2040. The costs and benefits are calculated by expressing these effects in money, on the basis of a valuation which citizens and decision makers have given to these effects. After that, the future annual amounts are 'translated' to 2003 by applying a inflation rate of 4%. Finally, the discounted annual sums are summarized. This gives an indication of the total costs and benefits for the total period of 2003 to 2040.'

Concerning the summarizing table:

- Preferably put the table on one page.
- To make this possible, only show the relatively large effects in the summarizing table (for example a maximum of 10 effects), show the rest in a separate appendix and/or mention the other effects in a footnote.
- Use different scenarios in one table, but not too many.
- The relationship between monitary values and absolute numbers (of casualties) should be clear for laymen, put them next to each other in a table. For instance:
  1. First column: description of the character of the effects;

2. Second column: non-monitary (absolute) effect (number of casualties);
3. Third column: monitary effects (if possible).

- If effects can not be expressed in money, do not use the Pro Memoria item, but try to express the effect in other quantities or in plus and minus signs. Give a (short) reason why the effect can not be expressed in money (not examined, not known, negligible et cetera). Mention these non-monetary effects also in the total sum of the CBA.
- Depending on the needs of the policy makers, use one (or more) representative year (e.g. the year of the road safety target) to illustrate the effects, or totalize for the total project range. The most desirable form depends on the policy goals.
- An example of a summary table is given below:

	Effetcts in 2030 in euros	**Effects in 2030 in other quantities**	**Net present value 2010-2040**
Benefits:			
i.e. Safety	Euro	Casualties	Euro
i.e. Travel time	Euro	Hour	Euro
i.e. Air pollution	Euro	Kg CO_2/No_x	Euro
…	…	…	…
Total benefits	Total Euro	No total	Total euro
Costs:			
Investments	Euro	Euro	Euro
Maintenance	Euro	Euro	Euro
Total Costs	Total euro	Total euro	Total euro
Balance	Euro	No balance	Euro

Table 5.1. *Example of a summary table.*

5.3. Training of decision makers

This section addresses two questions:

1. What role can education play with regard to the use and implementation of Efficiency Assessment Tools (EATs) in the field of transportation?
2. Which types of education are available or can be developed in order to bring about changes in knowledge and skill amongst professional decision makers?

In *Section 5.3.1* a short introduction is provided concerning educational goals relevant for EATs. From these general goals, specific training objectives can be derived. *Section 5.3.2* addresses the question of specific EAT-related training objectives for various types of EAT user groups (politicians and civil servants). Section *5.3.3* describes several educational methods or instruments which can be used to achieve training objectives.

5.3.1. *The role of education and training*

In general, education can be defined as a specially planned, structured process aimed at improving knowledge, motivation, behaviour and skills by way of providing specific information, experiences and feedback. With regards to EATs education can be used to achieve the following goals:

1. Achieving a better conceptual understanding, insight into the basic philosophical and technical assumptions underlying EATs;
2. Providing encouragement for application of EATs to various traffic/transportation measures by providing inspiring examples and new knowledge;
3. Achieving better skills to present the method, assumptions and results of EATs in a convincing, clear and persuasive way;
4. Increasing insight into the pros and cons of particular data sets needed to perform EATs;
5. Enhancing several theoretical and technical skills to use an EAT.

Although education and communication alone cannot overcome all possible barriers against the use and implementation of EATs, it certainly can provide motivation, knowledge, and skills to overcome some of them.

Irrespective of whether education is aimed at children or adults, or aimed at providing knowledge or skill regarding EATs or painting skills, there are some basic principles underlying all educational programmes. Effective educational courses or programmes are guided by a clear description of training objectives (stating what the student should know or be able to do after following the programme) and a clear description of programme elements (quality of teacher, didactic methods, sequence of training subjects, learning plan) which are necessary to achieve a durable change in knowledge or skills. In general, educational programmes will be more successful in achieving effects to the extent that students are better motivated to learn, teachers have higher didactic qualities, good learning materials are provided, and the programme is more adapted to the specific learning needs and capabilities of the students. Especially with regard to training of adult professionals, it is important that education or training is adjusted to specific needs or experiences of the students and that the training makes good use of the knowledge that students may already have. In adult education, trainees may also learn a lot from one another. Therefore, exchange of ideas, experiences and solutions amongst practitioners in the field of transportation and safety can be a crucial part of the whole learning process.

The design of a new educational programme should be steered by a formulation of all the training objectives the programme aims to realise. Training objectives describe what the student should know, what he or she should be able to do and also certain attitudes or motivation he or she should preferably show. Thus, training objectives fulfil several functions:

1. They help design and implement an educational program;
2. They help students to decide whether the programme suits their interests or needs;
3. They provide basic measurable terms of reference which can be used to evaluate the success of the programme.

5.3.2. *EAT-related training objectives for specific user groups*

In practice, various types of politicians and civil servants in the field of transportation and safety will have different tasks and different questions with regard to EATs. A few examples may easily illustrate this. The national or provincial politician may have to think about whether a request for an EAT would be appropriate for a certain policy which is under political review. The case may also be that the politician has read an EAT report about a certain controversial policy, but he/she is not certain how the information in the report should be appraised. A decision maker in a Ministry may have an assignment to prepare a contract/an offer for performing an EAT, but he may not feel sure about what the terms of reference should be. A professional in lower or middle transport management may have some fairly good knowledge about the basic principles of EATs and may be thinking about performing an analysis on his/her own, but is not sure about particular technical details of the analysis he/she is planning.

So, although political decision makers do not need to have detailed knowledge of CBA methods, they should be informed about the existence and nature of the method so that their decisions become more established, objective, more efficient economically, and therefore more justified and 'defensible'. It is enough if the decision makers are aware of the efficiency of the different applicable measures and the list of materials with the surveying results available to them in a concise and easy to understand form. They must know that the CBA has to be a part, or rather a precondition, of the decision. It would be useful if the decision makers themselves could formulate their own requirements on the application of the method, and on the expected results. They have to be informed whom they can contact in a given case if there is no available CBA result. They must be acquainted with the professional organisations and the expert groups dealing with the theme (institutions of higher education, research institutes, experts' associations, etc.)

Of course the situation is basically different in the case of professional decision making, notwithstanding that this also varies depending on whether the high level or middle level management is concerned. Professional decision makers should be acquainted with the CBA method, even if in not so detailed a form as the middle- and lower level managers. The professional high level managers may not be supposed to carry out themselves such analyses, but they must be well informed about the details, the possibilities and the costs concerning the application of the method. The middle- and lower level managers themselves may perform such analyses but they can closely cooperate with the experts of the analyses. Therefore, the necessary tools (software, handbooks, thesaurus of examples, etc.) and detailed knowledge are important for the application of the method. In our case, training should deal with all these questions. According to our present knowledge, the higher-grade institutional courses seem to be the most appropriate for this.

Concerning the contents of the necessary information for decision makers, these are also closely related to the character and the level of decision-making.

The information important for political decision makers is the following:

- Importance of CBA in the cost efficient use of the available resources;

- Comprehensive, concise references, well and easily usable in practice, enhancing the safety effect of different measures and containing their cost/benefit ratio;
- List of professional associations dealing with CBA.

Further information essential for professional decision makers:
In case of high-level leaders:
- major methodological questions, considerations in relation to CBA application;
- the scope and composition of the demands on the CBA necessary for decision-making.

In case of the middle- and lower-level leaders:
- major practical questions related to the application of CBA ('tricks');
- data necessary for the application of CBA;
- necessary tools of CBA application.

Preferably, education programmes address specific information or knowledge needs of different user groups. In the field of transportation and safety, as in many other fields, politicians and civil servants are typically faced with the following types of tasks:

Task 1. To assess whether information from an EAT would be appropriate for decision making about certain policies, given possible constraints arising from the political process or the policy under consideration.

Task 2. To assess what type of EAT (CEA/mini-CBA, CBA) would be best suitable to provide strategic information for the problem under consideration.

Task 3. To assess during which phase in the (political) procedural process information of the EAT is necessary.

Task 4. To assess how the specific information from the EAT should be weighed both against 'internal' standards (the quality and certainty of the information provided) and against 'external' standards (all other political considerations concerning the policy under review).

Task 5. To assess the specific terms of reference for outsourcing an EA.

Task 6. To assess the specific conceptual and technical steps for performing an EA

Task 7. To communicate the results of the EAT to various audiences

The knowledge and skills involved for these various tasks differs from 'simple' to very 'complex', from fairly standardized skills to creative, problem-solving skills, and from good conceptual understanding to an ability to convert conceptual understanding to the actual calculations needed to produce EAT-outcomes. The 'simple-complex' dimension is also to a large extent determined by the specific nature of the set of measures or policies under political review. For some transportation measures, the problem formulation can be fairly straightforward, the impacts can be measured reliably and the outcomes can be fairly clear and certain. For other measures, there may be various impacts in complex interaction with one another leading to very different, sometimes uncertain outcomes dependent upon the exact set of assumptions.

Table 5.2 presents an overview of the various tasks of different types of civil servants with regard to EATs.

Task	Type of user group		
	Politicians (national/ regional)	High level civil servants	Middle/low level civil servants
Task 1. To assess whether information from an EAT would be appropriate for decision making about certain policies given possible constraints arising from the political process or the policy under consideration.	X	X	
Task 2. To assess what type of EAT (CEA/mini-CBA, CBA) would be best suitable to provide strategic information for the problem under consideration.		X	X
Task 3. To assess during which phase in the (political) procedural process information of the EAT is necessary.	X		
Task 4. To assess how the specific information from the EAT should be weighed both against 'internal' standards (the quality and certainty of the information provided) and against 'external' standards (all other political considerations concerning the policy under review).	X	X	X
Task 5. To assess the specific terms of reference for outsourcing an EA.		X	X
Task 6. To assess the specific conceptual and technical steps for performing an EA		X	X
Task 7. To communicate about the results of EATs with various audiences	X	X	X

Table 5.2*. EAT related tasks for various civil servants.*

Table 5.3 provides a taxonomy of possible training objectives in regard to EATs. The distinctions regarding factual and conceptual knowledge and reproductive and productive skill are taken from the theory of Romiszowski (1981). Like other education experts, he assumes that knowledge is a precondition for skill. Factual knowledge is knowledge about facts and procedures. Conceptual knowledge is more similar to insight or understanding. Reproductive skills refer to well-learned actions, heavily based on standard procedures or standard situations. Productive skills represent the planning of new actions in response to new, complex problems or situations. With regard to EATs reproductive and productive skills can further be divided into conceptual skills (having to do with analysing a situation in words/concepts/theories and being able to communicate about this) and technical skills (analysing a situation with the help of statistical/economical/mathematical methods). This last subdivision is not specifically taken from the original theory of Romiszowski.

1	2	3	4	5
Knowledge or skill	Type of knowledge of skill	Examples of specific objectives with special attention to barriers to the use and implementation of EAT	Tasks and user groups	Educational method or channel
Knowledge	1a Factual ('recall'/'recognise': to be able to describe facts and procedures)	– is able to describe the cost-effectiveness ratio – is able to describe limitations of CEA – is able to name basic costs and benefits involved in many transport measures	Needed for all tasks 1-7. All users (politicians and civil servants of all levels)	Leaflets, newsletters, internets-sites, books, cd-rom, vocational or academic training, books or special workshops
	1b Conceptual ('insight'; to be able to describe concepts and explain principles)	– is able to explain the value principle – is able to explain the riterion of potential Pareto improvement	Needed for all tasks 1-7. All users (politicians and civil servants of all levels)	Vocational or academic training, manuals/books, cd-roms or special workshops/seminars
Skills	2. Reproductive (to be able to apply principles/proce-dures to standard situations)	2a. Conceptual – is able to come up with a fairly complete list of cost and benefits for standard transportation measures – is able to communicate the outcomes of a sensitivity analysis in clear message	Needed for tasks 1 (assess appropriateness),2 (assess type tool),4 (to assess weighing info) and 7 (communicating results) Civil servants of all levels who have to supervise or outsource this work and those politicians who need a more advanced expert level of knowledge	Higher vocational training/academic or post-academic training, or specially arranged intensive 2-3 day workshops.
		2b. Technical – is able to do a 'standard' sensitivity analysis	Needed for tasks 5 (outsourcing) and 6 (performing EAT). Civil servants who have to be able to perform an analysis themselves	Higher vocational training/academic or post-academic training
	3. Productive (to be able to plan and think about novel, complex situations/problems)	3a. Conceptual – is able to provide a list of costs and benefits for 'new'/'complex' measures	Needed for tasks 5 (outsourcing) and 6 (performing EAT). Civil servants who have to be able to perform an analysis themselves or to supervise or outsource the work	Higher vocational training/academic or post-academic training and preferably experience in particular projects (on-the-job training)
		3b Technical – is able to do a sensitivity analysis	Needed for task 6 (performing EAT) Civil servants who have to be able to perform an analysis themselves	Higher vocational training/academic or post-academic training and preferably experience in particular projects (on-the job-training)

Table 5.3. *pecific training objectives for types of user groups.*

5.3.3. *Educational instruments*

The concept of an 'educational programme' includes many forms such as class-room instruction, courses during higher vocational training, academic and post academic curricula, special workshops or seminars. Also, education can use many materials or channels/media such as leaflets and brochures, handbooks or manuals, televized lessons, or internet discussion groups. Leaflets/brochures are very good in attracting attention to new reports or developments in regard to EAT.

Obviously, in almost all EU countries academic or post-academic curricula exist in order to teach students the technical skills to execute CEA/CBA. In fact, many civil servants do not need or only partially need technical skills for their particular job. For these civil servants a one or two day workshop or seminar regarding EAT and the latest developments in this regard can be an excellent means to both enhance conceptual knowledge and skills in regard to EAT and to encourage more or better use of EAT in the own professional field. In general these kind of workshops should be well prepared.

Preferably a workshop should include the following elements:
- a pre-workshop survey in which an inventory is made of problems and questions with regard to EAT that will be addressed during the workshop;
- interaction and exchange of information between different professionals working in the same field of transportation;
- provision of several specific examples of both good and bad use of EAT (preferably examples from own country or similar country);
- provision of new and important data which can be used to improve or start a new EAT;
- special attention to how results of EAT can be communicated through figures/tables/drawings;
- a good manual containing all materials, presentations and guidelines of the workshop.There are myriad possibilities in the field of EAT education. However, in practice, financial and organizational constraints exist. Therefore, specific educational programmes will have to meet certain efficiency criteria (low costs against high effects in terms of number of trainees and importance of subject etc.). Preferably, market research amongst professionals in the field of transportation and safety should indicate the need for new educational programmes and materials with regard to EAT and should provide an indication of the economic feasibility of new educational programs or materials.

Organising the various courses on different levels could be done by various parties. Of course the government can take care of the education by organising courses herself for civil servants and politicians on various governmental levels. Besides that, a separate group could be set up within a ministry which is specialized in the use of EAT, and which offers her expertise in various projects in the ministry. This group can also make a special newsletter with information about EAT and organise a regular (for instance 2 yearly) workshop on a large traffic (safety) conference.

Apart from the government, the institutes which perform CBAs could take care of a good education of the receivers of their knowledge. These courses could be offered seperately or in a package deal together with the performance of the CBA. In this way, the courses or workshops can be tightly fitted to the target groups. Of course the market is free to offer such courses on a commercial basis, whether or not in existing structures as post-academic education and educational institutes for the government.

Part of the course material can be borrowed from similar courses in bachelor and master academies. Furthermore the courses should be fitted to the target groups (higher and lower civil servants, politicians, the different governmental levels) and preferably contain a concrete casus, so that the participants can exercise the reading and interpreting of the CBA (and may be even the performing) in practice. Various ways of presenting the material should be handled and if needed, computer tools can be used. Concerning the contents of the courses, the target herefor are extensively descibed in the preious text. We suggest that Workpackage 4 designs a concept for such a (small) course by means of a concrete casus, fitted for various target groups. The concept can also be tested in WP 4.

As an alternative to existing education – provided by schools, universities or specialized institutes – and commercially feasible new education initiatives, voluntary, informal initiatives may be undertaken or organised to increase learning about EAT. Networks of decision makers and experts may organise themselves on a voluntary basis in order to discuss important transportation subjects, and to organise free exchange of knowledge and information regarding specific transportation developments and measures. Supported by modest subsidies, special workshops or seminars can be the start of a new network of professionals who are interested to learn from one another and to exchange experiences and knowledge. Also, on-the-job training may have a more loose, informal character and could be arranged on a partly commercial and partly voluntary basis.

5.4. Conclusions

In this chapter suggestions are made how to communicate the knowledge from CBAs and CEAs to decision makers. First, this can be promoted by keeping the presentation of the results of CBAs clear and simple. Give specialized information for the various user groups and mention the context of the study. Make clear what the assumptions in the study are and consider using a communication expert to communicate the results to the users of the information.

Apart from a clear presentation of the results it is useful to teach decision makers skills to understand the CBA information properly. These trainings also have to be fit for the various user groups, while every groups (like political decision makers, high or low level civil servants) need their own type of information and skills. The form of the trainings can vary from classroom instructions in post-academic courses, to seminars organized by networks of decision makers and on the job-training. The courses can be organized by the government, by institutes which perform CBAs and by the market. The targets in terms of contents of the courses are described above. Finally, education can also be part of a more informal way of learning about CBAs such as networks of decision makers and the organisation of conferences to discuss the subject of CBA use.

6. Conclusions and recommendations

Paul Wesemann (SWOV)

6.1. Introduction

This workpackage aims at finding practical solutions for the barriers that have surfaced in WP 2.

From the start, a number of barriers were declared beyond the scope of ROSEBUD: either because of their philosophical nature (fundamental barriers), or because they are central elements in a certain system of political decision-making (a number of institutional barriers).

Some beliefs, convictions and political cultures are just too much in contradiction with the principles of efficiency assessment and are considered to be *absolute* barriers.

However, sometimes the resistance to the use of CBA is more of a practical nature (little knowledge and experience, lack of time and budget) and not a question of principles. These so called *relative* barriers may be overcome by solutions like training of decision makers or a legal obligation to apply EA tools for certain decisions, in combination with supplying budgets or offering other facilities.

The relative barriers (of an institutional or technical character) have been analysed extensively in the previous chapters. This has resulted in various types of solutions.
Part of the solutions relate to improvements of the technical features of the EA tools and their application. Other solutions relate to improvement of the performance of decision makers and analysts.

This chapter provides a summary of these solutions. Recommendations for the implementation of these solutions have been added. They have been adressed to analysts and decision makers, to one of the remaining workpackages of ROSEBUD, and to the EC in a follow-up of ROSEBUD.

6.2. Improving technical features of Efficiency Assessment

6.2.1. *Best practice guidelines*

Public authorities on the national and EU level can enhance the quality and uniformity (comparability) of efficiency assessment studies by establishing 'best practice' guidelines for the methods and techniques. These can be based on the state of the art in *Chapter 2* which outlines the two main methods, cost-effectiveness analysis (CEA) and cost-benefit analysis (CBA). After an overview of the theoretical principles and the technical framework for the application of these methods it enters into detail on the valuation of all impacts of road safety measures: safety, travel time, pollution, and noise. The chapter is rounded off with a discussion on uncertainties and equity aspects.

The sections on the theoretical principles, the technical framework of CBA and CEA, and the valuation of the impacts of road safety policy, reflect generally held views among economists, founded in neo-classical welfare economics.

According to this methodology, guidelines can be formulated for the following steps in a CBA: describing projectalternatives; estimating implementation costs, safety effects and side effects (on mobility and environment); valuation /monetising all effects; calculation of present value of costs and benefits, and of efficiency measures (NPV, C/B, IRR). A number of these activities will not be necessary if a CEA is performed.

Special attention should be given to mini-and maxi-CBA and computerized tools (presented in *Chapter 4*). Because of differences of projectalternatives, applicable data and budgets for EA, distinction should be made between decision making at the national and the local level. Situations with multiple decision makers and/or powerful interestgroups also require special attention because of the emphasis that will be put on the distributional effects.

It is acknowledged that neo-classical welfare economics does not provide theoretically sound solutions for the problems of uncertainties and equity aspects. Nevertheless it is generally felt that they should be considered explicitly. The guidelines can provide some examples of best practice solutions; e.g. a sensitivity type of analysis with scenario´s (optimistic, realistic, pessimistic) to handle uncertainties and careful descriptions of the distribution of costs and/or benefits among the various groups that are affected by a measure.

It is recommended that WP 4 will draft a first version of such best practise guidelines and test it. WP 5 could disseminate the draft version to experts and receive their responses.

It is recommended that the EC takes initiatives to establish and authorize the best practise guidelines, taking the ROSEBUD experiences into account.

6.2.2. *Creating and maintaining a database*

Lack of information on safety effects, side impacts and costs as well as doubts on the validity of the available values present one of the major practical barriers for the performance of the efficiency assessment of safety related measures (see *Chapter 3*).

In different countries, many evaluation studies have been conducted which demonstrated the effects of safety related measures on accidents. In order to make the safety effects available for CBA/CEA applications, there is a need to arrange them on a systematic basis, i.e. relevant data should be retrieved, ordered, screened and made accessible for CBA/CEA experts. In some countries there are already databases of values, which are immediately available for application (e.g. the Norwegian Traffic Safety Handbook (Elvik et al., 1997)).

To stimulate the application of more uniform and well-based values of safety effects in the EU, it would be useful to establish a *database* with typical values of the effects, based on international experience. Such a database might be accessible to a European network of experts and provide *general* values of safety effects on initial steps of CBA/CEA as well as assist in comparisons of local effects observed. The values of safety effects kept in the database should be regularly updated, in accordance with the last evaluation results in the EU.

For local applications, a collection of local experiences is usually preferable. In order to provide the local values of safety effects, a systematization of the results of the evaluation studies, which have been performed under local conditions, is required.

The database should contain information of similar quality on the implementation costs of measures and on the effects on mobility and environment.

It is recommended that the EC takes the initiative and responsibility for the creation and maintenance (updating) of such a database. In fact some start has been made recently by contracting the new EU project SafetyNet. This aims at designing an European Road Safety Observatory with a similar information system. The necessary data quality assurance will receive ample attention.

6.2.3. *A system of quality control*

In addition to the establishment of best practise guidelines, the quality of efficiency assessments can be improved by the introduction of an impartial quality control. To this end it is advised in *Chapter 4* to consider the introduction of a permanent or ad-hoc evaluation board that would judge large CBAs, at the national level. It is recommended that WP 4 experiments with various types of evaluation procedures.

Another instrument to improve the quality of CBAs might be the stimulation of a competitive market for institutes executing CBAs and certifying institutes that are highly specialised in this type of analyses.

It is recommended that the EC takes initiatives to establish quality assurance procedures, taking the ROSEBUD experiences into account.

6.3. Improving role performance of decision makers and analysts

Performing a proper Efficiency Assessment requires a close cooperation between decision makers and analysts. This process has been analysed in detail in *Chapter 4*. At the very start they should agree on the definition of the decision problem (project alternatives, relevant impacts, equity issues), whether an efficiency assessment would be feasible and useful and which evaluation method (CEA or CBA) would be adequate. Next they should discuss the use of a computerized tool, a mini- or a maxi-CBA (at an early stage and at the final stage of the decisionmaking process), the presentation format of the results, the involvement of other interested parties and the timing of the deliverables. All the agreements which are reached on these items constitute the terms of reference of the CBA. Exchanging views on these issues put demands on the knowledge and skills of the decisonmaker and on the workingmethod of the analyst.

It is recommended to support and structure this process of cooperation by introducing an informal professional code for analysts, by training and education of decision makers and by creating a legal framework for decision making on infrastructural projects.

6.3.1. *Training and education of decision makers*

The required knowledge and skills are different for each type of decision maker (like political decision makers, high or low level bureaucrats). *Chapter 5* outlines various forms of the trainings, ranging from classroom instructions in post-academic courses to seminars organized by networks of decision makers and on the job-training. The courses can be organized by the government, by institutes which perform CBAs and by the market. The targets in terms of contents of the courses are described above. Finally, education can also be part of a more informal way of learning about CBAs such as networks of decision makers and the organisation of conferences to discuss the subject of CBA use.

Increased user understanding may not be an excuse for reporting on the results of CBAs in a needlessly complicated way.

Although the education of decision makers is not ment for solving the absolute barriers, an increased understanding of the principles of CEA and CBA might weaken fundamental resistance against the use of these assessment tools as well.

It is recommended that WP 4 will design a concept for a (small) training course, eventually consisting of a number of modules that are suitable for various target groups. This concept can also be tested in WP 4. WP 5 could disseminate these drafts to the various target groups and receive their responses.

It is recommended that the EC will take initiatives to introduce training programmes for decision makers, taking the ROSEBUD experiences into account.

6.3.2. *A professional code for analysts*

Standard procedures for analysts will be helpful in dealing with these issues in a systematic way. It is suggested to establish an informal professional code. This could contain:

- checklists of items to be discussed with decision makers at the start of the assessment;
- techniques for questioning them on these items (e.g. by presenting alternative options and its consequences for the next steps in the assessment procedure);
- examples of various types of deliverables (CBA/CEA, mini/maxi, various presentation formats);
- a model for the terms of reference;

- tips for reporting (clear and simple presentation of results, well tuned to the information need of the various user groups and with mention of the context of the study and its assumptions);
- examples of the use of CBA/CEA in previous cases (at the national, regional and local level).

It is recommended that WP 4 will draft a first version of such a professional code and test it.
WP 5 could disseminate the code to analysts and receive their responses.

6.3.3. *Legal embedding*

The need for CBA in decision making can be stimulated by legal embedding of this assessment tool in certain kinds of decision making processes, such as decisions about large road investments. It is felt to be too early to generally recommend a legally binding CBA for road safety measures; more experience is needed with the application of the best practice guidelines, notably for non-infrastructural measures. But in those countries where such an obligation does already exist for large investments in infrastructural projects, it is advised that the safety aspects should be included as an inherent part of the procedure. Furthermore, it is recommended that the EC will introduce a similar obligation at the European level.

6.4. **Summary of recommendations**

Recommendations addressed to WP 4:
- draft and test a first version of an informal professional code for analysts;
- draft and test a first version of the 'best practice' guidelines for EA-studies;
- test the presented data sources;
- draft and test a first version of a (small) training course for decision makers;
- test a quality assurance procedure by experts in an evaluation board.

Recommendations addressed to WP 5:
- disseminate a second version of a professional code for analysts;
- disseminate a second version of a (small) training course for decision makers;
- disseminate a second version of the 'best practice' guidelines for EA-studies;
- receive the responses to these drafts of the various target groups.

Recommendations for follow up activities of ROSEBUD addressed to the EC:
- establish quality assurance procedures;
- initiate training programmes for decision makers;
- establish and authorize the 'best practice' guidelines for EA studies;
- create and maintain a databank (taking into account the SafetyNet plans);
- introduce a legal obligation to perform a CBA/CEA for certain decisions, both at the national and at the EU level.

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Appendix 1 Effects on travel demand in CBA

With respect to measures that affect travel demand or mobility demand (traffic volume), the relevant valuation is the change in consumers' surplus that results from the change in travel. The amount of travel depends on the generalized costs of travel. By generalized cost is meant the sum of all costs, direct out of pocket costs as well as other costs incurred when travelling, like the use of time, the exposure to pollution, and the exposure to the risk of accident.

Figure A.1.1 shows how the amount of travel done by an individual (measured, for example, as the number of trips done per day) depends on the generalized costs of travel. Suppose a measure is introduced that cuts the generalized costs of travel from 4 to 3 (arbitrary units). The amount of travel can then be expected to increase. The expected increase in travel demand is shown in *Figure A.1.1* by the lines connecting price and number of trips before and after the drop in the generalized costs of travel.

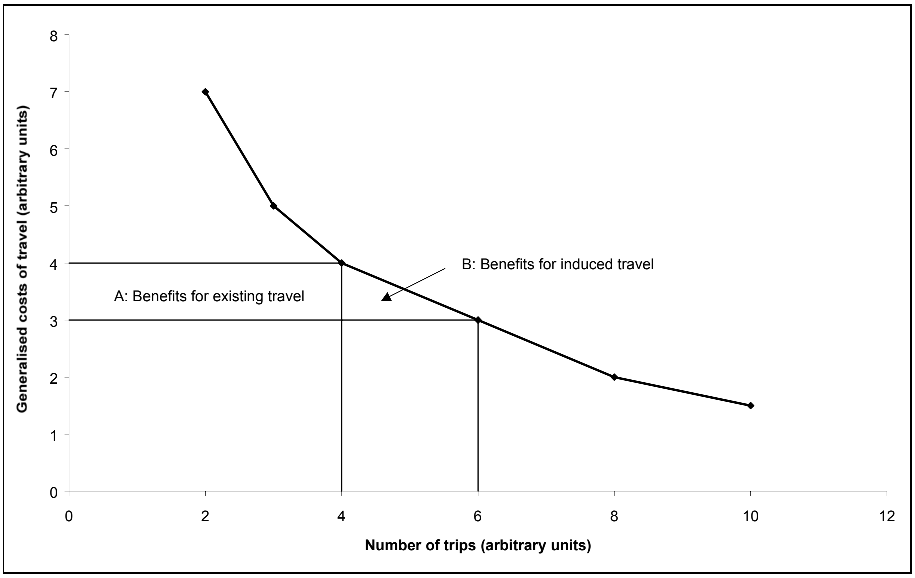

Figure A.1.1. *Illustration of the valuation of changes in travel demand in terms of changes in consumers' surplus (Source: Elvik, 1999).*

The area denoted A in *Figure A.1.1* is the benefits to existing travel of the decline in generalized costs. The area denoted B in the figure is the benefits of induced travel, that is, of the increase in travel demand generated by the decline in the generalized costs of travel. By convention, the size of the benefits of induced travel is approximated by a triangle, the size of which is estimated by multiplying the increase in travel demand with the savings in generalized costs of travel, divided by two.

Both the time value and the value of other elements in the total generalized costs of travel are in practice not known with sufficient precision. Further, it is not always obvious which items go into the generalized costs of travel. Are, for example, the harmful effects on human health of exposure to pollution fully included? We still lack knowledge about both effects on health and insecurity (Sælensminde 2002). It can be readily hypothesized that pedestrians and cyclists try to avoid the most congested and polluted roads. But, what about car drivers? Some drivers may try to avoid the most polluted conditions for the sake of their own well being, but in general car drivers cannot be assumed to include the effects of pollution in the community at large in their generalized cost of travel. Hence, most of the costs of pollution are likely to be external from a car driver's point of view.

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

Misperception of risks, costs, or other things that go into a cost-benefit analysis raises a dilemma. Let us merely note here that most economists tend to accept the observed demand for a market commodity as the correct basis for estimating the value of the commodity, following the revealed preference (RP) theory. This is maintained even if demand may in part be based on incomplete information or seemingly irrational behaviour.

Appendix 2 Controlling for regression to the mean

A regression to the mean might occur in 'after' period, due to a selection bias of sites, which were chosen for the treatment. Control for regression to the mean can be performed by the Empirical Bayes method proposed by Hauer (1997). The method relies on a comparison of the recorded number of crashs for the site considered, in the 'before' period, with the 'normal' number of crashes for similar road sites. The similar sites compose a 'reference group' for the site considered.
The long-term expected number of crashes for the site considered, removing the regression-to-the mean effect, is estimated as follows:

$$\varepsilon = \alpha E(m) + (1 - \alpha)x$$

where:
ε - adjusted expected number of crashes at the site,
x - recorded number of crashes at the site,
E(m) – 'normal' number of crashes for sites of this type[10],
α - the shrinkage factor, which describes the amount of systematic variation in the number of crashes observed in the reference group. It is given as:

$$\alpha = \frac{1}{1 + \frac{VAR(m)}{E(m)}}$$

where E(m) is the mean and VAR(m) is the variance of the number of crashes, which are estimated on the basis of reference group sites.

The value of α depends on the homogeneity of the reference group. If this group is relatively homogeneous, then VAR(m) will be small and larger weight will be given to E(m). In this case, the estimated value for the site (ε) will be closer to the mean of the reference group.

In practice, E(m), VAR(m) are unknown and are replaced by their estimates:

$$\hat{E}(m) = \frac{1}{n}\sum_{i=1}^{n} y_i = \bar{y}$$

where $y_1, \ldots, y_n$ are the crash counts in the n sites of the reference group during the 'before' period.

$$V\hat{a}r(m) = s^2 - \bar{y}$$

where s^2 is the sample variance of $y_1, \ldots, y_n$.

The derivations can be found in Hauer (1997), Hauer & Persaud (1987).

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[10] To be accurate, m – expected number of crashes for sites of this type, E(m) – its mean value

The reference group includes elements of the road network, which are similar to the sites where the treatment takes place. In the case of infrastructure improvements, the reference sites should be similar to the treatment sites in most engineering characteristics and are left untreated (unchanged) during the 'before' periods of all the sites in the treatment group.

Another way for providing E(m) is by means of a multivariate model, which predicts the crash counts for specific types of sites based on infrastructure and traffic parameters of these sites. Following Hauer (1997), the best estimate of a in this case is

$$\alpha = E(m)/[E(m) + E(m)^2/k]$$

where k is an empirically determined constant.