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Preliminary Guidelines for Priority Setting Between Measures

Deliverable D3.4

SafetyCube

Preliminary Guidelines for Priority Setting Between Measures

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Table of contents

Executive Summary

The present deliverable describes the economic assessment of counter measures. Cost-effectiveness analysis and cost-utility analysis are compared to cost-benefit analysis. *Cost-effectiveness* analysis helps to estimate the costs per prevented fatality or injury. To evaluate the effectiveness in terms of different levels of severity jointly, one has to conduct a *cost-utility analysis*, where fatality reduction and injury reduction are brought together on a joint scale: quality adjusted live years (QALY) saved. QALYs represent the years of life lost due to fatalities and the quality of life loss resulting from injuries.

Cost-benefit analysis also allows the joint evaluation of measures' effectiveness in reducing crashes of different severity. Moreover it provides information on the socio-economic return of counter measures, and in principle allows to include side-effects into the analysis. The valuation of other possible impacts of road safety measures is beyond the scope of SafetyCube, but presentation in terms of cost-benefit ratios allows for the post hoc inclusion of other impacts if DSS users have estimates of these. In the discussion of decision criteria within cost-benefit analysis it is demonstrated that measures with a high cost-benefit *ratio* (benefits/costs) do not necessarily have a large net-effect (benefits – costs). The net-present value will favour measures with large benefits even if they come at a relatively large cost, while the cost benefit ratio will favour measures with the best value for money, even if their actual benefits are relatively small (e.g., because they are targeted at a small group of crashes).

The meaning of costs in the framework of economic welfare theory (the basis of cost-benefit analysis) is not necessarily the same as in everyday language. In this context concepts like opportunity costs and discounting are discussed. Opportunity costs (the value of things you could have done with the money or resources otherwise) are usually approximated by the market price. The exception are costs that are payed from tax-money, which are brought into cost benefit analysis at a higher rate. Discounting is used to bring costs made at different points in time to the same present value. There is a relation between the discount rate and a preference for short-term vs. long term projects.

For the estimation of the cost of measures, different components and data sources for these costs are discussed with examples from infrastructure and vehicle measures. Furthermore, the report presents an overview and classification of crash costs components and estimation methods. One of the biggest components are the human costs. These are an indication of how much the prevention of crashes is worth for us (the people), which is measured by the willingness to pay method. Other costs are estimated by the restitution method (what are the costs to compensate the damage done) and the human capital approach (how much benefit would the victim have produced).

The information on economic efficiency assessment will be integrated into the SafetyCube Decision support system by means of a cost-benefit calculator that is based on the costs of measures collected in the analysis work packages (WP4, 5, 6) and costs of crashes collected in WP3.

1 Introduction

This chapter describes the project and purpose of the deliverable. A short description of the work package that produced the deliverable is also provided.

1.1 SAFETYCUBE

Safety CaUsation, Benefits and Efficiency (SafetyCube) is a European Commission supported Horizon 2020 project with the objective of developing an innovative road safety Decision Support System (DSS) that will enable policy-makers and stakeholders to select and implement the most appropriate strategies, measures and cost-effective approaches to reduce casualties of all road user types and all severities.

SafetyCube aims to:

1. Develop new analysis methods for (a) Priority setting, (b) Evaluating the effectiveness of measures (c) Monitoring serious injuries and assessing their socio-economic costs (d) Cost-benefit analysis taking account of human and material costs.
2. Apply these methods to safety data to identify the key accident causation mechanisms, risk factors and the most cost-effective measures for fatally and seriously injured casualties.
3. Develop an operational framework to ensure the project facilities can be accessed and updated beyond the completion of SafetyCube.
4. Enhance the European Road Safety Observatory and work with road safety stakeholders to ensure the results of the project can be implemented as widely as possible.

The core of the project is a comprehensive analysis of accident risks and the effectiveness and cost-benefit of safety measures focusing on road users, infrastructure, vehicles and injuries framed within a system approach with road safety stakeholders at the national level, EU and beyond having involvement at all stages.

1.1.1 Work Package 3

The objective of work package 3 is to define the methodological foundations of the road safety Decision Support System. The methodological guidelines developed are applied in Work Packages 4, 5 and 6 to identify and analyse road safety problems and measures addressing road users, road infrastructure and vehicles. A road safety decision support system should help policy makers identify important risk factors and the accidents, injuries and fatalities resulting from them; select measures by estimating their safety effects; and set priorities among measures on the basis of their costs and benefits.

To do so, results from different types of studies are collected for a broad range of risk factors and measures. The literature is reviewed for the decision support system. The studies are selected and prioritised by a systematic and documented literature search, they are "analysed" in terms of their research design and possible biases, and entered into a coding template capturing all relevant information for the Decision Support System (DSS) users. Studies addressing the same countermeasure or risk factor are summarised into a synopsis using the information contained in the coding template and other information from the literature review. Whenever possible the synopsis will result in an estimate of measure effectiveness (like a CMF – crash modification factor) and a description of how this varies across different conditions, or types of risks. The synopsis will also give an indication how well a risk factor or countermeasure has been studied.

To do so, Work Package 3 has produced two guidelines so far

- Guidelines for identification of risk factors and evaluation of safety measures (M10)
- Evaluation of measures by reviewing the literature: Search strategy, writing a topic synopsis, and meta-analysis (M11)

and will produce an up-dated and joint document of these two guidelines (M13).

The present Deliverable sets the methodological framework for the economic efficiency assessment of road safety counter-measures.

1.2 CONTENTS OF THE GUIDELINES

Chapter 2 and 3 give the general principles of economic efficiency analysis. Chapter 2 describes alternative criteria for prioritising road safety countermeasures (cost effectiveness, cost utility) and compares them to cost-benefit analysis. Chapter 3 zooms in on cost-benefit analysis and describes what it is used for, the underlying assumptions and different possible decision criteria.

In Chapter 4, 5, and 6 the input to cost-benefit analyses is discussed, the monetary valuations of crashes and counter-measures. The meaning of "costs" in the framework of the economic welfare theory (which is the basis of cost benefit analysis) is not the same as it is in everyday language. This is explained in Chapter 4. In Chapter 5 we zoom in on the estimation of the costs of measures and in Chapter 6 on the estimation of crash costs.

In Chapter 7, the implementation of economic efficiency analyses in the SafetyCube Decision Support System is discussed, indicating which decision criteria are included and why and discussing the practical implementation.

2 Economic efficiency assessment

In this chapter the economic assessment of countermeasures is described. The principles of cost-effectiveness analysis and cost-utility analysis are explained and compared to those of cost-benefit analysis.

Efficiency assessment refers to analyses made for the purpose of identifying how to use scarce resources to obtain the greatest possible benefits of them. The main reason for doing efficiency assessment of road safety measures is to help develop policies that make the most efficient use of resources, i.e. that produce the largest possible benefits for a given cost**. Cost effectiveness analysis** (CEA), **cost-utility analysis** (CUA) and **cost-benefit analysis** (CBA) seek to identify the cheapest way of improving road safety and are therefore tools to help choose the policy which gives the highest return on investments. The first two analysis types will be described in the present chapter. Cost benefit analysis will be described in more detail in Chapter 3.

2.1 EFFECTIVENESS

At the basis of all efficiency assessments is the evaluation of a measure's **effectiveness**. In CEA, only one type of effect (e.g. the reduction of crashes) can be taken into account. CUA and CBA are in principle suited to take into account several different effects of a measure.

In road safety the effectiveness of a countermeasure is often defined as the number of crashes or casualties that can be prevented by it. A general definition includes also a reduction in outcome severity. In the following we will often refer to the reduction of crashes but the same reasoning also applies to the reduction of casualties or the severity of crashes.

The crashes that are potentially 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.

The number of crashes prevented, calculated on the basis of the number of target crashes and percentage effect on target crashes, defines the numerator of the cost-effectiveness ratio of a safety measure.

2.2 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:

$$\text{Cost} - \text{effectiveness} = \frac{Number\ crashes\ prevented}{Unit\ cost\ of\ implementation}$$

In order to estimate the cost-effectiveness of a road safety measure, the following information is needed (Hakkert & Wesemann, 2004):

- 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.

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 per year may be a suitable unit of implementation. Once a suitable unit of implementation is defined, unit costs can be estimated.

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 therefore highlights the safety effects of measures.
- 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.
- The cost-effectiveness criterion cannot be used to trade off safety against other policy objectives. It disregards the effects of safety measures on mobility and the environment.
- The criterion does not say at what level of cost-effectiveness a measure becomes too expensive.

2.3 COST UTILITY ANALYSIS

In recent time there is a growing awareness that the burden of road crashes does not only concern road crash fatalities but to the same extent the number of serious injury casualties. While the costs in terms of human suffering might be smaller for injury crashes than for fatal crashes, the number is so much larger that in economic reasoning there can be a trade-off between the two and the reduction of injury crashes is more and more becoming its own objective rather than being considered a natural consequence of reducing fatal crashes.

Moreover, it has been shown that injury crashes do not necessarily develop in parallel with fatal ones (e.g., ETSC, 2016). For example, serious injuries tend to involve a bigger share of vulnerable road users than fatal ones and they have decreased much less in the last decades than the fatal crashes

(OECD/ITF, 2015; ETSC, 2016). As a consequence, for the evaluation of road safety measures, it is important to take into account differential effects of measures on crashes of different severities.

Cost-utility analysis (CUA) is an economic assessment tool that allows inclusion of different crash outcomes in a single measure. In CUA the road safety impacts resulting from a countermeasure are expressed in Quality Adjusted Life Years (QALYs). A QALY is a measure for the health impact that combines the impacts on mortality and morbidity (injuries). The measure for mortality impact is the number of years of life lost (YLL) saved and the measure for morbidity impacts is the years lived with disability (YLD) saved. QALYs reflect the utility that is gained by preventing health loss. In cost-utility analysis the cost per QALY are calculated (similar to the cost per casualty saved in a cost-effectiveness analysis) and road safety measures can be ranked according to their 'cost-utility', that is by the cost per QALY. The main advantage of a utility-analysis compared to a cost-effectiveness analysis is the fact that a different value is attached to fatalities, serious injuries and slight injuries, based on the number of life years lost and the health impact of injuries. However, the other two shortcomings related to the effectiveness analysis discussed above also apply to the utility analysis. Moreover, calculating the number of QALYs gained by a measure may be quite challenging. This will be described in more detail in D7.3.

2.4 CONCLUSION

Cost-effectiveness analysis helps to find the cheapest way of realising one particular policy objective (e.g. reducing the number of crashes). Cost-utility analysis helps to find the cheapest way to realize multiple criteria, which are however related (e.g. different severities of crashes or injuries). Neither method is suited to include side effects of measures or other policy objectives (e.g. optimizing traffic flow, protecting the environment, etc). This is why we in the next Chapter discuss cost-benefit analysis, which allows to do that.

3 Cost Benefit Analysis

Cost-benefit estimates allow the joint evaluation of measures' effectiveness in reducing crashes of different severity and provide information on the socio-economic return of countermeasures. The underlying idea, some restrictions, and interpretation of the results are explained here.

3.1 WHEN DOES COST-BENEFIT ANALYSIS MAKE SENSE?

Cost-benefit analysis (CBA) is a formal analysis of the impacts of a measure or programme, designed to assess whether the advantages (benefits) of the measure or programme are greater than its disadvantages (costs). It is typically applied to help find efficient solutions to social problems that are not solved by the market mechanism. Typical characteristics of problems to which cost-benefit analysis is applied include (Elvik 2001):

- They involve public expenditures, often investments. Projects are sometimes financed by direct user payment, but more often by general taxation.
- There are multiple policy objectives, often partly conflicting and requiring trade-offs to be made. It is assumed that policy makers want solutions that realise all policy objectives to the maximum extent possible.
- One or several of the policy objectives concern the provision of a non-marketed public good, like less crime, a cleaner environment or safer roads.
- It is assumed that an efficient use of public funds is desirable, since these funds are scarce and alternative uses of them numerous.

All relevant impacts should first be estimated in "natural" units. Like in a cost effectiveness analysis of road safety measures, this would be the number of crashes prevented – possibly separately for different severities. But in cost benefit analysis other outcomes, like the number of additional hours of travel or the reduction of fuel consumption can (and should) also be included. To make different impacts comparable, they all have to be converted to monetary terms, that is applying monetary valuations of the various impacts.

Some people find the very idea of assigning a monetary value to lifesaving or to quality of life meaningless and ethically wrong. Human life, it is argued, is not a commodity that can be traded against other goods. However, the purpose of assigning a monetary value to human life is not to engage in trading in the usual sense of that term. The purpose is to provide ***a guideline with respect to the amount of resources we would like to spend on the prevention of crashes or injuries.***

Some form of economic reasoning – that is some form of thinking that recognises the fact that resources are limited and can be put to very many alternative uses – is simply inevitable, given the following basic facts (DaCoTA, 2012):

- A limited amount of resources are at our disposal for the prevention of accidents or injuries, or indeed for catering to any human need.
- Human needs and value systems are complex and multi-dimensional. While safety is certainly one of the more basic human needs, it is not the only one, and no society would ever be able to spend more than a fraction of disposable resources on the prevention of crashes or injuries.

- How much to spend on the prevention of crashes or injuries will depend, and ought to depend, on how important people think this good is, seen in relation to all other goods they would like to see produced.

So, while cost-effectiveness analysis simply helps to find the cheapest way of realising one particular policy objective (e.g. reducing the number of crashes), the aim of cost-benefit analysis is to help find the right balance between safety and other possible objectives. Instead of interpreting one specific objective as absolute, CBA evaluates the economic benefits and costs of this objective in the context of other objectives. Thus, it aims to find if pursuing a proposed objective is economically efficient at all and how efficient a measure under investigation is with respect to the combined objectives (Hakkert & Wesemann, 2004).

Policy options in cost-benefit analysis are always compared to a reference scenario and represent changes from that scenario. Often the reference scenario will be to do nothing, i.e. not introduce the road safety measure for which a cost-benefit analysis is performed. In some cases, however, one may foresee that a certain road safety measure will be introduced without any action from government. As an example, electronic stability control is now rapidly becoming standard equipment on new cars and will spread in the car fleet during the next 10-15 years. In such cases, the foreseen rate of introduction should be regarded as the reference scenario (DaCoTA, 2012).

3.2 THEORY AND PRACTICE OF CBA

3.2.1 How much do we want to pay for Road Safety?

In theory, the monetary value attached to each objective in a cost benefit analysis is objectively determined based on the principle of consumer sovereignty. According to this principle the choices made by consumers with respect to how to spend their income are accepted and are treated as data. Economists are not moralists. They will not say that someone who spends most of his income on alcohol, tobacco and unhealthy foods is a fool, whereas someone who saves part of his income for old age, while spending the rest prudently on safe foods and safe activities is a wise person. Economists simply treat individual demand for various goods and services as data.

The value of improving road safety is indicated by the willingness-to-pay for reduced risk of injury. Willingness-to-pay is the measure of benefits used in cost-benefit analysis. Assessing willingness-to-pay for non-market goods like road safety is a complex task, and even small changes in methodology can lead to large differences in cost-estimates. As a consequence there seems to be an element of arbitrariness in the value attached to saving a life or preventing an injury. (DaCoTA, 2012)

In practice, the valuation for crashes that is applied in a cost-benefit analysis is as much the result of a political debate as of scientific research. The largest part of crash costs consist of human costs (see D3.2). These costs do not refer to money that is actually spent, but to the value that people attribute to the prevention of fatal or serious crashes. Usually there is a (wide) range of estimates of these values available, and one of these values is chosen for use in cost-benefit analysis. Often a lower value is chosen than the values that have been found in scientific literature or a value at the lower end of the available values is chosen, in order not to overestimate the safety benefits of countermeasures (see for example Wijnen et al., 2009). Choosing a higher value can be seen as a way of formalising that it is now thought to be more worthwhile to spend money on preventing crashes than it used to be. A higher estimate of crash costs means that more (expensive) measures will be considered economically efficient when analysed in a CBA.

A more fundamental objection is that willingness-to-pay depends on ability to pay. The rich can afford to pay more for road safety than the poor. If the distribution of income is highly unequal, an indiscriminate use of the willingness-to-pay principle may lead to the provision of non-market goods, like road safety or cleaner air, only to the richest groups of the population. Since road accidents represent a threat to human health, one could argue that all groups of road users ought to have equal access to measures intended to improve road safety, irrespective of their individual demand for it. The question becomes even more complicated when the CBA does not concern the provision of a safety-measure as a public good, but the legal obligation for the individuals to provide it themselves (e.g. taking lessons for a driving licence or undergoing a medical exam to prove their fitness to drive). For the poorer groups, the costs that are forced on the individual by such a measure might not fit their willingness to pay.

Difference in willingness to pay becomes particularly relevant when considering cost-benefit analyses at an international level. The value of a statistical life in Sweden is more than 4 times larger than in Portugal (see D3.2). This means that a CBA at European level (e.g. for the introduction of a directive that makes the implementation of a particular safety system mandatory) underestimates the value of road safety for Sweden and overestimates it for Portugal. While for some measures only a Europe-wide implementation makes sense, this will lead to a situation where the net benefits for Portugal are lower than for Sweden. Possibly Portuguese buyers have to pay more than they want for the safety of their vehicle, while the willingness to pay for Swedish drivers is higher than the price they actually pay.

3.2.2 Who pays what?

Cost benefit analysis does not say anything about who pays the cost and who receives the benefit. In theory, a measure should improve the welfare of at least one person without reducing the welfare of any other person – or in economist terms it must be Pareto-optimal. In practice, this is very rare. For many measures there will not only be gainers but also a few losers. For example, a law requiring bicycle helmets must apply to all cyclists, although some cyclists will be less involved in accidents than others and will therefore benefit less from a helmet. The problem that a measure cannot be tailored to the individual demands of each and every person is called indivisibility (Elvik, 2014). It means that countermeasures cannot be divided in sufficiently graded alternatives (e.g. judging for each cyclist separately whether for him a helmet is necessary) to permit strict optimisation. Therefore in practice a less strict criterion is applied: those who gain from a measure have to gain so much that they are (in theory) able to compensate those who lose from it, while still retaining a net benefit. This softer criterion is called *potential Pareto-improvement*. A measure is commonly regarded as satisfying this criterion if its benefits are greater than the costs.

Furthermore, cost benefit analysis remains neutral with respect to the distribution of benefits and costs among groups of the population (or groups of road users, for that matter). Cost-benefit analysis is not intended to help find the most equitable solution to a social problem, only the most efficient solution. An example of this problem is the observation that the measures addressing car-users tend to be more cost-beneficial than a measure protecting pedestrians or cyclists. To the extent that realising a desired distribution requires the use of other policy instruments than those sanctioned by cost-benefit analysis, it follows that actual policy priorities cannot be based on cost-benefit analyses exclusively (DaCoTA 2012).

3.3 DECISION RULES

The main result of a cost-benefit analysis is a monetary estimate of the benefits and costs of a road safety measure. A measure is cost-effective if its benefits are greater than its costs. In general, the term costs refer to any negative impacts of a measure. By convention, however, the costs of a measure are normally defined as the costs of implementation and other negative impacts are defined as negative benefits.

The objective of cost-benefit analysis is welfare maximisation. Welfare is maximised by maximising the difference between benefits and costs, the net present value. As an example, consider the five road safety measures listed in **Table 3.1**. For each measure, three statistics showing its benefits are given: (1) Its effect on the number of fatalities, (2) Net present value = Benefits - Costs, (3) The benefit-cost ratio = Benefits / Costs. The measures have been sorted according to their effect on the number of fatalities.

Table 3.1 Choice between five road safety measures based on net present value (source DaCoTA 2012)

Measure	Fatalities prevented	Net present value	Benefit-cost ratio	Choice
Intelligent speed adaptation on all cars	34	7441	1.51	1
3.5 times more speed enforcement	21	855	3.28	4
4 times more random breath testing	16	716	4.62	5
Seat belt reminders in all cars (now 58 %)	10	3952	7.93	2
Front impact protection on heavy vehicles	7	1560	2.52	3

Which of these measures should be introduced first? Intelligent speed adaptation is the first choice, because it has the largest net present value (i.e., surplus of benefits to costs). It does not have the highest benefit-cost ratio; on the contrary, it has the lowest. This seeming contradiction results from the fact a ratio does not account for the scale of a measure. Mounting ISA to all cars has a very high cost but an even higher benefit (in terms of fatalities prevented). As both – costs and benefits – are large numbers, the difference between the two (i.e. the net-present value) is very large as well, even if the ratio of costs and benefits is actually a lot smaller than that for other measures, where both the costs as well as the benefits are smaller.

It is mostly advised to use the net-present value rather than the benefit-cost ratio as a decision rule in cost-benefit analysis (DaCoTA, 2012). The net-present value will favour measures with large benefits even if they come at a relatively large cost, while the cost benefit ratio will favour measures with the best value for money, even if their actual benefits are relatively small (e.g., because they are targeted at a small group of accidents).

4 Principles of Cost Estimation

The monetary valuation of all impacts needed for cost benefit analysis is based on the estimation of the costs of measures and the valuation of their benefits. In this Chapter, some theoretical concepts of the meaning of costs within the economic welfare theory are explained, among them utility, opportunity costs, and discounting.

4.1 PERSPECTIVE OF COST ANALYSIS

The costs of road crashes as well as countermeasures can be considered at different levels – globally, at European or at national level – and from different perspectives: stakeholders such as governments, companies, or citizens. Most cost studies are carried out for individual countries and calculate the costs from a socio-economic perspective. The society consists of all relevant stakeholders, such as road casualties, governments, employers and insurers, and in cost studies the costs are generally estimated at the society level as a whole regardless of who bears these costs. This is consistent with economic welfare theory that provides the basis for cost-benefit analysis (see for example Boardman et al., 2006). Although economic welfare theory allows taking into account distributional or justice effects among stakeholders, in standard CBA these impacts are usually not accounted for.

The socio-economic perspective means that some financial transactions that do not necessarily represent any loss of welfare are not included into the calculations. Examples are taxes on repaired vehicles for instance: these are revenues for government bodies on the one hand and expenditures for citizens on the other, so there is no social cost and these money transfers do not represent any loss of welfare at the society level. They consist only of transfers between agents. Note that a breakdown of the socio-economic costs into stakeholders who bear these costs can nevertheless be made, as has been done for example in the US and the Netherlands.

4.2 COSTS ACCORDING TO ECONOMIC WELFARE THEORY

In economic theory welfare is determined by the 'utility' that each individual derives from consumption but also from intangible issues that affect quality of life (e.g. nature, safety), see for example Johansson (1991). Following this theory, socio-economic costs of road crashes consist of loss of utility resulting from crashes. For example, a reduction of a casualty's ability to consume or to enjoy life implies a reduction of utility derived from consuming and quality of life, and this represents a cost. Alternatively, usage of resources needed to restore the utility level after a crash to the initial level can be regarded as a cost. For example, the value of resources (labour, equipment) needed to repair a damaged vehicle represents the costs of this vehicle damage. This value is determined by the 'opportunity costs' of the resources.

Opportunity costs of using a resource are defined as 'its value in its best alternative use' (Boardman et al., 2006): the value that society must forgo if the input is used to produce a certain good or service. The idea is that resources that are used for, e.g. repairing a car, cannot be used for producing something else (that would bring forth utility) and this is regarded as a cost. The same applies to the costs of countermeasures. In practical applications, it is assumed that market prices of resources reflect the value in its best alternative use, and so the prices of resources (in this case the price of labour and equipment that is needed to repair a car) can be used to estimate the costs of vehicle damage. The costs of a countermeasure are mostly opportunity costs (e.g., time invested by the police for alcohol checks cannot be spent on the observation of suspects of other crimes). In some cases countermeasures can also involve a loss of utility resulting from side impacts (e.g. a reduction in speed can increase road safety but also travel time).

In practice the opportunity cost is usually considered to be the market price. In two important cases, however, recorded (market) costs are not identical to opportunity costs. The first case is public expenditures funded by tax revenue. Taxes on income and consumption are distortionary due to wedges between buying prices and selling prices. Thus, income taxes mean employers pay more for employees than the employees collect. In a grocery shop, value added tax means that consumers pay more for the commodities than the grocery shop paid when buying the commodities. On a well-functioning market, there is only one price, the equilibrium price. Taxes introduced for fiscal reasons, i.e. only to fund the public sector, do not represent compensation for the use of scarce resources. To correct for the efficiency loss created by taxes, it is recommended in cost-benefit analysis to add a tax adjustment factor to public budgetary costs. In Norway, the recommended value for the tax adjustment factor is 20%. If a highway agency pays contractors 5 million for a roundabout, the societal opportunity cost is therefore 5 x 1.2 = 6 million.

The second case is, in a sense, the mirror image of the first. It concerns the treatment of taxes imposed on private expenditures. Cars, as an example, are heavily taxed in many countries. When you buy a car, you do not just pay what it costs to produce the car, but also taxes. The relevant cost to measure in a cost-benefit analysis is the production cost. What did it cost the car manufacturer to install electronic stability control in the car? This is the relevant cost concept, not what it costs you when you buy the car.

To sum up: Opportunity cost of a road safety measure is the value of the resources used to produce the measure and can be estimated by means of market prices in all cases, except when taxes distort market prices. For public expenditures, which represent the use of money collected by means of taxes, one should add a tax adjustment factor to the budgetary cost. For private expenditures on goods that are taxed, the opportunity cost should be estimated net of the taxes, i.e. these should be subtracted.

4.3 ILLEGALLY GAINED BENEFITS AND COSTS

An issue that is related to welfare theory is the extent to which benefit and costs resulting from illegal activities should be taken into account. This is particularly relevant in economic analysis of crime, for example: should benefits that criminals gain from illegal activities be included in CBA? But it also applies to road safety: for example how to treat benefits gained from violating speed limits (reduced travel time)? This is known as the 'issue of standing' (Wittington & MacRae, 1986): which individuals have 'standing' in CBA and whose costs and benefits should (thus) be included? This issue is debated in the literature and although there are different opinions, there is evidence for a trend towards not including costs and benefits that are gained in an illegal way. Regarding costs of road crashes, this is an issue regarding the estimation of production loss: should the loss of production resulting from illegal activities be included? To our knowledge, 'illegal production loss' is usually not included in road crash cost studies. Following the trend of not including costs and benefits resulting from illegal activities as well as common practices in road crash studies, production loss related to illegal activities will not be included in estimates for crash- or measure costs.

4.4 DISCOUNTING

Discounting makes values that occur at different moments in time comparable by expressing their value at the time when they occur (current value) as their value at the moment of analysis (present value). Generally, it is assumed people prefer goods and services now to their availability in the future (all other things being equal). The individual has a so-called pure preference for present (Frederick, 2006). Another argument for discounting relates to the fact that money that is spent today could also have been invested yield a positive return, implying that 1 Euro today has a higher present value than 1 Euro in the future (see for example Boardman et al., 2006).

With respect to road safety, it can be assumed that road users and road safety decision makers would generally prefer safer vehicles or safer infrastructure now rather than to wait for 10 years. In that sense, road safety countermeasures can be interpreted as a provision of goods and services, of which the availability is more or less delayed in the future.

The preference for present implies that available goods and services in the present show a higher value or make it possible to reach a higher level of welfare than the same goods and services available in the future. The economic calculus taking such different appraisal into consideration is called social discounting[1] (NCEC 2010).

How to take into consideration such difference for valuation? The value attached to time preference can be measured through the ***discount rate***, which enables us to express all monetary values at different points in time in terms of what they would be worth in cash today. The present is considered as the reference point and the discount rate indicates the depreciation for future values. So that a good valued at 100 now is worth less than that value in x years depending on the discount rate and the time period concerned. In practice, the discount rate is ***a percentage that is detracted from benefits and costs for each year that they are delayed into the future***.

4.4.1 Evaluating road safety measures

Implementing a countermeasure for reducing traffic accident figures involves different streams of revenues and costs. They can occur in different moments in the life duration of the countermeasure. The timing of costs and benefits is an important concern. Indeed, let's suppose a road safety project making it possible to prevent 10 injuries each year, for which the value was estimated at a same unitary value in money terms for a period of 10 years. It is suggested 100 injuries could be avoided. But they could not be valued at the same discounted value or present value by following the discount rate approach. It means the first prevented casualties present a higher value in money terms. The discount process reduces the current value of the future saved casualties, and the importance of this depreciation depends on when in the duration of the project the casualty is saved.

A similar reasoning could be applied to the cost dimension. A countermeasure could require some investment at the beginning of the intervention, but also involve additional recurrent spending for maintenance in the future. Again such monetary values have to be discounted or expressed in a present value. The first outlays cost more now than the same amount in the future. Future costs are discounted and benefit from the same process of depreciation through the discounting process. Consequently, the timing of the costs and the benefits is important, because their expression in present value terms imply a modification of their weight for the economic calculus. Three particular cases are not concerned by this effect. (1) A road safety countermeasure could involve cost and benefits occurring in the same period, so that the discounting process does not modify the economic efficiency of the project. Both benefits and costs are impacted simultaneously by the discounting process. (2) The costs and benefits are spread constantly over the duration of the

[1] There is also private discounting which concerns individuals, firms or economic agents, but the assessment of road safety measures concern society at large.

project. Again no relative modification is involved. (3) Costs and benefits occur at the initial period so that net present values are similar to current ones.

Another important consideration is the duration of the project. The longer the project duration, the lower the present value for future events for a same value of the discount rate. This sensitivity of the economic calculus to the duration of the project is particularly important when the decision maker faces projects with different durations. It means that traffic safety measures with delayed benefits and a long duration project will see its benefits substantially diminished comparatively with shorter ones. In economic calculations, a higher discount rate will lead to a larger advantage for short term project above long term ones.

Discounting the monetary values is a prerequisite for being able to compare the different streams of benefits and costs in the implementation of different countermeasures. It is obvious that we need some discounting, because it is always preferable to prevent crashes and casualties immediately as compared to having an unchanged crash-rate a couple of years longer. So the discount rate is a way of formalising the "urgency" of reducing crashes. A large discount rate means a strong preference for measures that reduce casualties immediately. A small discount rate means that investments that only pay off in the long term have a bigger chance to be considered economically efficient.

4.4.2 Determining the discount rate

Although the discount rate has a political impact, it *must not be considered as an intervention variable with which the public decision maker could vary* to determine the appropriate rate, making some countermeasures more efficient (Gollier, 2005). For each country, the discount rate should be defined a priori with a sound scientific basis. Whether it is a single rate for all economic assessments or whether there can be separate discount rates for different domains of interventions (e.g., infrastructure measures as compared to enforcement measures) is open to debate. However, costs and benefits of each measure must be discounted at the same rate. While the urgency of preventing casualties implies a large discount rate, it has to be consistent with that used for discounting other costs and benefits.

The discount rate could be interpreted as a rate of substitution between present and future consumption. It has to deal with a wealth effect, so that the economic growth should be taken into consideration for determining its value (Gollier 2005, p. 69). Regularly the discount rate can be decomposed into different elements: The pure preference for present, a component dealing with the expected level of future consumption, and another one related with uncertainty. While this decomposition by components can help in determining the discount rate, the whole value has to be taken into consideration for discounting costs and benefits.

4.5 COSTS OF ROAD CRASHES VERSUS PREVENTION COSTS

We distinguish between costs that result from road crashes (costs of road crashes, e.g. medical costs and property damage) and costs to prevent road crashes. A road crash cost study usually only focuses on costs resulting from crashes, to give a picture of the economic burden of road crashes. In a cost-benefit analysis, information on these costs is used to estimate the benefits of reducing the number of crashes. In a cost-benefit analysis, this is contrasted with the costs of a countermeasure that can be implemented to improve road safety.

5 Estimating Costs of Measures

In this chapter the estimation of the costs of road safety measures is described. Different components and data sources for these costs are discussed with examples from infrastructure and vehicle measures.

5.1 TYPES OF COSTS

There are two main types of cost: one-time costs and running costs. A one-time cost is paid only once at one moment in time. If the cost is for a permanent construction or for a durable consumer good, it is normally referred to as an investment cost. Building a roundabout is an investment. Buying a new car is an investment. Running costs are costs that recur in each time period. If road lighting is installed, it is an investment. There is in addition annual cost of electricity and of maintaining the equipment. These are running costs.

Some road safety measures have only investment costs, and no running costs. Building a roundabout might be an example. There are costs in building the roundabout, but once built, it will not generate new costs. It will have no, or at worst a negligible influence on road maintenance costs.

Quite a few road safety measures have both investment costs and running costs. To estimate the total lifetime costs of these measures, the easiest procedure is to make an assumption about the service-life of the measure and estimate the present value of the running costs, applying a (risk-adjusted) discount rate. Total costs are then the sum of investment costs and the present value of running costs. The period for which running costs are estimated should be the same as the period for which benefits of the measure are estimated in a cost-benefit analysis.

Finally, some road safety measures have mainly running costs. Police enforcement is an example. Given that a police force exists, and that the police force has cars and other equipment needed to perform enforcement, the costs are mainly related to the number of man-hours devoted to enforcement. One might say that buying police cars and other equipment is an investment. On the other hand, both cars and other equipment are renewed regularly as part of the annual budget. When the police do traffic enforcement, all costs are therefore running costs and are incurred instantaneously. As a good approximation, there is simultaneity between costs and benefits for police enforcement. Benefits occur at the same time as costs and the issue of discounting does not arise. Strictly speaking, there is a short time-halo effect; i.e. the effect of police enforcement may last a few weeks after enforcement ceased. Normally, however, one year is the shortest period for which costs and benefits of road safety measures are estimated.

It is important to note that even if future costs and benefits have been discounted to present values, one may not directly compare cost and benefits of measures that have different time horizons. Consider, for example, Intelligent Speed Assistance (ISA) and conventional speed enforcement. Suppose that if a car fleet (e.g. all cars in a country) have ISA, benefits (present value) are 3,500 and costs 2,000. The net benefit is 1,500 and benefit-cost ratio is 1.75. Suppose that in the same jurisdiction, a cost-effective increase of conventional speed enforcement has an annual benefit of 320 and an annual cost of 200. These values will occur annually as long as the stepped-up enforcement lasts. The net benefit per year is 120 and the benefit-cost ratio is 1.60.

Which measure is the most cost-effective? One cannot answer this question without knowing the length of the period to which the discounted values for ISA apply. The annual net benefit of ISA is then only 100 million (1,500/15), which is less than the 120 million generated by conventional police enforcement. Only equivalent annual net benefits are directly comparable and suitable as a basis for setting priorities.

5.2 SYSTEMATIC VARIATION IN COSTS

The costs of road safety measures can be estimated at two levels: the unit level and the aggregate level. The unit level is for each entity of a road safety measure, like one junction converted to a roundabout, one kilometre of road where road lighting is installed, one car equipped with electronic stability control, or one driver going through driver training.

The aggregate level is the total cost for all units implemented during a given time period, for example, the total annual costs of all road safety measures in a country. In most cases, it is the unit costs that are of primary interest. For many road safety measures, in particular infrastructure-related measures, there is systematic variation in costs. This systematic variation must be known and modelled as accurately as possible.

Some years ago, cost-benefit analyses of a number of road safety measures were made in Norway (Elvik and Rydningen 2002). To get the best possible basis for these analyses, data were collected from the county offices of the Public Roads Administration about recently implemented road safety measures. The county offices were given a list of road safety measures, and for each measure they were asked to provide details regarding, among other things, the costs of implementing the measures.

The information given indicated that for many of the measures, costs vary greatly between locations. For each location, traffic volume (AADT) was stated. It was therefore possible to investigate whether costs varied according to traffic volume. **Figure 5.1** shows an example of the relationship between traffic volume and the cost of converting a four-leg junction to a roundabout. Although the data points are widely spread around the regression line fitted to them, it is nevertheless clear that costs increase as traffic volume increases. The wide dispersion of the data points indicate that costs are influenced by other factors in addition to traffic volume. An important factor in Norway is the terrain. If it is not flat, or rocky, which is often the case in Norway, construction costs will be higher than if the terrain is flat without rocks.

One would expect there to often be a positive relationship between traffic volume and the costs of measures on roads. One reason for this is that design standards for roads depend on traffic volume. It costs more to build a road according to a high design standard than according to a lower standard.

The running costs of road safety measures on roads also vary systematically according to two main factors: climate and traffic volume. In particular, frost action during winter causes movements in roads that may damage both the road surface and the underlying structures. Running costs are positively related to traffic volume. A guardrail installed on a high-volume road will be hit more often than a guardrail installed on a low-volume road. It will therefore need repair and replacement more often. Highway agencies will often have computer software to help them model the systematic variation in costs, in order to prepare budgets that are as accurate as possible.

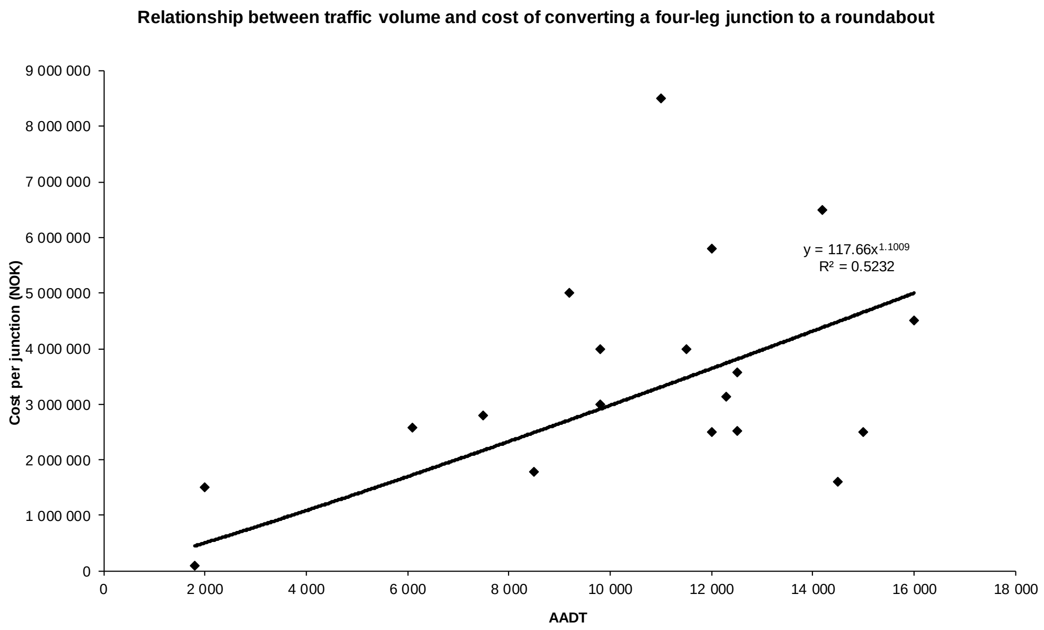

Figure 5.1 Relationship between traffic volume and cost of converting a four-leg junction to a roundabout

If one aims for an optimal use of road safety measures, it is essential to perform an analysis of their marginal costs and benefits. The marginal cost is the additional cost of implementing one additional unit of a measure. For infrastructure related road safety measures, marginal costs when the measures are used optimally may often be lower than average costs. Consider the cost data for roundabouts in **Figure 5.1**. It will often be optimal to convert high-volume junctions to roundabouts before converting low-volume junctions. All else equal, the expected number of accidents depends strongly on traffic volume and will be higher in high-volume junctions than in low-volume junctions. The first junctions to be converted to roundabouts will therefore be the most expensive.

There are often increasing returns to scale in modern production. This means that producing a large volume is associated with a lower mean cost per unit produced than producing a small volume. This means that current estimates of the costs of technology which is still not widely used, like ISA or alcolocks, probably indicate higher costs than one would expect if these technologies became standard equipment in all cars.

5.3 SOURCES OF DATA ON COSTS

It is rarely, if indeed ever, the case that a road safety budget exists from which one can easily find the costs of road safety measures. On the contrary, obtaining good cost estimates may involve complicated data collection. The best sources of data will vary depending on the type of measure. All countries have highway agencies that are in charge of measures related to the design of roads and traffic control. Highway agencies may be able to supply cost figures for many of the measures they are in charge of.

Major roadworks are normally contracted to construction contractors following competitive bidding. The contracted amount will be publicly known. Even for minor improvements, like installing guardrails or road lighting, competitive bidding is often used, and both the project owner, i.e. the highway agency, and the contractor will know the cost of the measures included in the contract. For some types of equipment, like guardrails, signposts, road markings or other minor equipment, market prices can be obtained from the producers of this equipment. Producers of speed cameras or variable message signs may also be able to provide information on the cost of these products.

It may be difficult to identify very precisely the costs of various safety features on motor vehicles. Car manufacturers will know what it costs to produce the car. They may also know the cost associated with specific systems like airbags or electronic stability control, or at least indicate the order of magnitude of the costs. Still, the various components are highly integrated and their cost may not be easy to identify. Furthermore, car manufacturers may not want to reveal costs for competitive reasons.

As far as the police are concerned, the total cost of the police will often be known. One can then try to apply a "top-down" approach, trying to list all the activities performed by the police and estimating the amount of time spent on each activity. This way, one may get an acceptable estimate of the total cost of traffic enforcement. Another option is a "bottom-up" approach, which implies that the costs are estimated on the basis of the time (hours) spent by police officers and the costs per hour (wages and indirect costs such as overhead costs and equipment). Some countries have a dedicated traffic police. If that is the case, the costs of that police force ought to be known.

5.4 SIDE EFFECTS

Side effects, or indirect costs of a measure, might be larger than the direct costs. As an example, consider the withdrawal of a drivers' licence. To withdraw a licence requires a formal decision, which must be written and communicated to the licence holder. The costs of this procedure are small. It may involve, at most, a few hours of working time for a police officer or someone else who has the authority to withdraw licences. Indirect costs are loss of consumer surplus as a result of no longer being able to perform the activity that generated the surplus. A driver who loses his or her licence must either reduce travel or find other means of doing so than driving a car. This involves either a loss of benefit, if one assumes that travels are only made when there is a net benefit associated with them and using the transport mode that yields the highest consumer surplus, or new expenditures, if public transport is used to replace trips made by car.

Each driver has his or her own consumer surplus of driving. For drivers who drive only a little and who get little pleasure out of it the consumer surplus will be small. For passionate drivers – those who take to the road for the pure fun of it – the consumer surplus will be large. However, even passionate drivers cannot spend all their time and income on driving, but face monetary and time constraints on their consumption of car driving.

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

For the purpose of quantifying the benefits of private car driving, we must know the demand function of a typical car driver. Ideally speaking, one should know the demand functions for several categories of drivers, since it does not seem reasonable to believe that a single demand function will correctly describe the behaviour of all car drivers in response to changes in the costs of driving. Demand functions will normally not be known or only very imperfectly known. Therefore, estimating indirect costs may often be impossible.

In a cost-benefit analysis, the monetary valuation of side effects is entered in the “benefits” side. In the case of indirect costs, this is a negative benefit. Side effects can however also concern real (positive) benefits (like a reduction in fuel consumption due to speed reduction measures).

6 Crash Cost Estimates

In this chapter the estimation of crash costs is described. Among the components of crash costs one of the biggest components are the human costs. These are an indication of how much the prevention of crashes is worth for us, which is measured by the willingness to pay method. Other costs are estimated by the restitution method (how much do you have to pay to compensate the victim) and the human capital approach (how much benefit would the victim have produced).

This Chapter gives a brief overview of the important crash-cost components and their estimation. The principles described here are mostly based on the report of the COST 313 guidelines which can be considered the standard for Europe. This section summarises a more detailed description in D3.2.

6.1 CRASH COST COMPONENTS

On the basis of the COST313 guidelines, road crash costs can be classified in five main categories related with the functional dimension of these costs.[2] In scientific and operational literature (e.g. Wijnen & Stipdonk, 2016; Bickel et al., 2006; Trawén et al., 2002; Alfaro et al., 1994) the defined categories are quite similar. A sixth category can be added and concerns others costs (see **Figure 6.**). This category is sometimes not included, because it represents a marginal contribution to the total costs of road crashes. Indeed, the review by Wijnen and Stipdonk (2016) shows these five cost components on average make up 98% of the total costs in ten high income countries. Other costs that are included by some countries are costs of congestion resulting from crashes, costs of vehicle unavailability and funeral costs.

1- Medical costs
2- Production loss: the loss of production or productive capacities
3- Human costs: immaterial cost of lost quality of life and lost life years
4- Administrative costs: police, fire service, insurance, legal costs
5- Property damage: damage to vehicles, infrastructure, freight and personal property
6- Other costs, such as costs of congestion resulting from road crashes, vehicle unavailability and funeral costs

Figure 6.1 Components of crash costs

[2] COST313 distinguishes between medical and non-medical rehabilitation. Following common practices, we have merged these two categories.

A common classification of costs of road crashes that has been introduced in the COST313 guidelines, distinguishes between injury related costs and crash related costs. Following this classification, the six main components can be categorised as illustrated in **Figure 6.2**.[3] Note that other costs can be either casualty related (e.g. funeral costs) or crash related (e.g. congestion costs). The interest of investigating crash costs this way is to emphasize the costs borne by the victim and some others costs related with material dimension and administration counterpart.

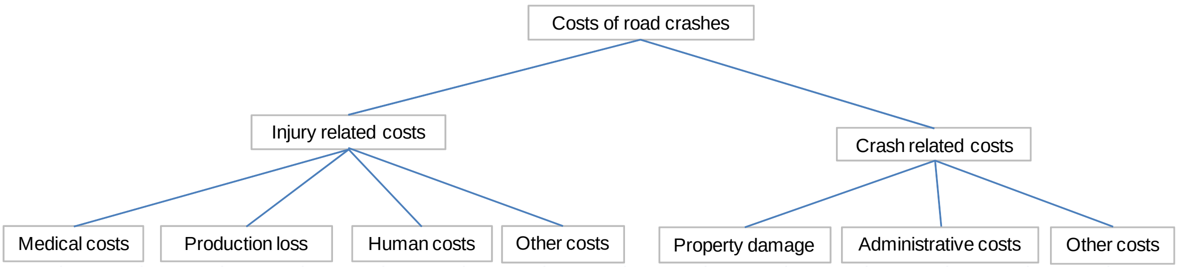

Figure 6.2 Classification of road crash costs: casualty and crash related costs

Classifications that differ from COST313 are also used, for example in European cost studies such as ECMT (1998) and HEATCO (Bickel, 2005) that distinguish between direct and indirect costs. Examples of direct cost are medical costs and property damage, while indirect costs include production loss and human costs. Also some individual countries use their own classification, for example the US and Australia. However, these classifications can be traced back to the six cost components in **Figure 6**.1, so eventually the same main cost components are included in these studies (Wijnen & Stipdonk, 2016).

6.2 ESTIMATION METHODS

Figure 6.3 illustrates the 3 main valuation methods. Generally speaking there are three estimation methods, Restitution costs approach, human capital approach and the willingness to pay (WTP) approach.

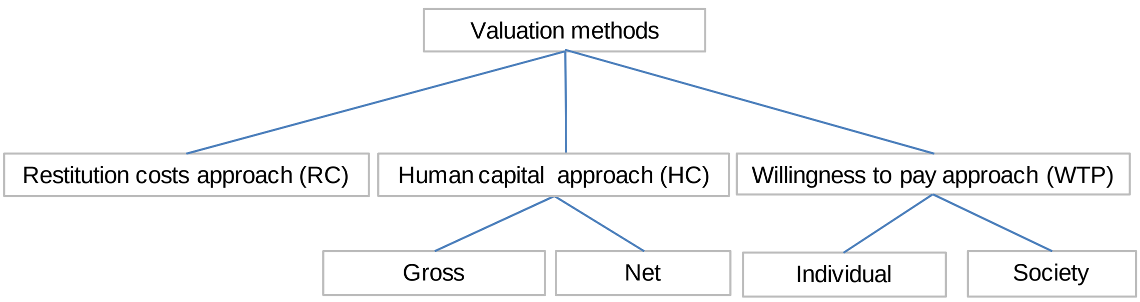

Figure 6.3 Classification of valuation methods (adapted from Alfaro et al., 1994)

6.2.1 Restitution costs approach

The restitution costs are the costs of resources that are needed to restore road casualties and their relatives and friends to the situation which would exist if they would not have been involved in a road crash. These costs can be interpreted as the direct costs resulting from a crash (DaCoTA 2012),

[3] Administrative costs related to health insurances are injury related instead of crash related. Since this is not regarded as a main cost component, we have classified administrative costs as crash related.

such as the costs of medical treatment and vehicle repair. The restitution costs approach also applies to administrative costs, as these costs are also aimed at restoring the consequences of a road crash. Market prices or proxy prices are used to value these costs, if they are available. For example, costs of vehicle damage are calculated using the price of repairing a vehicle (including among other things the costs of labour and materials to repair the vehicle).

6.2.2 Human capital approach

In this approach the value for society of the loss of productive capacities of road casualties is measured. The human capital approach is applicable for estimating production loss. A distinction is made between gross production loss (including consumption loss) and net production loss (excluding consumption loss).

6.2.3 Willingness to pay (WTP) approach

In this approach costs are estimated on the basis of the amount individuals are willing to pay for a risk reduction. This approach is used to estimate the economic value of lost quality of life, since there is no market price for such impacts. The results of WTP studies are used to derive the value of a statistical life, which is used to calculate human costs. COST313 distinguishes between individual WTP and social WTP. In the social WTP approach the amount society as a whole is willing to pay for a risk reduction. This amount can be derived for example from the (public) expenditures to prevent road casualties ('cost per life saved method'; De Blaeij et al., 2003). Furthermore, COST313 distinguishes between WTP and 'willingness to accept'. The latter measures the amount people are willing to accept for a risk increase.

6.2.4 Overview

Table 6.1 below, imported from D3.3, summarises which items are included within each component and how they are estimated. We differentiate between main items (these do not only include costs that have a large share in total costs, like human costs of fatalities and injuries, but also smaller costs that are commonly included, like police costs) and minor costs (which are thought to be very small and are not commonly included in cost studies, like costs of vehicle unavailability). In Deliverable 3.3 it is described in detail which methodology can and should be applied for which component.

6.3 COST PER CASUALTY/CRASH

Information about the total costs of road crashes gives a picture of the economic burden of road crashes and can serve as an input for setting policy priorities and as a stimulus for improving road safety. It can also be used for making international comparisons and comparisons with the economic burden of issues in other policy fields (e.g. congestion, environmental pollution or other types of accidents and injuries). For cost-benefit analysis (CBA) information about the costs per casualty and/or per crash is needed. In CBA the reduction of the number of casualties is translated into economic benefits by multiplying the number of casualties/crashes saved (by severity) by the costs per casualty/crash.

Road crash cost studies usually also include estimates of the cost per casualty and/or crash. Since most costs are calculated on the basis of information on the costs per casualty and the number of casualties, information on costs per casualty is available for most cost items. In case only total costs have been estimated (e.g. total vehicle damage), cost per severity category should be estimated to be able to calculate costs per casualty/crash. In CBAs road safety impacts are usually expressed in terms of number of casualties prevented, which means that cost per casualty should be known (instead of costs per crash). Costs per casualty preferably include both injury related costs and crash related costs, so all costs are included in CBA. This requires that crash related costs are attributed to casualties on the basis of information on the number of casualties per crash.

Table 6.1 Crash cost components with subcomponents and method of estimation

Cost component	Subcomponent	Method	Explanation
1. Medical costs			
Main	a) First aid at crash location and transportation	Restitution costs	– Actual costs of medical resources (labour, equipment, etc.), – Calculation: costs per 'unit' (per ambulance trip, per day, per treatment, etc.) times the number of 'units' (number of ambulance trips, average duration of hospital stay, frequency of non-hospital treatment, etc.)
	b) Treatment at the accident and emergency department of hospitals	Restitution costs	
	c) In-patient hospital treatment	Restitution costs	
	d) Out-patient hospital treatment	Restitution costs	
	e) Non-hospital treatment (rehabilitation centres, general practitioners, etc.)	Restitution costs	
Minor	f) Aids and appliances	Restitution costs	
2. Production loss			
Main	a) Lost market production	Human capital	– Calculation: production per person per year (e.g. GDP/capita or income) times lost productive years – Gross production loss: including consumption loss – Potential production loss – Discounting future losses
Other	b) Lost non-market production (household work, taking care of children, voluntary work, etc.)	Human capital	– Calculation: time spent on non-market production times value of time (e.g. wage as indicator – Discounting future losses
Minor	c) Friction costs	Restitution costs	– Actual costs of recruiting and training new employees and actual costs of vocational rehabilitation
Human costs			
Main	a) Fatalities (lost life years)	Willingness to pay	– Value of a statistical life (VOSL) based on willingness to pay results (see D3.3 for more detail) – Individual WTP from stated or revealed preference studies
	b) Injuries (loss of quality of life)	Willingness to pay	– Serious and slight injuries – Usually considered a percentage of the value of a statistical life (see D3.3 for detail)
Other	c) Human costs for relatives and friends	Willingness to pay	– Not calculated separately: included in WTP fatalities/injuries
Property damage			
Main	a) Vehicles	Restitution costs	– Actual costs to repair damage or replace vehicles

Cost component	Subcomponent	Method	Explanation
			– Preferably cars, motorcycles and trucks/vans; optionally buses, mopeds an bicycles – Two calculation approaches: 1.Bottom-up: average damage per vehicle * number of damaged vehicles (including non-reported crashes) 2. Top-down: total vehicle damage (including estimate of non-reported damage)
Minor	b) Infrastructure, fixed roadside objects and buildings	Restitution costs	– Actual costs to repair damage or replace property
	c) Freight carried by lorries	Restitution costs	
	d) Personal property	Restitution costs	
Administrative costs			
Main	a) Police costs	Restitution costs	– Actual costs of resources of police assistance (labour, equipment) – Excluding costs of prevention – Two calculation approaches: 1.Bottom-up: time spent on road crashes * costs per unit of time 2. Top-down: total police costs * time share road crashes
	b) Fire service costs	Restitution costs	– Actual costs of resources of fire service assistance (labour, equipment) – Bottom-up or top-down calculation (similar to police cost)
	c) Vehicle insurance costs	Restitution costs	– All administrative costs related to vehicle insurances
	d) Legal costs	Restitution costs	– Actual costs of prosecution, lawsuits and imprisonment – Bottom-up or top-down calculation
Other	e) Other insurance costs	Restitution costs	– All administrative costs related to other insurances (e.g. health)
Other costs			
Main	a) Funeral costs		– difference between the actual funeral costs and (discounted) future costs of the funeral if the person was not killed in a crash
	b) Congestion costs		– Time loss due to traffic jams resulting from road crashes – Calculation: time loss *value of time, or total congestion costs * share road crashes – Cost of travel time unreliability of travel times, adapting travel behaviour, extra fuel costs and pollution may be included
Minor	c) Vehicle unavailability	Restitution costs	– Actual costs of replacing the vehicle (e.g. renting car and time costs)
	d) Visiting people in hospital	Restitution costs	– Actual costs of visits, in particular travel costs and time costs
	r) Moving and house adaption cost	Restitution costs	– Actual cost for moving and for adaptations (equipment, labour)

7 Economic efficiency analysis in the DSS

The integration of economic efficiency analyses into the DSS is discussed. It is described why cost benefit analysis is included next to cost effectiveness analysis. A proposition for the practical implementation is made.

7.1 CBA VERSUS OTHER CRITERIA

We have seen that one of the conditions for Cost Benefit Analysis to be recommended is the involvement of several different criteria. In principle this will usually be the case for the evaluation of countermeasures. After all there is often a trade-off between safety and mobility (e.g, for licence withdrawal), personal comfort (e.g., for helmet wearing), traffic flow and travel time (e.g., for speed reduction), to name just a few examples. Side-impacts of road safety measures can also be positive, like the reduction of fuel consumption and CO_2 production for speed-reducing measures or the increased comfort for cyclists on cycle paths that are separated from motor traffic.

Having said this, numerical evaluation of effects on objectives other than road safety and economic valuation of possible other impacts is out of the scope of the SafetyCube project. The evaluations of measures will be tailored to their effect on road safety, if possible to their impact on the number of crashes and/or casualties. As a consequence, the evaluation of the balance between casualty reduction and other objectives, which is the core-objective of cost-benefit analysis, will not be possible within the DSS.

In the study of barriers to the use of efficiency assessment tools in road safety policy, performed as part of the ROSEBUD thematic network (Elvik and Veisten 2005), road safety policy makers across Europe were asked: "Do politicians put more weight on the number of fatalities and injuries prevented than on the monetary valuation of these impacts?" 40 out of 70 respondents answered that politicians assigned a greater weight to the number of fatalities or injuries prevented than to the benefits of preventing fatalities or injuries as stated in economic terms.

Cost Benefit Analysis does have several advantages, though. Next to the possibility to compare costs with benefits and calculate the social return, it also allows the inclusion of different outcome severities of crashes and the analysis is extendable to a larger framework. Consequently the results of cost benefit analysis will be presented next to those of a cost effectiveness analysis.

7.1.1 Different severity of crash outcomes

As mentioned above, the evaluation of measures in terms of different crash outcomes (e.g., fatalities and injuries) has become very important and one objective of SafetyCube is to investigate the possibility of a joint utility function of different outcomes in terms of Quality Adjusted Life Years (QALYs). Potentially, these estimates can take detailed account of the consequences of different types of injuries. At present however, QALYs are not being used yet in road safety, except for a few countries, so there is no common practice to estimate QALYs. The joint valuation of injuries and fatalities in terms of "crash costs" is therefore the best presently available estimate of the joint utility that these two outcomes have. For now, the CBA can therefore be considered the best way to combine assessments of the effectiveness in terms of reducing injuries and the effectiveness in terms of reducing fatalities.

7.1.2 Extendibility of CBA's

Although SafetyCube will not provide estimates of side effects and their valuation, some end users of the DSS might have such estimates. They can use the valuation of road safety benefits presented in the DSS together with their own valuation of other impacts. This way, the SafetyCube estimates can be included in a larger framework of assessing the efficiency of (a set of) measures.

7.2 PRACTICAL IMPLEMENTATION

Economic efficiency analysis will be included in the SafetyCube Decision Support System (DSS) by means of a ***CBA calculator***. The main focus of the DSS is therefore to give the best available knowledge on each countermeasure and on risk factors that they can help to neutralize. Consequently, rather than assessing the efficiency of programs, the CBA calculator will be directed to assess the efficiency of the implementation of a single unit of a counter measure.

This Cost Benefit Analysis calculator will combine information on countermeasures from the analysis work packages (4, 5, 6) and information from WP3 about the crash costs, the relative frequency of crashes/casualties of different severities (i.e. how many severely injured are there for any fatality?), and about the discount rate. This information will be available for each country or as a European mean.

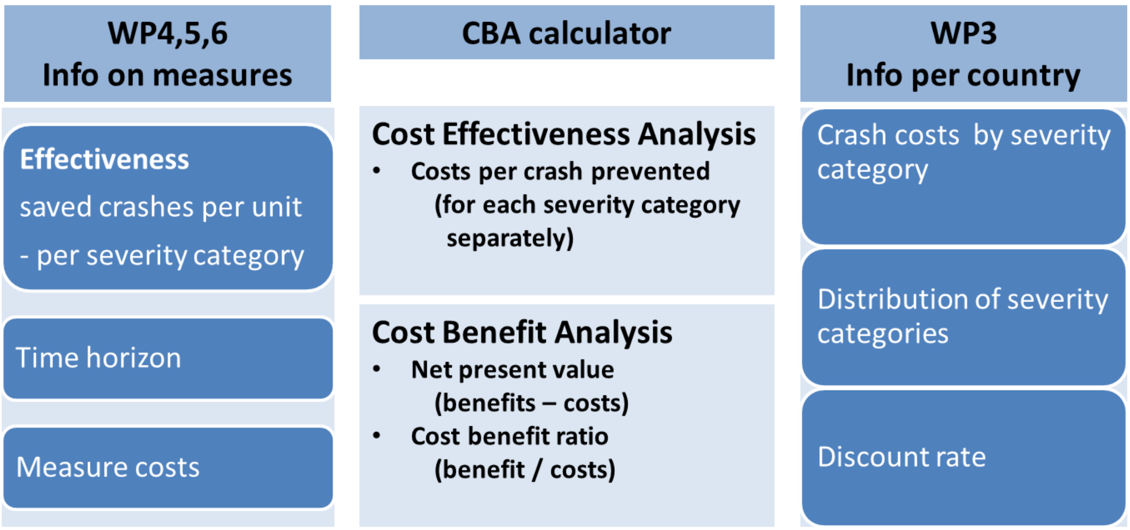

Figure 7.1 Inclusion of economic efficiency assessment into the Decision Support System.

For each countermeasure, the writer of the synopsis will fill the CBA calculator with default values (e.g. the crash-costs from the country in which the measure costs have been established). The user of the DSS can then replace the default values with his or her own values.

7.2.1 Assign priorities between measures

The DSS will support the decision making process by giving the user a number of criteria (cost per saved casualty, net present value, cost-benefit ratio) and in Chapter 2 it is explained how these have to be interpreted. The decision making process can, however, never be automated. It is not the purpose of the DSS to tell policy makers what to do. The purpose is to give them the best available information on which to base their decisions.

7.2.2 Sensitivity analysis

The systematic collection of key studies with respect to a wide range of measures allows a critical evaluation of how well the effectiveness of a countermeasure has been studied. The systematic comparison of different studies moreover allows users to estimate the random variation of the effect but also the variation due to (often unknown) circumstances under which it is established. If a meta-analysis can be conducted, the second type of variation will be taken into account for the choice of analysis model (fixed effects or random factor). The resulting overall estimate comes with a confidence interval that captures both types of variation. The CBA calculator will by default produce a sensitivity analysis on the basis of this confidence interval and will therefore indicate the range in which the true cost effectiveness is most likely situated.

8 Conclusion

In the present deliverable we have described different criteria for economic efficiency assessment of road safety counter measures, like the cost per saved casualty (cost effectiveness analysis), the cost per saved Quality-adjusted life year (QALY – cost utility analysis) and the balance of costs and benefits (net present value) and cost benefit ratio in a cost-benefit analysis. It has been shown that cost benefit analysis offers the most complete framework for measure evaluation. All aspects included in the first two analyses can be included in CBA, but not vice versa. Although it has also been shown that sometimes cost effectiveness analysis can be sufficient it is concluded that a presentation in terms of cost benefit analysis offers most flexibility to consider several criteria at the same time and for the DSS user to post-hoc include other aspects, like counter-measure side effects.

Cost-benefit analysis is based on welfare theory and requires the monetary valuation of all measure and crash impacts. It is important to understand that "costs" in this context do not necessarily refer to money actually spent. In the context of crash costs, it indicates the resources that are lost as a consequence of crashes *as well as loss of quality of life*. For some part the crash costs are based on costs of medical care, costs of repairing of material damage and other direct costs, but for the largest part, crash costs are human costs: the value that we are willing to pay to prevent human suffering that is caused by road safety crashes.

In cost-benefit analysis, the crash costs enter as benefits (because they are prevented) and the costs for measures are compared to them. For counter-measures the costs are mostly direct costs (i.e. resources used to implement the measure). The monetary valuation of side effects is beyond the scope of the SafetyCube project.

In the discussion of the principles of CBA it is shown how the applied criterion and parameters can influence whether a counter-measure is considered efficient or not. It is shown that a high discount rate favours short-term projects while a low discount rate gives projects a chance that only show benefits in the long term. It is also demonstrated that the CBA ratio (benefits/costs) does not necessarily "favour" the same measures as the net-effect (benefits – costs). The net-present value will favour measures with large benefits even if they come at a relatively large cost, while the cost benefit ratio will favour measures with the best value for money, even if their actual benefits are relatively small (e.g., because they are targeted at a small group of crashes).

In the SafetyCube Decision Support System (DSS) data on crash costs – collected in WP3 – will be combined with data on safety effects and costs of counter-measures – collected in WPs 4, 5, and 6. The system will allow the inclusion of standard estimates by the researchers from WPs 4, 5, and 6, as well as the replacement of these values by the user of the DSS (who might have more concrete costs for the specific case). For the counter-measures that allow an estimate of these input types, several criteria will be presented : the costs per saved fatality, costs per saved crash for different severity types (serious, light, damage only), the cost-benefit ratio and the net-effect.

In this way, the DSS gives the end-user the building blocks for developing a road safety program. It is based on a taxonomy of risk factors and measures, it will make the user aware of different options to treat a problem, it will indicate how well each approach has been found to work, and it will contrast the costs of each measure with its estimated effectiveness.

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