European Commission

Cost Benefit Analysis 2018

European Road Safety Observatory
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Transport

CONTENTS

1 Overview

This text describes the use of cost-benefit analysis to assess the impacts of road safety measures. The main steps of a cost-benefit analysis are outlined and the principles of cost-benefit analysis are explained. Figure 1 (next page) overviews the stages of cost-benefit analysis and the main requirements that must be fulfilled in order to perform such analyses.

The relationship between cost-benefit analysis and other normative principles for road safety policy-making is discussed. Guidelines for the monetary valuation of impacts in cost-benefit analyses of road safety measures are provided.

Furthermore, details are presented concerning the performance of cost-benefit analyses of road safety measures and the use of decision rules. Findings of cost-benefit analyses of road safety measures in Europe are discussed, with the possibility of their generalization. Problems that may be encountered when performing a cost-benefit analysis are also indicated.

In practice, it will never be possible to base road safety policy fully on cost-benefit analyses. Some of the reasons for this are briefly discussed at the end. Important considerations that may justify departing from the policy priorities implied by cost-benefit analyses include an objective of reducing disparities in risk, thus giving high priority to measures benefiting pedestrians and cyclists, and an objective of giving priority to those measures that provide the largest reductions of the number of road traffic fatalities. These measures may not always be the most cost-effective.

Figure 1: The stages and main requirements of cost-benefit analysis

REQUIREMENT FOR CONDUCTING COST-BENEFIT ANALYSIS	STAGE OF COST- BENEFIT ANALYSIS (CBA)	POTENTIALLY RELEVANT CONSIDERATIONS OUTSIDE THE FRAMEWORK OF COST-BENEFIT ANALYSIS
Inclusion of all relevant impacts (policy objectives)	Determine policy objectives and relevant impacts	Distributional objectives not normally considered in CBA
There should not be any indivisibilities	Develop measures and alternatives for their use	Perfect optimisation may be impossible
The reference scenario should reflect exogenous effects only	Describe a reference scenario (do-nothing option)	Past trends partly reflect effects of road safety measures
Some relevant impacts may be illegitimate to include	Identify relevant impacts of each measure	Controversies about impacts better resolved by negotiations
Numerical estimates of all impacts needed	Estimate impacts in "natural" units	Some impacts are qualitative in nature
Monetary valuation of human life must be applied	Convert all impacts & costs to monetary terms	Values of human life are controversial and imprecise
The marginal utility of money is constant	Compare cost and benefits for all measures	The marginal utility of money depends on wealth
All sources of uncertainty must be quantified	Conduct a sensitivity analysis of results	All sources of uncertainty cannot currently be quantified
All potentially effective measures have been surveyed	Recommend cost-effective policy options	Recommendations assume that similar analyses have been made all over

2 Introduction

This text explains the main points of the application of cost-benefit analysis of road safety measures as an element of road safety policy-making. The following questions are discussed:

- What is cost-benefit analysis? What are the essential steps of such an analysis?
- What are the main principles of cost-benefit analysis?
- Why do a cost-benefit analysis of road safety measures?
- Is there a relationship between cost-benefit analysis and other normative ideals for road safety, e.g. Vision Zero?
- How should impacts of road safety measures be valued monetarily? What are the best current estimates of the value of preventing road traffic casualties?
- What do we need to know to conduct cost-benefit analysis of road safety measures?
- What are the decision rules in cost-benefit analysis? How should choices be made between different road safety measures for which cost-benefit analyses have been performed?
- What are the findings of cost-benefit analyses of road safety measures at the European level? Can the results of cost-benefit analyses be generalised across countries?
- What are the problems that may be encountered in a cost-benefit analysis and that may prevent it from being conducted or its results from being applied?
- Can road safety policy be based strictly on the results of cost-benefit analyses, or are there other relevant considerations for priority setting of road safety measures?

This text does not aim to teach readers how to perform a cost-benefit analysis, but will discuss the use of such analyses in more general terms. For a detailed description of how to perform cost-benefit analyses or deal with various problems, references are given to relevant handbooks, guidelines and research reports.

3 What is cost-benefit analysis?

Cost-benefit analysis 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). Cost-benefit analysis is one of a set of formal tools of efficiency assessment (Hakkert & Wesemann, 2005). Efficiency assessment refers to analyses made for the purpose of identifying how to use limited resources to obtain the greatest possible benefits of them. Cost-benefit analysis provides an evaluation framework with a primary goal to estimate the extent to which the aggregate benefits of a policy exceed its costs, often comparing alternatives to identify which option (if any) is likely to be most economically effective (Robinson and Hammitt, 2013).

Cost-benefit analysis is a technique based on welfare economics. There are many textbooks explaining this technique in detail as well as the problems encountered in a cost-benefit analysis and how to solve them (Boardman et al., 2011; Pearce et al., 2006; Mishan, 1988; Adler & Posner, 2001). Cost-benefit analysis 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 policymakers 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.

Evidently, road safety problems have these characteristics and thus they are suited for cost-benefit analyses.

Unlike other tools of efficiency assessment, cost-benefit analysis involves monetary estimates of both costs and effects/benefits of a measure. Thus, in the road safety context, it may be useful for prioritizing various measures or their packages, particularly, if we need to account for different accident severities and for additional impacts (on mobility, environment, etc.) or to consider trade-offs of safety against other policy objectives (Elvik and Veisten, 2005).

The main steps of a cost-benefit analysis are as follows:

1. Develop measures or programmes intended to help reduce a certain social problem (e.g. road accidents).
2. Develop alternative policy options for the use of each measure or programme.
3. Describe a reference scenario (sometimes referred to as business-as-usual or the do- nothing alternative).
4. Identify relevant impacts of each measure or programme. There will usually be several relevant impacts.
5. Estimate the impacts of each measure or programme in “natural” units (physical terms) for each policy option.
6. Obtain estimates of the costs of each measure or programme for each policy option.
7. Convert estimated impacts to monetary terms, applying available valuations of these impacts.
8. Compare benefits and costs for each policy option for each measure or programme. Identify options in which benefits are greater than costs.
9. Conduct a sensitivity analysis or a formal assessment of the uncertainty of estimated benefits and costs.
10. Recommend cost-effective policy options for implementation.

To identify relevant measures or programmes, a broad survey of potentially effective road safety measures should be conducted. A measure is regarded as potentially effective if there is reason to believe that it will improve road safety by favourably influencing risk factors that are known to contribute to accidents or injuries or if it has been shown to improve road safety and has not already been fully implemented.

For each road safety measure, alternative options for its use should be considered. For example, if the problem to be solved is bicyclist injuries, and the measure considered is bicycle helmets, alternative policy options could be:

a. Do nothing; leave it to each bicyclist to decide whether or not to wear a helmet.
b. Conduct a campaign for bicycle helmets, while leaving their use voluntary.
c. Make the use of bicycle helmets mandatory for children.

d. Make the use of bicycle helmets mandatory for everybody.

These are distinct and mutually exclusive options. Considering vehicle-related and road user-related measures, typically a closed set of implemenation alternatives can be suggested. For many infrastructure-related safety measures, however, options for their use can be conceived of as a continuous variable reflecting the scope of implementation. For example, one may convert 50 junctions to roundabouts, 51 junctions, 52 junctions, and so on, i.e. infrastructure-related measures can be applied in small gradual steps. This can be approximated as a continuous variable, since there would normally be hundreds or thousands of junctions or kilometres of road that are candidates for implementation of a certain road safety measure.

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 decade due to new legislation. In such cases, the foreseen rate of introduction should be regarded as the reference scenario.

The most relevant impact of a road safety measure is, of course, changes in the number of accidents or injury severity. Some road safety measures may, however, have additional impacts on mobility (travel time, vehicle expenses) and the environment (noise, pollution). If a measure has such impacts, they should be included in a cost-benefit analysis. In addition, one of the purposes of such analyses is to help make trade-offs between different, and, sometimes, conflicting policy objectives. Impacts that are relevant for all policy objectives must therefore be included.

All relevant impacts should first be estimated in "natural" units, for example number of accidents prevented, number of additional hours of travel, and so on. Then all impacts should be converted to monetary terms, applying monetary valuations of the various impacts. More will be said later about the economic valuation of road safety.

Cost-benefit analysis is designed to identify policy options for which benefits are greater than costs. According to the theory underlying cost-benefit analysis, a policy option should normally not be adopted if benefits are smaller than costs. It will, however, often be the case that costs and benefits are not known with certainty. An explicit consideration of uncertainty, as a minimum in the form of a sensitivity analysis should be part of any cost-benefit analysis.

4 What are the main principles of cost-benefit analysis?

There are four main principles of cost-benefit analysis (Elvik, 2001; Elvik & Veisten, 2005):

1. Consumer sovereignty.
2. Valuation of goods according to willingness-to-pay.
3. Pareto-optimality as the criterion of welfare maximisation.
4. Neutrality with respect to income distribution.

Consumer sovereignty is the principle that the choices made by consumers with regard to how to spend their income are respected. 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 demands for various goods and services as data.

The strength of consumer preferences for the provision of public goods is measured by the amount of money that consumers are willing to pay for these goods. The value of improving road safety is indicated by the willingness-to-pay for reduced risk of injury. Assessing willingness-to-pay for non-market goods like road safety is a complex task, involving many potential sources of error. Hence, a common objection to the willingness-to-pay principle is that it is not possible to obtain credible estimates of willingness-to-pay. A more fundamental objection is that willingness-to-pay depends on the 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 traffic 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.

In response to these points of view, three arguments can be made in favour of basing the provision of road safety on the demand for it, as manifested in the amounts that individuals are willing to pay for safer roads. In the first place, it is never the case that the provision of road safety – at least when it is a public good – can be matched exactly to individual demand for it. The rich may state that they want to pay a lot for road safety, the poor may state that they cannot afford to pay anything, but both groups benefit when roads or cars are made safer. It is just not possible to match supply and demand at the individual level, as opposed to the case for most market goods (in the sense that, as a rule, we buy the mix of commodities that gives us the greatest satisfaction). In the second place, it is in principle possible to convert the amounts of money individuals are willing to pay for road safety to utility terms, by estimating the marginal utility of money. By converting monetary amounts to units of utility, one may account for the fact that giving up 1.000 Euro is a much smaller sacrifice for a rich man than giving up, say, 250 Euro would be for a poor man. At present, however, converting money to utility is not an easy task. In general, economists will recommend using the willingness-to-pay principle provided it does not lead to unacceptable changes in income distribution. What counts as “unacceptable” in this respect is, of course, ultimately a matter of politics. In the third place, basing the provision of road safety on the demand (willingness to pay) for it ensures that it is not over-provided. Road safety is over-provided if overall welfare can be improved by transferring resources from the provision of road safety to the provision of other commodities.

Pareto-optimality is the third principle of cost-benefit analysis. A measure is Pareto-optimal if it improves the welfare of at least one person without reducing the welfare of any other person. In practice, few measures taken by government will be strictly Pareto-optimal. There will almost never be only gainers and no losers. Hence, the criterion commonly applied in cost-benefit analysis is a less demanding criterion of a potential Pareto-improvement. This criterion is satisfied when those who gain from a measure can compensate those who lose from it (in utility terms), while still retaining a net benefit. A measure is commonly regarded as satisfying this criterion if its benefits are greater than the costs.

The fourth principle of cost-benefit analysis is that it remains neutral with respect to the distribution of benefits and costs among groups of the population (or groups of road users), provided of course that benefits in total exceed costs. Cost-benefit analysis is not intended to help find the most equitable solution to a social problem, only the most efficient solution. 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.

5 Why do a cost-benefit analysis of road safety measures?

Cost-benefit analysis is a prescriptive technique. It provides a rational framework for integrally assessing a variety of measures and is performed for the purpose of informing policymakers about expected impacts of investment alternatives. It is based on welfare economics and requires all policy impacts to be stated in monetary terms.

Some people find the very idea of assigning a monetary value to lifesaving or to quality of life, which is an essential element of cost-benefit analysis, meaningless and ethically wrong. Human life, it is argued, is not a commodity that can be traded against other goods. It should therefore not carry a price tag. However, the purpose of assigning a monetary value to human life is not to engage in trading in the usual sense of that term. It is simply to provide a guideline with respect to the amount of resources we would like to spend on the prevention of accidents or injuries, given the fact that not all of our resources can be spent for this purpose.

In the road safety field, some form of economic reasoning, i.e. 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:

- A limited amount of resources is 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 accidents or injuries.
- How much to spend on the prevention of accidents 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.
- It is, in principle, possible both to provide too little safety and to provide too much of it.

If these basic observations are accepted as a fair description of the choices we are facing, then we engage in this sort of thinking - cost-benefit reasoning - whether we are conscious of it or not.

The main reason for doing cost-benefit analyses 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-benefit analysis seeks to identify the cheapest way of improving road safety. While one can think of arguments for choosing expensive solutions, one should never forget the fact that once resources have been committed to an expensive solution to a problem, they are no longer available for alternative, and possibly more beneficial, uses.

Road safety policy analyses carried out in several countries showed that major improvements in road safety can be accomplished by implementing cost-effective safety measures. For example, Elvik (2003) demonstrated that cost-effective policies could prevent between 50-60% of the current number of road accident fatalities in both Norway and Sweden, during a decade, related to continuing the business-as-usual strategies which would save 10-15% only. A later analysis for Norway (Elvik, 2007; Elvik, 2008) indicated that continuing present policy may reduce the total number of fatalities to 190 in 2020, whereas implementing all cost-effective safety measures may reduce them to 138.

6 The relationship between cost-benefit analysis and other normative ideals for road safety

Vision Zero (known generically as Safe System approach – OECD, 2008) is a widely supported long-term ideal for road safety. It states that the long-term solution to the problem of road accidents is to create a road transport system in which nobody is killed or seriously injured as a result of road accidents. Vision Zero is based on ethics and shared responsibility principles, as follows (OECD, 2008):

- Human life and health are paramount ethical considerations which are not be allowed to be traded-off against the benefits of the road transport system, such as mobility.
- Rather than placing responsibility for accidents and injuries on the individual road users, it is shared between the providers of the system and the road users. The road user remains responsible for following basic rules, e.g. obeying speed limits; the system designers and enforcers are responsible for the functioning of the system. In the event that road users make errors or even fail to follow the rules, the responsibility reverts to the system's designers to ensure that such failings do not result in death or serious injuries.

Leading the change to a Safe System, the system's designers are obliged to apply evidence-based safety improving measures and to promote safety as a competitive variable in road transport contracts (OECD, 2008).

The ethical principle of Vision Zero that rules out trading-off human lives against other commodities can be considered as not consistent with the principles of cost-benefit analysis. Basically, a policy based on cost-benefit analysis will improve road safety if there is sufficient willingness-to-pay for it, but refrain from improving road safety if there is insufficient willingness-to-pay for it.

One should, however, not necessarily conclude that both concepts are incompatible. In the first place, by setting the highest possible ambitions for improving road safety, Vision Zero provides an incentive for giving high priority to the most cost-effective road safety measures. To identify the most cost-effective road safety measures, some form of cost-benefit analysis needs to be made. In the second place, estimates of the costs and benefits of road safety measures are subject to frequent revisions. Vision Zero aims to stimulate technological innovation that may result in the development of new and more cost-effective road safety measures than those that are currently used. As an example, in-vehicle safety systems based on information technology are rapidly becoming more versatile (i.e. able to perform a wider range of actions to support the driver), more reliable and cheaper. Such technological innovation can make measures cost-effective in the future, even if they are not regarded as cost-effective today.

In the third place, both concepts are complementary. Any claim that the “optimal” level of safety can be determined by means of cost-benefit analysis should be treated with considerable scepticism because estimates of both costs and benefits are highly uncertain. There will, therefore, not be any specific number of traffic fatalities that can be regarded as optimal. Using cost-benefit analysis, at best, a broad range of outcomes where the “optimal” level is likely to be, can be indicated. As a policy guideline, a broad range is clearly less demanding and motivating, and difficult to communicate, while a simple ideal like Vision Zero is much more suitable.

7 What is the best monetary valuation of road safety?

When cost-benefit analysis of transport projects started in the 1960s, the only impacts that were included in the first analyses were travel time, vehicle operating costs and accidents. The benefits of preventing accidents were normally valued according to the so-called “human capital” approach, which assigned a value to preventing a fatality or an injury proportional to the value of production lost. This had the rather awkward consequence that saving the lives of people outside the labour force, like children or the retired, did not have a monetary value, since these people did not produce anything that had a market value. Two important papers – one by Schelling (1968), the other by Mishan (1971) – paved the way for adoption of the willingness-to-pay approach to the valuation of road safety.

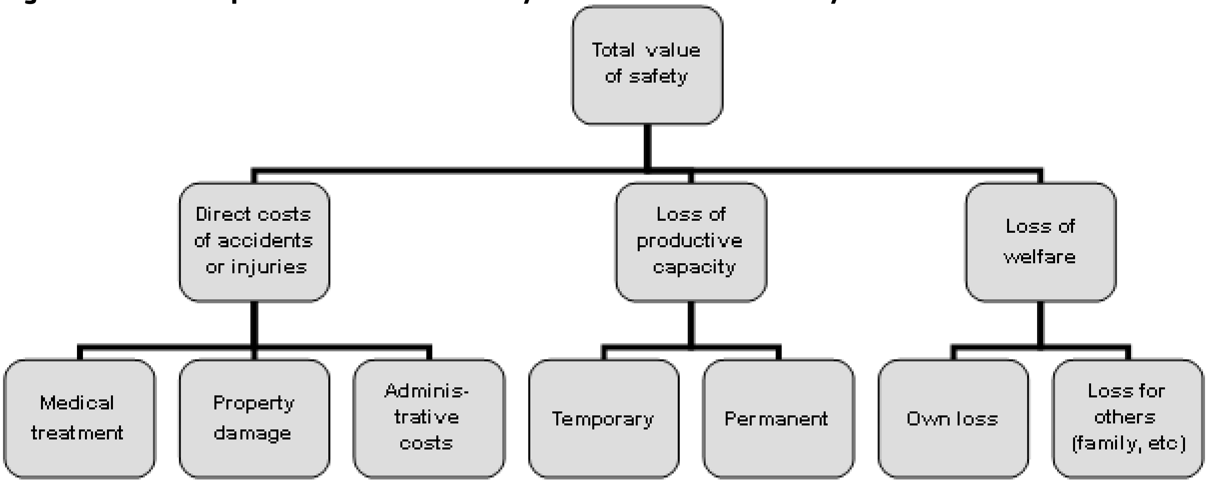
In the early 1990s, an international group of experts defined five categories of cost items that ought to be included in estimates of road accident costs, which are (Alfaro et al., 1994):

1. Medical costs: costs resulting from the treatment of casualties, e.g. costs of hospital stays, rehabilitation, medicines and adaptation.
2. Production loss: loss of production and income resulting from the temporary or permanent disability of injured, and the complete loss of production of fatalities.
3. Human costs: immaterial costs of suffering, pain, sorrow and loss of life or of quality of life.
4. Administrative costs: the costs of police services, fire services, law courts and administrative costs of insurers.
5. Property damage: damage to vehicles, freights, roads and personal property.

Similar components of road accident costs are common today in scientific and operational literature (Wijnen and Stipdonk, 2016; Elvik, 2010; Bickel et al., 2006; Pearce et al., 2006). A sixth category of "other costs" can be added which concerns costs of congestion resulting from road accidents, vehicle unavailability and funeral costs. However, it usually represents a marginal (if any) contribution to the total costs of road accidetns; Wijnen and Stipdonk (2016) showed that for high-income countries the five main components make up 98% of the total accident costs.

The five main components of valuation can be subdivided into three groups as shown in Figure 2. These are direct costs of accidents, lost productive capacity and loss of welfare (human costs), which differ in terms of how they are manifested in economic transactions. The direct costs are real expenditures. In principle, these costs can be retrieved or at least roughly identified in the accounts of hospitals, insurance companies, the police, the courts, car repair shops and households. Estimates of lost productive capacity partly reflect monetary transactions; partly these costs are of a more abstract nature. In particular, lost productive capacity attributable to a fatality is usually estimated as the present value of future earnings. This represents the value of what the individual could have produced if alive; this can never be known with certainty and is therefore most appropriately interpreted as a loss of productive potential or capacity, not an actual loss of production.

Figure 2: Main components of the monetary valuation of road safety.



Source: Elvik (2010)

Human costs (or loss of welfare) are estimated using a willingness-to-pay (WTP) method. WTP expresses the amount of money people are ready to pay for a reduction in risk of being killed or injured in a road accident. This reflects the hypothetical demand for improved safety and, thus, does not reflect any actual monetary transactions. This fact was clearly understood by the pioneers introducing the WTP approach to the valuation of road safety. Thus, Schelling (1968, page 143) wrote: "*Unexpected death has a hypothetical quality whether it is merely being talked about or money is being spent to prevent it.*" The willingness to pay for reducing statistical risks by an amount that corresponds to the prevention of one death refers to the ex ante evaluation; it has nothing to do with the ex post costs generated by the death of a known individual. The latter costs are at least two orders of magnitude smaller than the valuation of preventing a death (Elvik, 2010).

The monetary valuation of this component requires an estimate of the economic value of a *statistical life*. Again, valuation of a statistical life is concerned with valuation of changes in the level of risk exposure; it does not intend to value the life of a specific individual (de Blaeij et al., 2003; Robinson and Hammit, 2013). Here is an example illustrating the meaning of this notion. If individuals are willing to pay $100 (*wtp*) for a 1/1000 reduction in the underlying risk of death (*Δr*), then the value of a statistical life (*vsl*) can be worked out as:
vsl = wtp/Δr=100/[1/1000]=$100,000.

There are two main approaches for eliciting the value of a statistical life: stated preference methods and revealed preference methods. Most studies of the valuation of road safety have employed stated preference methods. These methods involve setting up a hypothetical market and asking people about the amounts of road safety they would purchase in these markets. The results of the studies are strongly affected by study design and methodology, and, thus, vary considerably (de Blaeij et al., 2003; Bahamonde-Birke et al., 2015).

Revealed preference studies examine actual choices in real markets. As far as road safety is concerned, such a choice might be, e.g., the purchase of a new car. Cars differ with respect to safety features; if the relative importance of the factors that influence the choice of car, such as price, size, motor power, safety features, etc. can be determined, the implicit value placed on various safety features can be estimated. In principle, revealed preference methods would be preferable for WTP estimations as they are based on the actual spending of real income. However, their applicability for road safety is limited due to the difficulties in isolating risk components and risk changes in actual people choices.

In general, the studies of the value of statistical life have not produced a consensus estimate of the value of preventing a road traffic fatality, among the countries. In some studies, the impact of the background variables such as the country's economic level (GDP per capita) and the level of risk (fatality number per inhabitants) on the value of statistical life, was indicated (de Blaeij et al., 2003). The number of WTP surveys, however, has grown exponentially over the last decade (Bahamonde-Birke et al., 2015) leaving room for an increase in the consistency of the results.

OECD (2012) considered 65 studies with estimates of the value of statistical life in road traffic, and reported a mean value of 4,88 million, with a standard deviation of 0,49 million (in 2005 US$, adjusted); the majority of studies were stated preference studies. In addition, a direct impact of national wealth (GDP per capita) on the value of statistical life was ascertained.

It is worth noting that the value of a statistical life in road safety comprises two components: the valuation of human costs and a value of consumption loss of those killed. The latter should be subtracted from the value of a statistical life, in order to provide human costs for the fatality value, as these costs have already been included in the category of production loss (SWOV, 2014; Wijnen & Stipdonk, 2016).

According to WTP method which is recommended today for road safety evaluations (Bickel et al., 2006; Pearce et al., 2006), the economic value of road accident fatality presents a composition of two major components: production loss and human costs. In countries that apply the WTP approach for valuing road safety, the later component normally represents more than half, in some cases nearly the whole, monetary value assigned to improving road safety (Elvik, 1995). Wijnen and Stipdonk (2016) reported that in high-income countries human costs have a share of 54%-85% in the costs of a fatality. One should remember that the valuation of improved road safety in terms of WTP is not subject to market transactions. This means that, although representing real benefits of improving road safety, it will not be realised in terms of added income or profits.

In many European countries, studies have been conducted to assess WTP for improved road safety. For example, WTP-studies have been conducted in Belgium (de Brabander, 2006), Denmark (Kidholm, 1995), France (Desaigues & Rabl, 1995), Great Britain (Jones-Lee & Loomes, 2003), Greece (Yannis et al., 2005), the Netherlands (de Blaeij, 2003), Norway (Veisten et al., 2010) and Sweden (Persson et al., 2000). The developments show that more countries today apply a WTP-based valuation of a road accident fatality than two decades ago. As a result, more road safety measures can pass the cost-benefit analysis test and higher investments in road safety improvements can be justified.

It should be noticed however that, although the official valuations of road safety in most developed countries are based today on the WTP principle, such valuations usually represent a conservative interpretation of the results of the studies that have been made. The main argument for interpreting WTP-studies conservatively is that there are numerous sources of error associated with such studies that may lead to inflated valuations. It is recognised that the details about how to perform a study of the WTP for road safety are a hugely complex topic. An accessible, yet quite profound introduction to the topic is given in a book by Jones-Lee (1989).

The best monetary valuation of road safety is based on a combination of resource cost estimates for the direct costs of road accidents and injuries, use of the human capital approach for estimating the lost productive capacity, and use of the willingness-to-pay approach for estimating loss of welfare (or, more precisely, the ex ante value of avoiding loss of welfare). The best way is when each country develops its own values. However, when detailed estimates for a country are not available, results of international comparisons and suggested proxy-values may be of use.

It was presented in Hakkert and Wesemann (2005) that for the European countries that included human losses in the estimation, the costs per fatality ranged between 1,7-3,0 million Euro (price level 2002), with the highest value for Norway. For the Netherlands, an updated value of fatality costs of 2,6 million Euro, in 2009, was reported (SWOV, 2014). Recent estimates indicate that in high-income countries which apply a WTP method, the total costs per fatality lie in the range of 2,4-3,6 million US$, price level 2012, with a considerably higher value for the USA, 9,5 million US$ (Wijnen and Stipdonk, 2016).

Regarding the proxy-estimates, in the evaluations for all European countries, the European Transport Safety Council applies the value of preventing one road fatality which is based on a WTP approach and applies the adjustments recommended by the HEATCO guidelines (Bickel et al., 2006). The latter accounts for the economic level of the country (in terms of purchasing power parity) and the changes in the economic situation in the intervening years. The monetary value for 2015 of the losses avoided by preventing one fatality was 1,97 million Euro (Adminaite et al., 2016).

The European Commission (2009) recommended the values of 1 to 2 million Euros as the value of statistical life's estimates but noted that context-specific values may be used in lieu of this default.

Regarding human losses related to non-fatal injury, studies were carried out in a few European countries, e.g. the UK (Hopkin and O'Reilly, 1993), Sweden (Persson, 2004) and Belgium (de Brabander, 2005). Based on the British study, the human costs per serious road injury are estimated at 12% of those of a fatality (SWOV, 2014). Bickel et al. (2006) suggest to apply for this purpose 13% of the value of a statistical life of fatalities.

8 What do we need to know to perform cost-benefit analysis of road safety measures?

In principle, cost-benefit analysis is applicable to most road safety measures although such analyses are more readily done for some measures than for others. In the Handbook of Road Safety Measures (Elvik et al., 2009), the results of cost-benefit analyses are shown for various groups of road safety measures, such as:

- Road design and road equipment
- Road maintenance
- Traffic control
- Vehicle design and protective devices
- Vehicle inspection
- Driver training and regulation of professional driving
- Public education and information campaigns
- Police enforcement and sanctions
- Post-crash care
- General purpose policy instruments

General purpose policy instruments are a heterogeneous group of measures that include, among other things, motor vehicle taxation, regulation of commercial transport, urban and regional planning and access to medical services. Most of the general purpose policy instruments are quite complex, while their effects on road safety are indirect and for some of the measures poorly known. Due to their great complexity and the comparatively poor state of knowledge regarding their effects, these measures do not lend themselves very well to cost-benefit analysis. This is not to say that it is impossible to do cost-benefit analyses of some of these measures. There have, for example, been several cost-benefit analyses of road pricing.

In general, to be amenable to cost-benefit analysis, a road safety measure should satisfy the following criteria:

1. It should be known what category of accidents or injuries the measure affects (all, those involving young drivers, those occurring in the dark, etc.), preferably so that the number of "target" accidents/injuries can be estimated numerically.
2. The effects of the measure on target accidents/injuries should be known, i.e. numerical estimates of these effects should be available from the research literature. If possible, these estimates should state the severity of accidents or injuries they apply to.
3. It should be possible to describe the use of the measure in numerical terms, e.g. number of junctions converted, number of cars equipped, number of drivers trained, man-hours of police enforcement, etc. This information is needed in order to estimate marginal costs and benefits of the measure.
4. Other impacts of the measure should be known, for example impacts on mobility (travel time, vehicle expenses) or the environment.
5. Costs of the measure should be known, and it should be known who pays the cost. This is because private expenditures and public expenditures are not treated identically in cost-benefit analyses. For example, a cost of taxation is added to public expenditures, but not to private expenditures.
6. Monetary valuations should be available for all impacts of the measure.

Clearly, cost-benefit analysis requires quite extensive knowledge of the impacts of a measure. This knowledge will not be available for all road safety measures. For example, in a road safety impact assessment for Norway (Elvik, 2007; Elvik, 2008), a survey was made of 139 road safety measures. Only 45 of them were included in a cost-benefit analysis. Other measures were omitted due to various reasons such as:

- Effects were not sufficiently well known.
- Measure was ineffective (did not improve road safety).
- The measure overlapped another measure.
- The measure was not fully implemented.
- The measure was analytically intractable.

Some of the measures were included because they may impact risk factors related to road safety but have so far not been used extensively. This applies, for example, to ISA (Intelligent Speed Adaptation), which favourably influences driving speed, a known risk factor for accidents and injuries.

Here is a short example of estimating safety benefits associated with a measure of converting three-leg junctions to roundabouts, from Elvik (2007). For Norway, it was determined that 120 junctions with a mean daily traffic of 12.000 are candidates for conversion to roundabouts. Thus, the effect on fatalities can be estimated as follows:

$$120 \times 12.000 \times 365 \times 0{,}091 \times 10^{-6} \times 0{,}018 \times 0{,}49 = 0{,}42$$

The first three terms (120, 12.000, 365) denote the total traffic volume in the 120 junctions during one year. This is the traffic that will be exposed to the conversion. The next term (0,091 x 10^{-6}) is the mean risk of injury per million vehicles entering a three-leg junction. A little less than 2% of the injuries (0,018) are fatal, the rest are serious or slight. Thus, the overall injury rate is decomposed into a rate of fatal injury, a rate of serious injury and a rate of slight injury. Finally, roundabouts reduce the number of fatalities by 49% (0,49). Hence, in the 120 junctions, 0,42 fatalities will be prevented.

The fatalities prevented can be converted to monetary terms as follows:

0,42 x 26,5 x 14,828 = 165 million NOK

Here, 0,42 is the number of fatalities prevented, 26,5 is the value, in million NOK, of preventing a fatality, and 14,828 the accumulated present value factor for a 25-year time horizon using a discount rate of 4,5 % per year. In general the present value of a benefit (or cost) is estimated as:

$$\text{Present value} = \sum_{i=0}^{n} \frac{Bi}{(1+i)^{r}}$$

In this formula, B denotes benefit in year *i* and *r* is the discount rate. The summation is from year 0 to year n, the end of the time horizon considered. As the years pass, the present value of a constant stream of benefits gradually becomes smaller.

9 Decision rules in cost-benefit analysis

The main result of a cost-benefit analysis is a monetary estimate of the benefits and costs of a road safety measure, where both estimates are brought to the accumulated present value (according to the time horizon defined). The term "benefits" refers to the costs of accidents/injuries saved due to the measure, with an addition of changes in travel costs and environmental costs (if relevant). The term "costs" of a measure normally comprises the implementation costs (e.g. of changing the infrastructure or vehicles, carrying out a campaign) and operational costs (e.g. of infrastructure maintenance).

A measure is cost-effective if benefits are greater than costs. This can be examined by a number of metrics, e.g. the net present value, the benefit-cost ratio, and the internal rate of return.

The net present value is defined as:
Net present value = present value of all benefits - present value of all costs.

The objective of cost-benefit analysis is welfare maximisation. This can be attained by maximising the difference between benefits and costs, i.e. by selecting a measure with maximum net present value (among the alternatives compared).

The benefit-cost ratio is defined as:
Benefit-cost ratio = present value of all benefits/present value of all costs.

When the net present value is positive, benefit-cost 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 value (e.g. a long-term market interest rate); if the first value is greater than the second, then the project is judged as "desirable".

For most applications, using all three metrics will provide similar results (Hakkert & Wesemann, 2005). If our task is to choose among two or more mutually exclusive projects, then the use of net present value is recommended.

Let us consider an example of five road safety measures listed in Table 1. For each measure, three metrics showing its benefits are given: the number of fatalities prevented; the net present value, i.e. the surplus of benefits over costs, and the benefit-cost ratio. The measures are sorted according to their effect on the number of fatalities. Which of these measures should be introduced first? ISA is the first choice, because it has the largest net present value. It does not have the highest benefit-cost ratio; on the contrary, it has the lowest. In general, benefit-cost ratio should not be used as a decision rule in cost-benefit analysis, because it is a ratio and therefore does not account for the scale of a measure. Thus, a measure may have a high benefit-cost ratio, yet produce minor safety benefits because it is targeted at a small group of accidents or injuries. Besides, if a measure can be used in different doses, its benefit-cost ratio will, in general, not be independent of the dose applied.

Table 1: Choice between five road safety measures based on net present value

Measure	Fatalities prevented	Net present value	Benefit-cost ratio	Choice
Intelligent speed adaptation (ISA) on all cars	34	7.441	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 (versus current 58%)	10	3.952	7,93	2
Front impact protection on heavy vehicles	7	1.560	2,52	3

Beside a comparison of separate measures, cost-benefit analysis may help in prioritizing measure packages or policy alternatives. Table 2 shows an example of two measure packages that were analysed by Elvik (2007) as policy alternatives for promoting road safety in Norway, in the years 2007-2020. Before the packages were compiled, the costs and benefits of separate measures were estimated. Option A consists of measures for which the individual benefits were higher than the costs; option B is an intensified continuation of measures that are already being taken in Norway. Both options are compared with the null-alternative in which these measures are not applied.

Table 2 shows that option A has higher safety benefits than option B. However, as option B has positive mobility impacts, the total benefits of both packages are close. The costs of option A are lower than benefits providing a positive net present value effect and a benefit-cost ratio of 1,5. On the contrary, option B has a negative benefit-cost balance. Thus, option A with optimal use of road safety measures should be preferred.

Table 2: Cost-benefit comparison of two measure packages in Norway, in million Euros (price level 2005)

Benefits and costs (present values)	Option A: Optimal use of road safety measures	Option B: Strengthening present policy
Total benefits	9.526	9.245
Of which safety Of which mobility Of which health and environment	9.907 -553 171	8.061 1.119 65
Total costs	6.384	10.112
Benefit-cost balance Benefit-cost ratio	3.142 1,49	-867 0,91

Source: Elvik (2007)

10 Can the results of cost-benefit analyses be generalised across countries?

Cost-benefit analysis is widely applied for evaluation transport projects in many countries. Guidelines for carrying out such analysis are available in the UK, France, Germany, the Netherlands and many other European countries. For transnational projects, guidelines were developed in the European project HEATCO (Bickel et al., 2006).

Cost-benefit analyses of road safety measures were conducted in many countries. Results of such analyses were summarised in the ROSEBUD project (Hohnschheid et al., 2006). They showed that the benefits of investment in road safety often exceed the costs. Moreover, within the ROSEBUD project methods for cost-benefit (and cost-effectiveness) analysis of road safety measures were developed and their applicability was demonstrated on a number of road safety measures, in different countries (Winkelbauer & Stefan, 2005; Yannis et al., 2008). Most evaluation examples took into account not only safety effects but mobility and environmental effects as well.

In a few countries, the costs and benefits of large measure packages were evaluated. For example, Elvik (2007) examined 45 potential measures and compared four measure packages for Norway; Wieser et al. (2009) conducted cost-benefit analyses of measures taken in Switzerland in the period 1975-2007; Weijermars and Van Schagen (2009) evaluated Sustainable Safety measures that were applied in the period 1998-2007 in the Netherlands. In addition, in European projects, cost-benefit analyses of dedicated packages of road safety measures were conducted, such as intelligent vehicle systems (Baum et al., 2008), potential alcohol-impairment countermeasures (Vlakveld et al., 2005), measures against driving under the influence of drugs (Veisten et al., 2011).

In light of the increasing amount of evaluation results, a question of possibility of generalising the findings of cost-benefit analyses among countries, can be raised.

The current monetary valuation of road safety differs greatly among European countries. One might, therefore, expect the results of cost-benefit analyses to vary correspondingly. To see if this is the case, results of cost-benefit analyses made in a number of European projects, in recent years, have been compiled and compared. The following measures were considered:

- Traffic calming and speed reducing measures: this measure was analysed in Great Britain (Elvik, 1999), Germany (Höhnscheid et al., 2006), Israel, Greece (Winkelbauer & Stefan, 2005), Norway (Elvik, 2007) and Sweden (Elvik & Amundsen, 2000).
- Daytime running lights: this measure was analysed for Norway (Elvik et al., 2009), Austria, the Czech republic (Winkelbauer & Stefan, 2005) and for the EU as a whole (Koornstra et al., 1997; ETSC, 2003; Elvik, Christensen & Fjeld Olsen, 2003; COWI, 2006; Knight et al., 2006).
- Intelligent Speed Adaptation: this measure was analysed for Norway (Elvik, 2007), Sweden (Elvik & Amundsen, 2000), Great Britain (Carsten & Tate, 2005) and the EU as a whole (COWI, 2006).
- Increasing speed enforcement: this measure was analysed in Norway (Elvik, 2007), Sweden (Elvik & Amundsen, 2000), Greece, Israel (Winkelbauer & Stefan, 2005), and the EU as a whole (ICF consulting, 2003).

- Random breath testing: this measure was analysed in Norway (Elvik, 2007), Sweden (Elvik & Amundsen, 2000), the Czech republic, the Netherlands, Spain (Vlakveld et al., 2005) and for the EU as a whole (ETSC, 2003; ICF consulting, 2003).
- Driver eyesight testing: this measure was analysed for Norway, Switzerland, the Czech Republic, the Netherlands and Spain (Höhnscheid et al., 2006; Vlakveld et al., 2005).

As far as traffic calming and speed-reducing measures are concerned, Elvik (1999) found benefit-cost ratios varying from 9,7 to - 0,4 for Great Britain, depending on the type of road. For all types of road considered together, the benefit-cost ratio was estimated to about 3,5. In Germany (Höhnscheid et al., 2006), the benefit-cost ratio of narrowing lanes and installing speed humps in residential areas was estimated to 17. Corresponding benefit-cost ratios were estimated to between 2 and 4 in Israel and around 1,1 to 1,2 in Greece (Winkelbauer & Stefan, 2005). For Sweden (Elvik & Amundsen, 2000) as well as for Norway (Elvik, 2007), negative benefit-cost benefit ratios were estimated for speed reducing measures in residential areas. Thus, the findings of cost-benefit analyses of this measure are somewhat inconsistent. Reasons for the inconsistency are not known, but one can speculate that residential streets in Norway and Sweden typically carry lower traffic volumes than in the other countries and have lower accident and injury rates.

Daytime running lights have been found to be very cost-effective in all the analyses quoted above, except for one (Knight et al., 2006), with benefit-cost ratios typically ranging between 2 and 5. The assumptions leading to these results are questioned by Knight et al. (2006). They argue that the assumption made in most analyses of a greater effect of daytime running lights on fatal and serious accidents than on slight injury accidents is weakly supported by available evidence from evaluation studies. Replacing it by an assumption of an effect of about 6% reduction of daytime multi-vehicle accidents at all levels of accident severity, Knight et al. (2006) find that benefits are smaller than costs. However, by slightly altering other assumptions made in the analyses, for example relying on the HEATCO recommendations for the monetary valuation of safety (Bickel et al., 2006), benefits once more become greater than costs, even if a uniform effect of 6% on daytime multi-vehicle accidents is assumed. This example shows that sensitivity analyses should always be a part of cost-benefit analysis and that, in some cases, results are found to be quite sensitive to small changes in the assumptions made. On balance, it is more likely that the benefits of daytime running lights are greater than the costs than the opposite.

With respect to intelligent speed adaptation, all the analyses quoted above report that benefits are greater than costs. For this measure, therefore, there is perfect consistency in the findings of cost-benefit analyses.

Increasing other forms of speed enforcement has also been found to be very cost-effective in all analyses. It would seem that speed enforcement is an underutilised road safety measure in all of Europe. The same conclusion applies to random breath testing.

The cost-effectiveness of driver eyesight testing, on the other hand, has been found to vary substantially among the countries in which this measure has been analysed. More specifically, it appears to be rather ineffective in Norway and the Netherlands, but more cost-effective in Spain, the Czech Republic and Switzerland. Reasons for these differences are not known.

The conclusion is that in some cases the results of cost-benefit analyses appear to be valid in many countries, while in other cases there are large differences. The lesson is that cost-benefit analyses should be performed in every country and that one should not uncritically assume that the results of a cost-benefit analysis made in one country apply to another country.

11 Problems that may be encountered in cost-benefit analysis

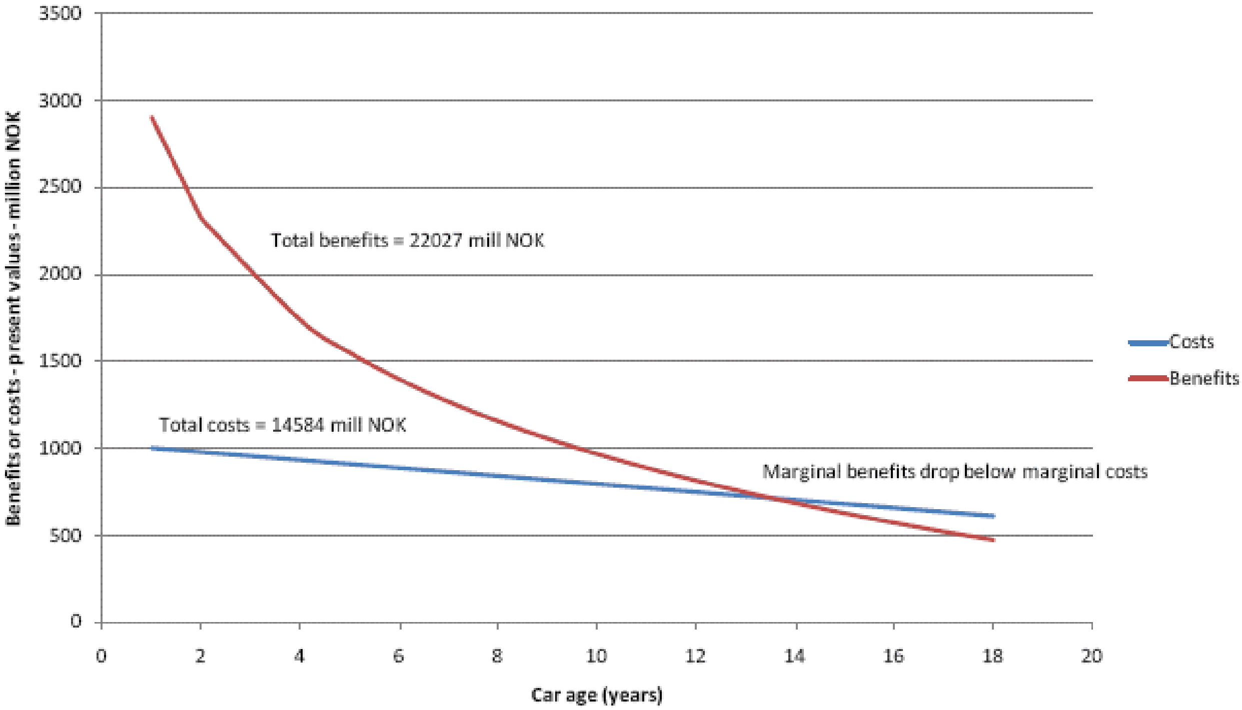
Hakkert and Wesemann (2005) overview the problems that may be encountered in conducting cost-benefit analyses of road-safety measures and discuss possible solutions for such barriers. Data unavailability, disputable values of parameters, lack of knowledge of relevant impacts, inadequate treatment of uncertainties are examples of technical problems for which practical solutions can be suggested based on the international experience. In addition, more "structural" problems can be met in the analyses. Two such problems are briefly discussed below: indivisibilities and path dependence.

An indivisibility occurs when a measure cannot be divided into sufficiently fine graded alternatives to permit strict optimisation. As an example, consider the case of introducing new safety features in cars. The decision is dichotomous: either to install a safety feature or not to install it. Once installed, it will in most cases be impractical to remove a safety feature. A cost-benefit analysis found that the benefits of ISA (Intelligent Speed Adaptation) clearly exceed costs, see Table 1. Costs and benefits were then assessed for a period of 18 years, after which the car was assumed to be scrapped.

Costs and benefits do not, however, accrue at constant rates during this period. New cars tend to be driven longer distances than older cars. Thus, all else equal, the largest benefits will accrue when the car is new. As the car gets driven less and less, benefits become smaller. This is illustrated in Figure 3. While, for the whole lifetime of the car, benefits clearly exceed costs, marginal benefits drop below marginal costs when the car is 14 years or older. It is, however, impractical to require that ISA is de-activated when the car reaches the age of 14 years. This is an example of an indivisibility. Legislation measures will often involve indivisibilities.

Another problem that can influence the possibility of maximising welfare (the purpose of measures selected by a cost-benefit analysis) is path dependence. This refers to the situation in which the benefits, and sometimes the costs, of a specific road safety measure depend on whether other road safety measures have been introduced. If, for example, introducing ISA is politically impossible, one may decide to increase other means of speed enforcement. Increased speed enforcement will reduce the number of accidents and their severity and make ISA less cost-effective. In some cases, interactions between road safety measures influencing the same target accidents or injuries can make them cost-ineffective if they are all introduced in combination, even if each measure is cost-effective if introduced by itself.

Figure 3: Marginal costs and benefits of ISA as a function of car age



12 Can road safety policy be based strictly on cost-benefit analyses?

Cost-benefit analysis summarizes a great deal of information in a rational framework but leaves the responsibility of choice for decision-makers. Other considerations can be involved in this process, e.g. of ethical or legal nature. Elvik and Veisten (2005) provide an overview of reasons why actual road safety policy may not be based strictly on the results of cost-benefit analysis. This could be, for example, *lack of power* of the authority to introduce certain road safety measures; *scarcity of resources* available for the programme's implementation; *social dilemmas* when a road safety measure is cost-effective from a societal point of view but not from the point of view of a certain group of road users. Lowering speed limits may be a case for the latter point, where the benefits are external from the driver's point of view and are not experienced as a personal gain.

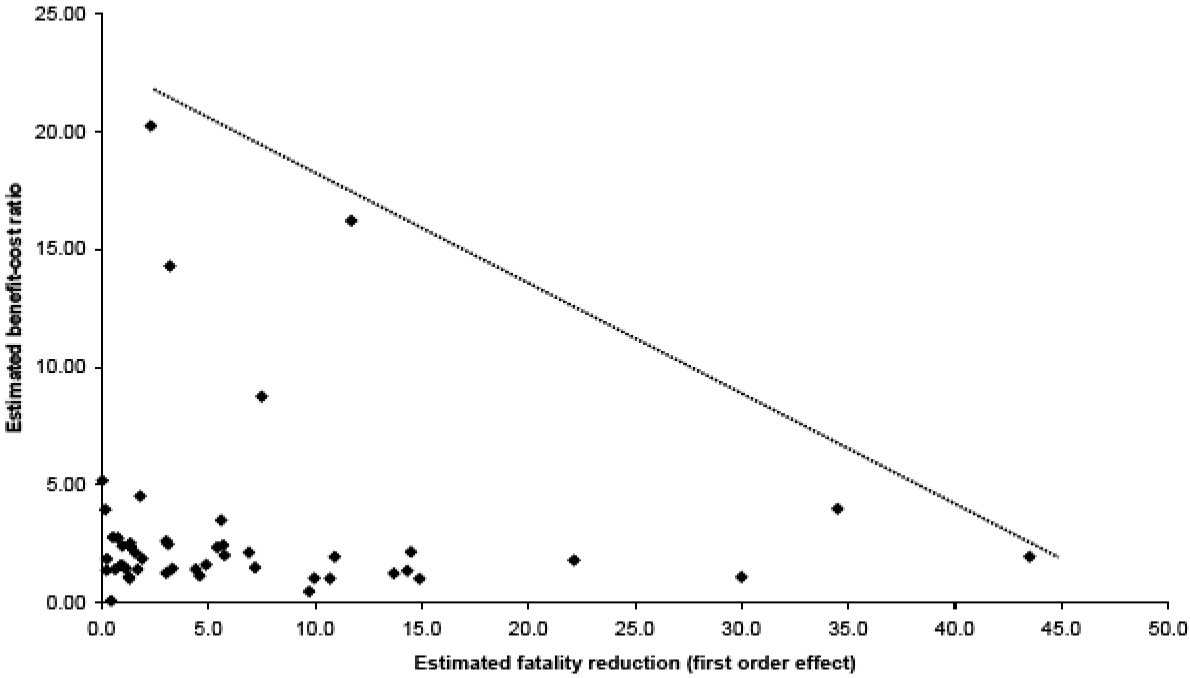
An additional reason that prevents basing road safety policy strictly on cost-benefit analyses lies in the existence of competing criteria for priority setting. More detailed explanations on that are given below based on Elvik (2007).

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 & Veisten, 2005), one of the questions that was posed to road safety policymakers across Europe was: "Do politicians put more weight on the number of fatalities and injuries prevented than on the monetary valuation of these impacts?" Among 70 answers given to this question, 40 respondents agreed 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. This reflects a common practice of priority setting.

Elvik (2007) argued that such an approach may be reasonable because road safety measures that have the most favourable benefit-cost ratios will not always be those that contribute to the greatest reductions in the number of fatalities or injuries. It could be the case that measures whose benefits only marginally exceed the costs will produce the greatest improvement of road safety, maybe even a greater improvement than, say, ten very highly cost-effective measures that influence small target groups. Figure 4 probes if this is the case for the road safety measures included in the impact assessment for Norway.

Taking all measures into consideration, Figure 4 shows no correlation between the size of the estimated fatality reduction and benefit-cost ratio. Yet, as indicated by the dotted line close to the most outward data points in the figure, a tendency can be seen for the measures producing the greatest reductions in fatalities to have the lowest benefit-cost ratio. The mean benefit-cost ratio for measures that may reduce the number of fatalities by more than 20 is 2,20. The corresponding mean value is 3,25 for measures that can reduce the number of fatalities by between 10 and 20, and 2,99 for measures that can reduce the number of fatalities by less than 10. There thus seems to be a tendency, although not very strong, for the most cost-effective measures to have the smallest effects on the number of road traffic fatalities. This may be felt as a dilemma for policymakers, in particular if Vision Zero is the basis for road safety policy, as is the case in Norway. The paramount criterion for setting priorities according to Vision Zero should be the size of the reduction in the number of fatalities and severe, non-fatal injuries.

Figure 4: Relationship between estimated fatality reduction and benefit-cost ratio for road safety measures in Norway.



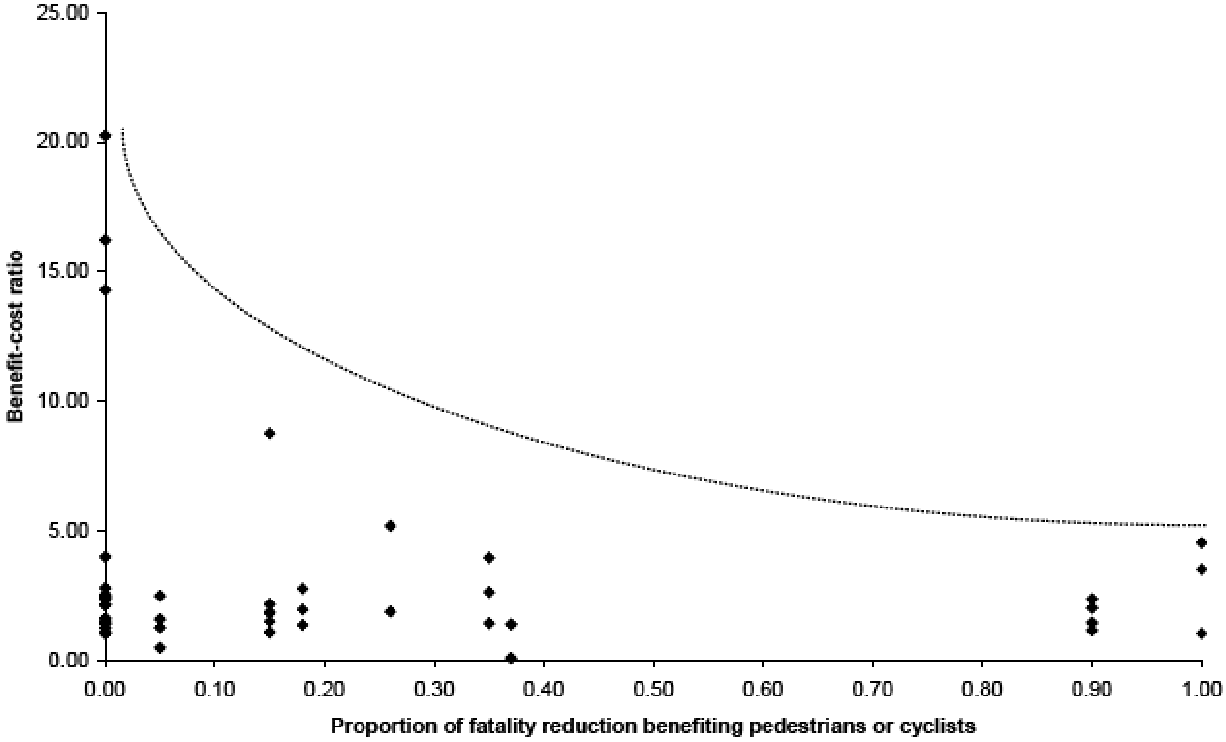
Source: Elvik (2007)

It is not just the size of the safety effect that may compete with economic efficiency as a criterion for priority setting. Some policymakers regard pedestrians and cyclists as disadvantaged groups in the current transport system and want to favour these groups. A difficult trade-off arises if the most cost-effective measures mainly benefit motorists, rather than pedestrians or cyclists.

To investigate if this is actually the case, the estimated first order reductions in the number of fatalities for each road safety measure have been allocated between motorists and pedestrians or cyclists. Figure 5 shows the relationship between the proportion of the estimated fatality reduction benefiting pedestrians or cyclists and benefit-cost ratio for the measures included in the road safety impact assessment.

As in Figure 3, a dotted line has been drawn around the outer data points in the figure, indicating a negative relationship between the proportion of fatality reductions benefiting pedestrians or cyclists and benefit-cost ratio. The (simple) mean benefit-cost ratio for road safety measures for which more than 40% of the fatality reduction benefits pedestrians or cyclists is 2,28. The mean benefit-cost ratio for measures for which between 20 and 40% of the fatality reduction benefits pedestrians or cyclists is 2,35. Finally, the mean benefit-cost ratio for measures for which less than 20 % of the fatality reductions benefit pedestrians or cyclists is 3,27. This suggests that the most cost-effective measures are those that provide the smallest benefits for pedestrians or cyclists. There may thus be a trade-off between efficiency and equity in road safety policy. Cost-benefit analyses focus only on efficiency, not on equity.

Figure 5: Relationship between proportion of estimated fatality reduction benefiting pedestrians or cyclists and benefit-cost ratio of road safety measures.



Source: Elvik (2007)

In summary, performing cost-benefit analyses of road safety measures does not eliminate the potential presence of competing criteria for priority-setting, in particular criteria referring to the size of effects on road safety and to the distribution of safety effects between different groups of road users. To the extent that policymakers regard such criteria for priority-setting as more relevant than the benefit-cost ratio, actual policy priorities may depart from the results of cost-benefit analyses.

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Notes

1. Country abbreviations

	Belgium	BE		Italy	IT		Romania	RO
	Bulgaria	BG		Cyprus	CY		Slovenia	SI
	Czech Republic	CZ		Latvia	LV		Slovakia	SK
	Denmark	DK		Lithuania	LT		Finland	FI
	Germany	DE		Luxembourg	LU		Sweden	SE
	Estonia	EE		Hungary	HU		United Kingdom	UK
	Ireland	IE		Malta	MT			
	Greece	EL		Netherlands	NL		Iceland	IS
	Spain	ES		Austria	AT		Liechtenstein	LI
	France	FR		Poland	PL		Norway	NO
	Croatia	HR		Portugal	PT		Switzerland	CH

2. This 2018 edition of Traffic Safety Synthesis on Cost Benefit Analysis updates the previous versions produced within the EU co-funded research projects SafetyNet (2008) and DaCoTA (2012). This Synthesis on Cost Benefit Analysis was originally written in 2008 and then updated in 2012 by Rune Elvik, TØI and in 2016 by Victoria Gitelman, Technion Israel Institute of Technology.

3. All Traffic Safety Syntheses of the European Road Safety Observatory have been peer reviewed by the Scientific Editorial Board composed by: George Yannis, NTUA (chair), Robert Bauer, KFV, Christophe Nicodème, ERF, Klaus Machata, KFV, Eleonora Papadimitriou, NTUA, Pete Thomas, Un. Loughborough.

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5. Please refer to this Report as follows:
European Commission, Cost Benefit Analysis, European Commission, Directorate General for Transport, February 2018.

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