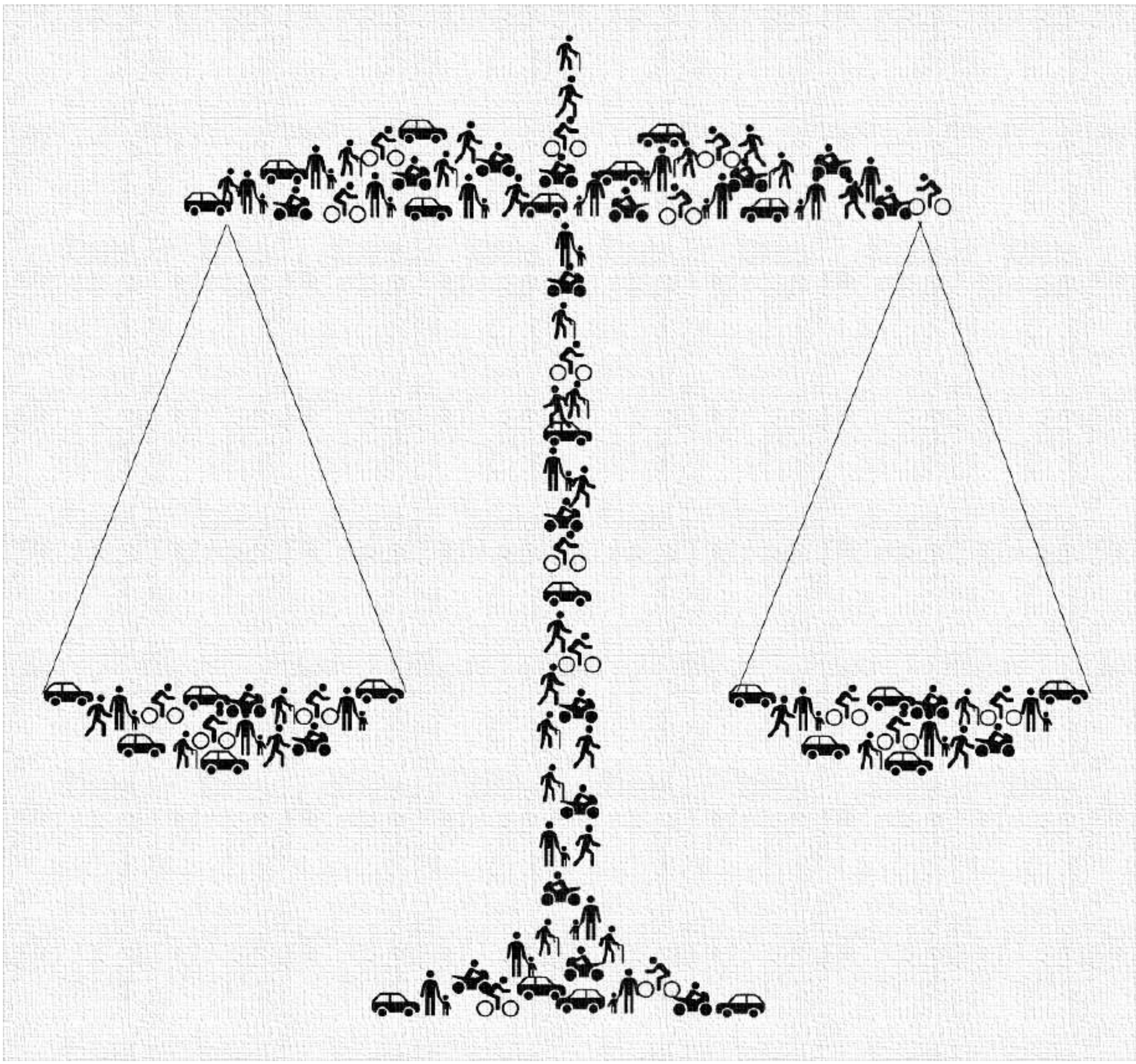

Economic evaluation of road user related measures

Deliverable 4.3

SafetyCube

Economic evaluation of road user related measures

Work package 4, Deliverable 4.3

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Executive summary

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). The DSS 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.
This document is the third deliverable (4.3) of work package 4, which is dedicated to the economic evaluation - mainly by means of a cost-benefit analysis - of road user related safety measures.

The following steps have been taken to achieve the results presented in this document:

- Selecting effective measures, suitable for a cost-benefit analysis
- Collecting data on measure costs, target group, effectiveness and penetration rates
- Applying the common methodology to conduct cost-benefit analyses, using the E^3 calculator developed in WP3
- Searching for existing cost-benefit analyses on effective measures if required data is missing
- Updating existing cost-benefit analyses in the SafetyCube E^3 calculator with updated crash and measure costs
- Documenting all steps and assumptions for each cost-benefit analysis

In a previous task of work package 4 (Theofilatos et al., 2017) the effectiveness of road safety measures in preventing road crashes or casualties was assessed by giving color codes to each measure. Measures which were marked with the colour codes 'green' (effective) or 'light green' (probably effective) were screened for their suitability in terms of economic evaluation. It is important to note that studies dealing with road user related countermeasure often assess the impact on safety performance indicators rather than accident outcomes (see Theofilatos et al., 2017 for further information). That leads to a limited number of measure topics that qualify for economic evaluation in the SafetyCube E^3 calculator in the first place.

An economic evaluation can be done by cost-effectiveness analysis, cost-utility analysis or cost-benefit analysis. Within SafetyCube the economic evaluation principally is done by executing cost-benefit analyses (CBA). In a CBA, the crash costs enter as benefits (because they are prevented) and the costs for measures are compared to them. The core output of this task are exemplary economic evaluations for 12 road-user related road safety measures, of which 11 cost-benefit analyses and 1 measure for which the break-even costs are calculated.
The documentation of these CBAs is added in the Appendix and provide detailed information on the used data and calculations. The principal tool for all the analyses was the Economic Efficiency Evaluation (E^3) calculator that has been developed in the SafetyCube project. A major advantage of this tool is that it enables to standardise the input and output information.

Most of the assessed human related measures have a benefit-to-cost ratio (CBR) that is higher than 1. This means that the benefits outweigh the costs and are economically efficient. The conducted calculationsshow a wide range of benefit-to-cost ratios (BCR) between 1 and 125.1. For only one measure the CBA resulted in a BCR smaller than 1, which means that it is not economically efficient.

Sensitivity analyses are performed using different rates of effectiveness of the measure in preventing crashes, and different values for measure costs. A best and worst-case scenario are estimated, and it was shown that in a worst-case scenario (with a lower effectiveness estimate and higher costs) the BCR still remains above 1 for the majority of the measures benefit-to-cost ratio.

The most important limitation of using cost-benefit analyses is its dependence on the underlying assumptions about the measure effectiveness, the target group and the measure costs. Therefore, the CBAs were accompanied by a sensitivity analysis. These analyses clearly demonstrated that changing the basic assumptions on the effectiveness or costs of measures has a large influence on the value of the BCR. Furthermore, it has to be noted that in the 12 economic evaluations conducted, side effects of countermeasures were only available for mandatory exe-sight testing, but are generally hardly reported.

The results of these CBAs can be used by policymakers, but – given the limitations – the values should be used carefully and with a critical eye. The assumptions that are made should be checked thouroughly. Furthermore, it is recommended to complement the available information with specific information on the measure's target group, likely effects, the measure costs and the circumstances in which they are applied.

All together the number of CBAs on road safety measures in the scientific literature is very limited and much further work is needed to systematically assess costs and benefits of road safety measures.

1 Introduction

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 systems approach with road safety stakeholders at the national level, EU and beyond having involvement at all stages.

Work Package 4

The objective of work package 4 is to analyse data, implement developed methodologies concerning accident risk factors and road safety measures related to the road users. It examines accident risks and safety measures concerning all types of road users including Vulnerable Road Users (VRU). Personal as well as commercial transportation aspects are taken into account. Therefore, various data sources (macroscopic and in-depth accident data) and knowledge bases (e.g. existing studies) will be exploited in order to:

- identify and rank risk factors related to the road use
- identify road user related measures which address the most important risk factors
- assess the effect of measures

The work on human related risks and measures in road traffic is done according to the methodology and guidelines developed in work package 3 (Martensen et al., 2017) and uniform and in parallel with the work packages dealing with infrastructure- (WP5) and vehicle- (WP6) related risks and measures. Furthermore, the latter process is monitored and steered by WP8.
All main results of WP4 will be integrated into the DSS and linked with each other (risk factors and measures) and with outcomes of other work packages (WPs 5, 6 and 7[1]).

[1] WP7 is dealing with serious injuries.

1.2 PURPOSE OF THIS DELIVERABLE

This deliverable document the work carried out within task 4.3 of the SafetyCube project. The aim of task 4.3 is to assess the economic efficiency of road safety measures that are identified as effective in taks 4.2 (Theofilatos et al, 2017). The focus is on measures targeting road users – in contrast to measures targeting road infrastructure or vehicles. Based on the methodology developed in WP3, an economic evaluation of theselected road safety measures was done by conducting a cost-benefit analysis (CBA). This was done using the Economic Efficiency Evaluation (E^3) calculator, a tool developed within SafetyCube to standardize economic evaluations of road safety measures.

The process of this task comprised the following steps, taken to achieve the common purpose of SafetyCube to create an evidence based decision support system:

- Selecting effective measures suitable for a cost-benefit analysis;
- Collecting data on measure costs, target group, effectiveness and penetration rates;
- Applying the common methodology to conduct cost-benefit analyses, using the E^3 calculator developed in WP3;
- Searching for existing cost-benefit analyses on effective measures if required data is missing
- Updating existing cost-benefit analyses in the SafetyCube E^3 calculator with updated crash and measure costs;
- Documenting all steps and assumptions for each cost-benefit analysis.

The main result of deliverable 4.3 is the assessment of a variety of road user related measures in terms of economic efficiency, as well as a comparison of these measures. Information and results of the conducted and updated cost-benefit analyses will be made available through SafetyCube's 'Road Safety Decision Support System' (DSS): http://www.roadsafety-dss.eu/.

2 Method

2.1 OVERVIEW OF METHODS FOR PRIORITY SETTING

After assessing the different road safety measures and their estimated effects, it is important to define a methodology to assign levels of priority to each of the measures. This helps policy makers and other stakeholders to determine policies that make the most efficient use of resources. Priority can be assigned to the different measures by performing an economic assessment. There are three different methodologies: cost-effectiveness analysis (CEA), cost-utility analysis (CUA) and cost-benefit analysis (CBA). This section briefly describes the tools and explains why a CBA is preferred. More information can be found in SafetyCube Deliverable 3.4 (Martensen et al., 2017).

2.1.1 Cost-effectiveness analysis (CEA)

In a cost-effectiveness analysis (CEA) a road safety measure can be evaluated as the number of crashes prevented by the measure per unit cost of implementing the measure.
The necessary information to concuct this analysis is the effectiveness of a measure per unit of implementation, the cost of implementing the measure and a definition of a unit of implementation.

The main advantage of a CEA is that less information is necessary to conduct the analysis. It is not necessary to have an estimation of the monetary value of a crash. On the other hand, the CEA is limited to the economic evalution regarding only one outcome of the measure (for example the number of prevented crashes). It is not possible to take into account the effect of the measure on different levels of severity of crashes, or the effect on different policy areas such as the environment or mobility.

CEA is usefull to determine how to reach one specific policy objective (e.g. reducing the number of crashes) at the lowest costs.

2.1.2 Cost-utility analysis (CUA)

A cost-utility analysis (CUA) is an analysis in which the effect of a measure on different levels of severity of crashes can be taken into account. The impact of a measure on the health of traffic casualties can be expressed in Quality Adjusted Life Years (QALY). Fatalities are assessed by Years of Life Lost (YLL) avoided by implementing a road safety measure, while injuries are assessed by the Years Lived with Disability (YLD) that are saved. While a CEA calculates the cost per prevented crash a CUA calculates the cost per QALY, which combines the impact on fatalities and different injury severities. In that way road safety measures can be prioritised according to the cost-utility (cost per QALY).

The main advantage compared to CEA is that CUA allows includding the effect of the measure on different severity levels of crashes. Different values can be assigned to them depending on the impact on YLL or YLD. A similar limitation of the CUA is that 'side effects', the impact of the measure in other policy areas, cannot be taken into account.

CUA is useful to determine how to reach multiple objectives which are related to each other (e.g. number of fatalities, serious injuries, slight injurie), at the lowest cost.

2.1.3 Cost-Benefit Analysis (CBA)

A cost-benefit analysis (CBA) allows the joint evaluation of the effectiveness of measures in reducing crashes of different severity and to provide information on the socio-economic return of countermeasures. Therefore, a monetary value is assigned to each type of benefit that results from the measure. The sum of these monetary values is compared to costs of the measure. In a CBA two statistics can be calculated:

(1) the net present value (NPV) = Benefits – Costs
(2) the benefit-to-cost ratio (BCR) = Benefits / Costs.

If the benefits are greater than the costs, a measure is cost-effective. For the NPV this means a value higher than 0 and for the BCR this means a value higher than 1. Measures can be ranked or prioritized based on the NPV or BCR.

A CBA is often preferred above a CEA or a CUA because it is possible to take side effects - effects on other policy areas such as mobility or the environment - into account. As long as these effects can be monetarized, they can be included in a CBA. The determination of side effects is however not in the scope of the SafetyCube-project since the main focus is on road safety.

While CEA simply helps to find the cheapest way of realising one particular policy objective, the aim of CBA 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.

2.2 THE ECONOMIC EFFICIENCY EVALUATION TOOL

Within the SafetyCube-project an Economic Efficiency Evaluation (E^3) calculator has been developed. This tool facilitates conducting a CBA. All necessary input information can be filled in by the user: the effectiveness of the measure, the target group and its costs. Monetary values of the benefits (the prevented crashes or casualties) for different severity categories are provided by the tool. Using this information, the economic efficiency of the measure is calculated by the E^3 calculator in terms of the NPV, the BCR or, in case there is no information on the measure costs, the break-even cost. This tool has been applied to conduct CBAs for 12 road user related measures.

In order to use the tool, certain inputs and considerations should be taken into account. First of all, it is important to mention that the tool assumes that the road safety measures are evaluated in specific units of intervention, such as a vehicle equipped with a safety system or a specific infrastructure location. Furthermore, for the purposes of the E^3 tool it is important to define certain concepts including:

- Crash Modification Factor (CMF): A CMF is a multiplier that has to be applied to the number of crashes that occurred before the implementation of the measure. A CMF is used to estimate the number of crashes that (still) will occur when the measure is implemented. Thus, it is an estimate of the expected effect of a measure.
- Effectiveness (E) or Percentage Reduction (PR) is defined by the formula E=PR=100*(1-CMF) and it represents the reduction of crashes after the measure is implemented.

The following chart gives an overview of the E^3 tool, explained in more detail in SafetyCube's Deliverable 3.3 which will be available in February 2018.

2.2.1 Inputs

First it is important to consider whether a specific road safety measure or intervention is aimed at preventing crashes or casualties. In the E^3 tool, all the measures that can prevent crashes are assessed as a reduction of crashes and it is recommended to take into account different levels of severity of crashes when estimating the effectiveness of the measures. That is due to the fact that the implementation of a certain measure can have different effects depending on the level of severity, and can thus lead to different benefits because the monetary value differs for each severity category.

Second, when including the the costs of a road safety measure as an input to the E^3 tool, implementation and maintenance costs have to be differentiated. The implementation cost is only paid one time, while the maintenance cost is a recurrent cost and should be expressed on a yearly basis. These costs differ per country. These costs have to be updated to 2015 since this is the year in which the costs of crashes (benefits), that are provided in the E^3 tool, are expressed.

Another important input is the target group. This is the number of crashes on which the safety measure is expected to have an impact. In the tool, the target group should be specified for all the levels of severity for which there is information regarding the CMF. Moreover, the effectiveness (or percentage reduction) should be added for each severity level.

The number of crashes and an estimate of the value of the crash costs, per severity level, are provided by the E^3 tool for each European country, and for all European countries together. The user can select the relevant data for the country they analyse and include the values as an input in the calculator.

2.2.2 Method

First of all, the benefits, depending on the level of severity, that result from the introduction of a measure are calculated as follows.

$$Benefits = \sum_{s} TargetCrashes_s * Effectiveness_s * CrashCosts_s$$

Where, s= severity level.

The tool calculates the costs and benefits on a yearly basis. Time periods of more than one year can be considered, however. First, the actual values of the implementation and maintenance costs are calculated. Then, a discount rate that can be chosen as an input is applied to obtain the present value of the costs as follows:

$$present\ value = \frac{actual\ value}{(1 + discount\ rate)^{year}}$$

The benefits represent the number of prevented crashes per year due to the implementation of the measure. The number of prevented crashes can be filled in directly in the input, or will be calculated by multiplying the target group with the effectiveness. Next the benefits will be put in monetary values by multiplying the cost per crash with the number of prevented crashes.

2.2.3 Output

The output consists of the present values of the costs and benefits of implementing the measure over the selected time period.
Net present value and benefit-to-cost ratio are also shown, calculated with the following formulas to estimate the socio-economic return of introducing the measures:

Net present value = Present value benefits – Present value costs
Benefit-to-cost ratio = Present value benefits / present value costs

For measures with missing measure cost information, a break-even cost is calculated by the tool.

2.2.4 Other analyses

Extra analyses can be included in the tool. For example, sensitivity analyses and side effects derived from the implementation of the measure.

2.3 DATA COLLECTION PROCEDURE

Collection of data for cost-benefit analyses, was conducted for road user related countermeasures which were assessed as effective (colour code green) or probably effective (colour code light green) in Deliverable 3.2 (Theofilatos et al, 2017). The assessment of the measures in this deliverable already indicates the availability of an estimate of effectiveness, which makes this deliverable the primary source for the data collection.

Preferably, an estimate from a meta-analysis was used. Further literature research was carried out to find complementary information such as measure costs and the target group. Literature has also been scanned to find existing cost-benefit analysis studies which could be updated with new cost information. Some useful sources with a wide range of relevant information on various measures were used, such as NCHRP (2008) or Elvik et al. (2009).
For data on target groups or penetration rates, accident databases were consulted (e.g. CARE or GIDAS database).

3 Input for cost-benefit analyses

This chapter provides an overview of the information that was used as input for the Cost-Benefit Analyses (CBA). The first section 3.1 lists all the selected measures. The subsequent sections 3.2 and 3.3 provide information on the selected time horizons for the measures, the measure costs and the used values for the effect estimates. Section 3.4 explains the used method and the input data for the crash cost estimates.

3.1 SELECTED MEASURES

3.1.1 Selection criteria

Following a common method, systematic information on the safety effects of 24 traffic safety measures addressing the road user was collected in Theofilatos et al. (2017). The method included a literature search strategy, a 'coding template' to record key data and metadata from individual studies, and guidelines for summarising the findings (Martensen et al., 2017).

24 synoptic documents *(synopses)* were created, synthesising the coded studies and outlining the main findings in the form of a meta-analysis (if possible), a review type analysis or a vote-count analysis. In these synopses, each measure was assigned a colour code, which indicates how effective this measure is in terms of the amount of evidence demonstrating its impact on crash reduction. The code can be one of the following:

- Green: **clearly reducing risk**. Consistent results showing a decreased risk, frequency and/or severity of crashes when this measure is applied.
- Light Green: **probably reducing risk, but results not consistent**. Some evidence that there is a decreased risk, frequency and/or severity of crashes when this measure is applied but results are not consistent.
- Grey: **unclear results**. Studies report contradicting effects. There are few studies with inconsistent or not verified results.
- **Red: not reducing risk**. Studies consistently demonstrate that this measure is not associated with a decrease in crash risk, frequency or severity.

In total, seven measures were assigned a green code (e.g. general police enforcement, speeding), 13 were given a light green code (e.g. awareness raising and campaigns - child restraint), two were given a grey code (e.g. law and enforcement for mobile phone use) and one measure received a red colour code (age-based screening of elderly drivers).

For the purpose of the cost-benefit analyses, measures that turned out to have a green or light green code in Theofilatos et al. (2017) were selected in a first step. Measures with a grey or red code were not considered to be meaningful candidates for CBA as cost-benefit analyses only make sense if some beneficial effect of the measure can be assumed.
All these measures were reviewed and for each of them it was checked whether they could be the subject of a meaningful CBA. For some measures, insufficient information could be retrieved.

Table 1 gives an overview of this initial selection of measures and indicates for each of these measures whether a CBA could be elaborated or not. If not, an indication is provided on the most important reason(s) for not elaborating a CBA. The most important reasons for not being able to complete a CBA were:

- Lacking information on measure costs

- Lacking information on measure effectiveness
- Lacking information on the number or the nature of affected accidents

Table 1: Overview of measures

Measure	Colour code	CBA executed	Reason not to execute CBA
Law and enforcement – General police enforcement of speeding	Green	Yes	-
Law and enforcement – DUI checkpoints, selective and random breath testing	Green	Yes	-
Law and enforcement – Seatbelt wearing	Green	Yes	-
Law and enforcement – License suspension	Green	No	Effectiveness estimates from the US only No (good) cost estimates
Fitness to drive assessment and rehabilitation – Alcohol interlock	Green	Yes	-
Fitness to drive assessment and rehabilitation – Rehabilitation courses	Green	No	Effectiveness estimate only for recidivism rates
Education and voluntary training – Hazard perception training	Green	Yes	-
Law and enforcement – BAC limits (for novice drivers)	Light green	No	No (good) cost estimates
Law and enforcement – Red light cameras	Light green	Yes	-
Law and enforcement – Increasing traffic fines	Light green	No	Strong variation of measures of effectiveness No (good) cost estimates
Law and enforcement – Hours of service regulations for commercial drivers	Light green	No	Effectiveness estimates from the US only No (good) cost estimates
Law and enforcement – Demerit point systems	Light green	No	No (good) cost estimates
Formal pre-license training – Graduated driver licensing	Light green	Yes	-
Fitness to drive assessment and rehabilitation – Medical referrals	Light green	No	CBA on subtopic 'Mandatory eyesight test'
Fitness to drive assessment and rehabilitation – Mandatory eyesight testing	No synopsis	Yes	-
Education and voluntary training – Child pedestrian training	Light green	Yes	-
Awareness raising and campaigns – Seatbelt wearing	Light green	Yes	-
Awareness raising and campaigns – Child restraint	Light green	Yes	-
Awareness raising and campaigns – Drink-driving	Light green	Yes	-
Awareness raising and campaigns – Aggressive and inconsiderate behaviour	Light green	No	Heterogeneity of analysed campaigns and no CBA suitable for update found
Awareness raising and campaigns – Campaigns in general	Light green	No	Heterogeneity of meta-analysed campaigns
Awareness raising and campaigns – Speeding and inappropriate speed	Light green	No	Heterogeneity of analysed campaigns and no CBA suitable for update found

3.1.2 Selected measures per category

Law and enforcement measures

Cost-benefit analyses of this type of measures have been carried out for speeding enforcement, DUI enforcement, seatbelt enforcement and red light cameras.
Hours of service regulation, as a countermeasure for fatigued driving, has been previously assessed in the USA. However, overall cost estimates are not available and the US legislation has minor relevance for Europe. For demerit point systems, license suspension, lowering BAC limits as well as for increasing traffic fines, no good cost estimates are available. Furthermore, the effectiveness estimates for fines changes vary strongly and studies on license suspension were mainly conducted in the US.

Education and voluntary training

Within the measure category 'education and voluntary training', effectiveness was examined for child pedestrian training, voluntary training for novice drivers and hazard perception training. Regarding voluntary training for novice drivers (not including training relating to passing a driving test), there was not sufficient evidence to make a judgement about the effectiveness. Cost-benefit analyses were made for child pedestrian training and hazard perception. However, for hazard perception it was not possible to find concrete costs related to the implementation of this type of training. Therefore, only the break-even point (maximum cost of measure) was calculated.

Driver training and licensing

Within the measures category 'driver training and licensing', effectiveness was also examined for graduated driver licensing (GDL) and a cost-benefit analysis was carried out.

Fitness to drive assessment

While cost-benefit analyses have been conducted for mandatory eyesight testing and an alcohol interlock, it was not possible to conduct one for rehabilitation courses as countermeasure for drink-driving offences. The studies that were included in the corresponding SafetyCube synopsis only present an effectiveness estimate related to the rate of recidivism, and do not make the link with a reduction in crashes or casualties. Since the benefits in the SafetyCube Economic Efficiency Calculator are defined based on the number of prevented crashes or casualties, existing studies do not provide enough information to conduct a cost-benefit analysis.

Road safety campaigns

The effectiveness of campaigns is reported by two meta-analyses (Phillips et.al, 2009 and Phillips et.al, 2011). As campaigns vary considerably in various crucial factors like theoretical backgrounds, duration, target groups, range etc. a cost-benefit analyses for the general measure awareness raising and campaigns, is difficult to conduct. Therefore, analyses were conducted exemplary for three types of campaigns, where there were good quality evaluation studies available. Furthermore, for some topics tackled by means of campaigns and awareness raising, there were no existing cost-benefit analyses found which could have been updated.

3.2 UNIT OF ANALYSIS

The unit of analysis represents the dimensions of the area for which the CBA was executed. As measures addressing the road user are very diveres, several different units of intervention occured:

- one intersection, which was used in the cost-benefit analysis for red light cameras,
- one area of enforcement, including several dangerous road segments. This was the case with cost-benefit analyses on general police enforcement on speeding,

- one year of increased enforcement in one country as in the cost-benefit analysis of seat-belt enforcement,
- one campaign, program or training intervention. Examples of these can be found in the cost-benefit analyses for seatbelt campaigns and hazard perception training,
- one test or participation in a treatment for one single driver. Examples are cost-benefit analyses for alcohol interlock and mandatory eyesight test.

Table 2 contains an overview of the units of analysis that were used in every CBA.

3.3 TIME HORIZON

The time horizon in the cost-benefit analyses should equal as much as possible the real lifetime of the measure. For campaigns, programs or training interventions the duration is often shorter than one year, for these cases the minimum time horizon, one year, was chosen. Measures where equipment is installed such as red light cameras have longer time horizons. In the example of red light cameras, 10 years was taken as this is the period, where such cameras are economically written off. For enforcement measures the time horizon was chosen according to what was stated in the evaluation studies, this was one or five years.

No formal sensitivity analyses were done based on varying time horizons. Although it is not likely for most measures that changes in the applied time horizons within reasonable boundaries will deeply affect the outcomes of the cost-benefit analysis, the reader should keep in mind that time horizons are one of the input variables that eventually will determine the outcomes and therefore should be estimated with the best possible precision. Table 2 shows the applied time horizon for each of the selected measures.

3.4 INVESTMENT COSTS AND RECURRENT COSTS

Table 2 also presents an overview of the estimated investment costs and annually recurrent costs of the selected measures. To make a proper comparison possible, all measure costs are expressed in Euro and are converted to average EU-28 PPP (Purchasing Power Parity) values for 2015. More information on the sources of the provided measure costs can be found in the documentation of the cost-benefit analyses included in the Appendix. The reader should be aware that cost estimates in general tend to be rather weakly documented and only sparsely available. Even in the best cases, only a few cost estimates were available. In those cases, priority was given to the most recent estimates, the ones that were most applicable to the European situation and the ones that come from the most reliable sources.

Table 2: Overview of unit of analysis, time horizon and costs of the selected measures

Measure	**Unit of analysis**	**Time horizon** (in years)	**Investm. cost per unit of analysis** (in EUR EU-2015 PPP)	**Annual costs per unit of analysis** (in EUR EU-2015 PPP)	**Total costs per unit of analysis**[2] (in EUR EU-2015 PPP)
Law and enforcement – General police enforcement of speeding	One area of enforcement with a total length of 88 km.	5	€5,856,879	-	€5,856,879

[2] The total costs for measures with reocurring annual costs are available only if the time horizon is also available

Law and enforcement – DUI checkpoints, selective and random breath testing	DUI testing for 100,000 drivers for a year	5	€3,284,143	-	€3,284,143
Law and enforcement – Seatbelt wearing	One country, increase of seatbelt enforcement by factor 2	1	-	€5,173,139	-
Fitness to drive assessment and rehabilitation – Alcohol interlock	Participation of a serious offender in an alcohol interlock program	2	-	€1,534	-
Education and voluntary training – Hazard perception training	One harzad perception training	1			
Law and enforcement – Red light cameras	One red light camera on an intersection, 253 implemented units	10	€80,400	€2,900	
Formal pre-license training – Graduated driver licensing	One training intervention	1	€132,620	-	€132,620
Fitness to drive assessment and rehabilitation – Mandatory eyesight test	One mandatory eyesight test and treatment if necessary and possible	1	€47		€47
Education and voluntary training – Child pedestrian training	One child pedestrian training	1	€574,689	-	€574,689
Awareness raising and campaigns – Seatbelt wearing	One national seatbelt campiagn	1	€468,832	-	€468,832
Awareness raising and campaigns – Child restraint	One nationwide booster seat programme 4-8-years old	1	€463,980	-	€463,980
Awareness raising and campaigns – Drink-driving/riding	One drink-driving advertising campaign	1	€862,157	-	€862,157

3.5 SAFETY EFFECTS

Table 3 reflects the used estimates of the effects on crashes (or casualties). Obviously, this is a highly important variable in any cost-benefit analysis and assumptions about this variable are likely to have a decisive effect on the eventual outcomes.

In the ideal case, a meta-analysis is available. This is not only interesting because a well performed meta-analysis tends to provide a reliable estimate of the effect of the measure but also because confidence intervals (usually 95 % CI) are available that quantify the level of uncertainty of the effects. An absolute minimum requirement for a cost-benefit analysis is that at least one sufficiently reliable effectiveness evaluation has been done that provides a quantitative effect estimate. For some measures, no meta-analysis is available but a few studies with varying estimates of effectiveness were found. In these cases, it was left to the individual expert judgement either to run cost-benefit analyses with each of these estimates or to select the estimate that seemed more reliable for a good reason, for instance because one study meets best the typical conditions of the measure (e.g. it is the only European study or it is a study that meets best the conditions where proper cost estimates are available for). Sometimes the measure itself is very diverse like campaigns. A campaign can adress different target groups, use different media types, have different ranges (e.g. national or regional) and vary extremely regarding costs. Thus, cost-benefit analyses were calculated for exemplary campaigns and not using the effects of available meta-analyses.

Apart from the best estimate of the effect, table 3 also includes the lower and upper limits of the CI. Detailed information on the input variables that were used for the individual cost-benefit analyses, including references to the original sources, are available in the documentation of the cost-benefit analyses, see Appendix.

Table 3: Overview of effects of the selected measures (lower and upper limit given if available)

Measure	**Unit of analysis**	**Crash effects (best estimates)**	**Crash effects (lower limit)**	**Crash effects (upper limit)**
Law and enforcement – General police enforcement of speeding	One area of enforcement with 100km/h and 80km/h dangerous road segments	Injury crashes reduction: 18% PDO only crashes reduction: 18%	Injury crash reduction: 13% PDO only crashes reduction: 13%	Injury crash reduction: 23% PDO only crashes reduction: 23%
Law and enforcement – DUI checkpoints, selective and random breath testing	DUI testing for 100,000 drivers for a year	Crash reduction: 14%	Crash reduction: 11%	Crash reduction: 18%
Law and enforcement – seatbelt wearing	One country, increase of seatbelt enforcement by factor 2	Fatalities reduction by using seatbelt: 60% Serious injury reduction by using seatbelt: 60%	Fatalities reduction by using seatbelt: 53% Serious injury reduction by using seatbelt: 53%	Fatalities reduction by using seatbelt: 66% Serious injury reduction by using seatbelt: 66%
Fitness to drive assessment and rehabilitation – Alcohol interlock	Participation of a serious offender in an alcohol interlock programm	Prevented fatalities: 5.6 Prevented serious injuries: 145.3 Prevented slight injuries: 2250.0 Prevented PDO crashes: 7976.6	Prevented fatalities: 3.0 Prevented serious injuries: 77.5 Prevented slight injuries: 1,200.0 Prevented PDO crashes: 4,254.2	Prevented fatalities: 7.1 Prevented serious injuries: 184.1 Prevented slight injuries: 2,850.0 Prevented PDO crashes: 10,103.6
Education – Hazard perception training	One harzad perception training			
Law and enforcement – Red light cameras	One red light camera on an intersection, 253 implemented units	Casualty crashes reduction: 12% PDO only crashes reduction: -3%		Fatal and serious injury crashes reduction: 14% all injury crashes reduction: -5%

Measure	Unit of analysis	Crash effects (best estimates)	Crash effects (lower limit)	Crash effects (upper limit)
Formal pre-license training – Graduated driver licensing	One training intervention	Fatal injury casualties reduction: 20% Slight/serious injury casualties reduction: 20%		
Fitness to drive assessment and rehabilitation – Mandatory eyesight test	One mandatory eyesight test and treatment if necessary and possible	Prevented fatalities: 0.49 Prevented serious/slight injuries: 20.6 Prevented PDO crashes: 152		
Education and voluntary training – Child pedestrian training	One child pedestrian training	Fatal injury casualties reduction: 12% Slight/serious injury casualties reduction: 12%		
Awareness raising and campaigns – Seatbelt	One national seatbelt campiagn	Fatal injury crashes reduction: 50% Serious injury crashes reduction: 45% Penetration Rate of seatbelt usage before the campaign: 93,8% Penetration Rate of seatbelt usage after the campaign: 95,6%	Fatal injury crashes reduction: -45% Serious injury crashes reduction: -40%	Fatal injury crashes reduction: -55% Serious injury crashes reduction: -50%
Awareness raising and campaigns – Child restraint	One nationwide booster seat programme 4 to 8 years old	Fatal injury reduction: 8% Serious and slight injury reduction: 8%		
Awareness raising and campaigns – Drink-driving/riding	One drink-driving advertising campaign	Incapacitating and fatal crash reduction: 15.4 PDO only crashes reduction: 112		

3.6 SAFETYCUBE CRASH COST ESTIMATES

Within SafetyCube, costs of crashes were estimated for individual EU countries as well as for the EU in total. First, by studying international guidelines and best practices, it was determined which cost components should be included and how each cost component should be estimated. Second, information on costs of crashes were collected by means of a survey among all EU countries. Third, by means of value transfer costs were made more comparable between EU countries and an estimate of the total costs of crashes in the EU was provided. The three steps are discussed in more detail below. For more detailed information as well as actual estimates please see Deliverable 3.2 *'Crash cost estimates for European countries'* (Wijnen et al., 2017).

3.6.1 Crash cost components and methods to estimate them

Following international guidelines, like the COST313 guidelines (Alfaro et al., 1994), the following cost components are taken into account within SafetyCube:

- Medical costs (e.g. costs of transportation to the hospital, costs related to hospital treatment)
- Costs related to production loss
- Human costs
- Costs related to property damage (mainly vehicles)
- Administrative costs (e.g. police, fire department, insurances)
- Other costs (funeral costs, congestion costs)

Medical costs, costs related to property damage and administrative costs should be calculated by means of the restitution costs method. This means that the actual costs - like costs of an overnight hospital stay or costs related to the reparation of a vehicle - need to be calculated. Costs related to production loss should be calculated by means of the human capital approach: production loss of a casualty is calculated by multiplying the period of time the casualty not able to work due to the crash with a valuation of the production per person per unit of time.

The (individual) willingness to pay (WTP) approach is recommended for the estimation of human costs. In this approach, costs are estimated on the basis of the amount individuals are willing to pay for a risk reduction. On the basis of a WTP study, the value of a statistical life (VOSL) is estimated. This VOSL is subsequently used to calculate human costs. Several alternative approached are in use for the calculation of human costs. In Germany and Australia for example, human costs are based on financial compensations that are awarded in courts or by law. Another approach is to deduct human costs from premiums people pay for life insurances or from public expenditures on improving road safety. These alternative approaches typically result in much lower values than those from WTP studies. Within SafetyCube, the (individual) WTP approach is recommended to estimate human costs, because this is the most theoretically sound method, in particular for use in cost-benefit analyses, and is common practice in many countries.

3.6.2 Collection of data on crash costs EU countries

By means of a survey, information was collected on costs of crashes in European countries. The data collection was a joint effort of the H2020 projects SafetyCube and InDeV. A working group, consisting of SafetyCube and InDeV partners, developed an excel based questionnaire, asking for information concerning: costs per casualty and crash by severity level, total costs, costs per component, methods and definitions, and number of casualties. We asked for official cost figures used by governmental organizations. Questionnaires were prefilled by a responsible SafetyCube or InDeV partner using available information and then sent to experts in each country for a check and completion. Data from 31 European countries, out of the 32 initially included in the study, were obtained.

Within SafetyCube, the questionnaires were integrated into a SQLite database, consistency checks were carried out, and the data was standardized for currency, inflation and relative income differences between countries.

For all EU countries, except Romania, at least some information on costs of crashes was available. Reported costs per fatality vary between €0.7 million and €3.0 million per fatality. Reported costs per serious injury range from €28,000 to €959,000 and reported costs per slight injury range from

€296 to €71,742. The total costs of crashes vary between 0.4% and 4.1% of the Gross Domestic Product (GDP). Although a better road safety performance should in principle result in lower crash costs, we found only a weak positive relation between mortality rate and costs as a percentage of GDP. Differences between countries are also due to methodological differences, like whether the WTP method is applied for the calculation of human costs.

3.6.3 EU Cost estimates using value transfer

Not all countries have information for all cost components and/or all severity levels. Some countries for example exclude property damage only (PDO) crashes. Moreover, not all countries produce cost estimates according to the international guidelines. Some countries for example, didn't apply the WTP approach for the calculation of human costs. Within SafetyCube, the value transfer method is applied to estimate standard cost values per casualty/crash type and to estimate total costs of crashes according to international guidelines for each EU country and for the EU in total.

The value transfer method uses cost estimates from countries whose estimates are consistent with international guidelines to estimate costs for countries that do not have cost information according to the guidelines. Basically, for each cost component, median values per casualty (fatality, serious injury, slight injury), and per crash (fatal, serious injury, slight injury and PDO) are determined, using data from countries that determined costs according to the international guidelines. These median values are subsequently used for countries that have no information for that cost component or did not use the recommended method.

Applying the value transfer method to all cost components, the 'standard' costs of a fatality are estimated at €2.3 million. Costs per serious and slight injury are estimated at 13% and 1% of the value of a fatality. Total costs according to the international guidelines in all EU countries individually as well as the EU in total were calculated. Table 4 shows the cost estimates for the EU countries as well as for the EU in total. For the 28 EU member states together, costs are estimated at about €270 billion if the results of the value transfer approach are applied. This corresponds to 1.8% of the GDP.

Table 4: Total costs (in Million Euro), calculated with transferred values for crashes (EUR 2015, corrected for relative income differences using purchasing power parity (PPP), source: Wijnen et al., 2017)

Country	Total costs estimated on the basis of value transfer	Country	Total costs estimated on the basis of value transfer
Austria	€11,049	Latvia	€2,862
Belgium	€6,947	Lithuania	€1,043
Bulgaria	€2,855	Luxembourg	€236
Croatia	€3,147	Malta	€162
Cyprus	€282	Netherlands	€17,667
Czech Republic	€5,278	Norway	€2,447
Denmark	€1,113	Poland	€12,842
Estonia	€475	Portugal	€4,763
Finland	€2,605	Romania	€8,091

Country	Total costs estimated on the basis of value transfer	Country	Total costs estimated on the basis of value transfer
France	€30,431	Serbia	€3,939
Germany	€51,806	Slovakia	€1,414
Greece	€2,746	Slovenia	€828
Hungary	€4,295	Spain	€29,347
Iceland	€249	Sweden	€1,673
Ireland	€694	Switzerland	€6,279
Italy	€39,534	UK	€23,253
EU28 – Total (rounded)		**€267,000**	
EU28 + 4 Total (rounded)		**€280,000**	

Please note that the cost estimates are still an underestimation of the actual costs, because many countries have not corrected the numbers of casualties/crashes for underreporting. If unreported casualties and crashes are taken into account we expect that total costs are in the order of magnitude of at least 3% of GDP.

4 Results of the cost-benefit analyses

This chapter provides an overview of the results of the Cost-Benefit Analyses (CBA). In total for 12 measures a CBA was conducted or updated. All CBAs were conducted using SafetyCube's E^3 calculator. Section 4.1 provides and discusses briefly the benefit-to-cost ratios (BCR) and net present values (NPV) for all the selected measures while section 4.2 discusses break-even costs. In 4.3 the results of the sensitivity analyses are presented to show the variability of the ratios.

4.1 BENEFIT-TO-COST RATIOS AND NET PRESENT VALUES

Using the E^3-calculator, developed within SafetyCube, benefit- cost ratios were calculated for most of the selected measures. The results are provided in table 5. The table also contains a monetary estimate of the net present value per unit and the break-even point. All the values are expressed at the price level 2015 and accounted for PPP[3] EU-28.

Ratios above 1 indicate a favourable **benefit-to-cost ratio** (BCR). They are indicated in green. For example, a BCR of 2 indicates that the calculated benefits of the measure are two times higher than the costs. BCR values below 1 are indicated in red. They reflect a situation in which the measure benefits (in terms of the monetary value of the reduced number of accidents) are not likely to exceed the measure costs. The smaller the value, the larger the unbalance between costs and benefits. A BCR of 0.2 for instance indicates that the calculated measure costs are five times higher than the calculated benefits.

Negative values for the BCR are only possible in case a measure is likely to cause an increase in the number of crashes. For example, Høye (2013) concludes from the result of a meta-analysis that red light cameras reduce fatal and serious injuries, but increase PDO crashes by 3% due to an increase of vehicles breaking suddenly. In this particular case, however, the benefits still exceed the costs.

Table 5 also includes net present values (NPV) of the measures. All NPV are calculated per unit of analysis in order to enable a proper comparison. In case of a BCR below 1 the NPV becomes negative by definition as the estimated costs exceed the benefits. All negative NPV are indicated in red.

4.2 BREAK-EVEN COST FOR MEASURES

Break-even costs reflect the measure cost value at which benefits and costs are equally high. They indicate the maximal costs for one unit of a measure to be still economically efficient. Using break-even costs is especially relevent when no estimates or no reliable estimates of the measure costs are available. This was the case for the topic hazard perception training.

Table 5 provides the break-even costs for each of the included measure, independent of the availability of measure costs. Also, the used best estimate for the measure cost is provided. This easily allows to assess the magnitude of the difference between the currently known best estimate of the measure cost and the break-even cost.

[3] Purchasing Power Parities

Table 5: BCR and Net Present Values per unit for all the selected measures

Measure	Unit of analysis	**Total costs per unit of analysis** (in EUR EU-2015 PPP)	**BCR Best estimate**	**NPV** (in EUR EU-2015 PPP)	**Break-even measure cost**
Law and enforcement – General police enforcement of speeding	One area of enforcement with a total length of 88 km.	€5,856,879	1.0	€122,489	€5,979,369
Law and enforcement – DUI checkpoints, selective and random breath testing	DUI testing for 100,000 drivers for a year	€3,284,143	7.3	€20,732,246	€24,007,389
Law and enforcement – seatbelt wearing	One country, increase of seatbelt enforcement by factor 2	€5,173,139	1.4	€2,030,188	€7,077,153
Fitness to drive assessment and rehabilitation – Alcohol interlock	Participation of a serious offender in an alcohol interlock programm	€3,068	10.9	€131,281,642	€32,130
Education – Hazard perception training	One harzad perception training	-	-	€120,155	€120,155
Law and enforcement – Red light cameras	One red light camera on an intersection, 253 implemented units	€109,400	3.7	€71,491,929	€388,358
Formal pre-license training – Graduated driver licensing	One training intervention	€132,620	125.1	€16,462,021	€16,594,642
Fitness to drive assessment and rehabilitation – Mandatory eyesight test	One visual mandatory eyesight test and treatment if necessary and possible	€47	0.5	-2,782,968	€24
Education and voluntary training – Child pedestrian training	One child pedestrian training	€574,689	2.6	€935,422	€1,510,111
Awareness raising and campaigns – Seatbelt	One national seatbelt campaign	€468,832	42.2	€19,300,582	€19,769,414
Awareness raising and campaigns – Child restraint	One nationwide booster seat programme 4-8-years old	€463,980	4.6	€1,671,196	€2,135,176

Measure	**Unit of analysis**	**Total costs per unit of analysis** (in EUR EU-2015 PPP)	**BCR Best estimate**	**NPV** (in EUR EU-2015 PPP)	**Break-even measure cost**
Awareness raising and campaigns – Drink-driving	One drink-driving advertising campaign	€862,157	2.1	€932,113	€1,794,270

5 Sensitivity analysis

In this chapter, the results of sensitivity analyses that were made for all the measures concerned are presented. Firstly, the consequences of scenarios in which the effects of the measures were lower or higher than initially expected, were checked. Subsequently this information was combined with scenarios on higher and lower measure costs in order to calculate two 'extreme' scenarios: a worst case and an ideal case. These scenarios help to assess the sensitivity of the analysed measures to some assumptions in the underlying data.

5.1 VARIATION IN THE EFFECTIVENESS OF MEASURES

The results of any cost-benefit analysis are much dependent on the underlying assumptions about the effect of the concerned measure. However, effect estimates are – even in the best-known cases – only known within a certain uncertainty margin. It is therefore useful to run a sensitivity analysis based on some alternative assumptions about the effects of the measure. The purpose is to show to which extent benefit- cost ratios are sensitive to changes in the underlying effect estimates.

If available **the upper and lower limits of the 95% confidence intervals of the estimates** were used. Ideally these estimates were resulting from a meta-analysis, in other cases the used values result from one or two particular studies. The used values represent a (much) lower than expected and a (much) higher than expected effect respectively.

For only 6 measures a sensitivity analysis could be done using a variation in the effectiveness of measures. For the other measures, there was not enough information available in the literature to provide an upper and lower estimate.

Table 6: BCR ratios in 3 scenarios with varying effect estimates

Measure	**Benefit-to-cost ratio** (best estimate)	**Benefit-to-cost ratio** (low measure effect)	**Benefit-to-cost ratio** (high measure effect)
Law and enforcement – General police enforcement of speeding	1.0	0.7	1.3
Law and enforcement – DUI checkpoints, selective and random breath testing	7.3	5.7	9.4
Law and enforcement – seatbelt wearing	1.4	1.1	1.8
Fitness to drive assessment and rehabilitation – Alcohol interlock	10.9	5.8	13.8
Education – Hazard perception training[4]	-	-	-
Law and enforcement – Red light cameras	3.7	-	4.2
Formal pre-license training – Graduated driver licensing	125.1	-	-

[4] A break-even-point was calculated for this measure

Measure	Benefit-to-cost ratio (best estimate)	Benefit-to-cost ratio (low measure effect)	Benefit-to-cost ratio (high measure effect)
Fitness to drive assessment and rehabilitation – Mandatory eyesight test	0.5	-	-
Education and voluntary training – Child pedestrian training	2.6	-	-
Awareness raising and campaigns – Seatbelt	42.2	34.8	50.9
Awareness raising and campaigns – Child restraint	4.6	-	-
Awareness raising and campaigns – Drink-driving	2.1	-	-

5.2 VARIATION IN THE ESTIMATES OF THE MEASURE COSTS

Costs of measures are generally poorly known. The sources of these estimates and their rigour are sometimes unclear. Other estimates are rather old. Some of the estimates may only apply to very particular conditions. Costs of programmes, training or enforcement activities vary considerably.

These huge variations are an important source of uncertainty that can considered to be on the same level as the uncertainty about the effect estimates. Logically, also the scenarios for the measure costs should clearly reflect the inherent uncertainties of the analyses. However, in contrast to the effect estimates that are for some measures relatively well established and formally assessed, this is not at all the case for the costs of measures. For most cases only one or two estimates for the costs of the measures were available, which does not allow to express the uncertainty formally.

In order to reflect the inherent uncertainty of cost estimates we decided to include also two scenarios in which the measure costs vary from a 'very low' (-50% of the estimate) level to a 'very high' (+100% of the best estimate) level. These threshold values are to a certain extent arbitrary, but they are believed to reflect realistic boundaries for different reasons.

In many cases there are good reasons to presume that the current estimates are rather low. Many estimates tend to include only direct 'out-of-pocket costs'. It is therefore more likely that real costs will be underestimated than overestimated. This explains the choice for the +100% upper limit and also the 'skewness' of the used interval [-50%; +100%].

The results are provided in Table 7 BCR values above 1 are indicated in green. BCR values below 1 are indicated in red. A few measures are clearly sensitive to changes in the measure costs as their BCR values change from below 1 to above 1 throughout the different scenarios.

Table 7: BCR ratios in three scenarios with varying measure costs

Measure	Benefit-to-cost ratio (best estimate)	Benefit-to-cost ratio (low measure cost -50%)	Benefit-to-cost ratio (high measure cost +100%)
Law and enforcement – General police enforcement of speeding	1.0	2.0	0,5
Law and enforcement – DUI checkpoints, selective and random breath testing	7.3	14.6	3.7
Law and enforcement – seatbelt wearing	1.4	2.8	0.7
Fitness to drive assessment and rehabilitation – Alcohol interlock	10.9	21.7	5.4
Education – Hazard perception training[5]	-	-	-
Law and enforcement – Red light cameras	3.7	7.3	1.8
Formal pre-license training – Graduated driver licensing	125.1	250.3	62.6
Fitness to drive assessment and rehabilitation – Mandatory eyesight test	0.5	1.5	0.3
Education and voluntary training – Child pedestrian training	2.6	5.3	1.3
Awareness raising and campaigns – Seatbelt	42.2	84.3	21.1
Awareness raising and campaigns – Child restraint	4.6	9.2	2.3
Awareness raising and campaigns – Drink-driving	2.1	4.2	1.0

5.3 A WORST CASE SCENARIO AND AN IDEAL CASE SCENARIO

Finally, two rather extreme scenarios were defined:

- a 'worst case' scenario as a combination of a much worse than expected effect (in principle the lower limit of the 95% confidence interval of the effect estimate) and a higher than expected measure cost (i.e. the estimated cost +100%).
- an 'ideal case' scenario that is a combination of a much better than expected effect (upper limit of the 95% CI of the effect estimate) and a lower than expected measure cost (estimated cost -50%). This was conducted for those measures, where all necessary figures for calculating these scenarios were available. The results of the cost-benefit analyses for these scenarios are reflected in Table 8.

Even in these scenarios, most of the measures remain economically efficient (alcohol interlock, DUI checkpoints, selective and random breath testing, Seat-belt campaigns). Some other measures (general police enforcement for speeding, law and enforcement for seatbelt wearing), are clearly more susceptible to varying combinations of measure costs and effectiveness estimates.

[5] A break-even-point was calculated for this measure

Table 8: BCR ratios in the 'best estimate' scenario and in two extreme scenarios

Measure	**Benefit-to-cost ratio** (best estimate)	**Benefit-to-cost ratio** (worst case scenario = high cost + low effect)	**Benefit-to-cost ratio** (ideal case scenario = low cost + high effect)
Law and enforcement – General police enforcement of speeding	1.0	0.4	2.6
Law and enforcement – DUI checkpoints, selective and random breath testing	7.3	2.9	18.8
Law and enforcement – seatbelt wearing	1.4	0.5	3.5
Fitness to drive assessment and rehabilitation – Alcohol interlock	10.9	2.9	27.5
Awareness raising and campaigns – Seatbelt	42.2	17.4	101.9

6 Concluding summary

6.1 THE OBTAINED RESULTS

The results of the performed CBA provide the reader with relevant information about the balance between costs and benefits of the selected measures. The CBA documentations themselves are added in the Appendix and provide more details about the underlying assumptions and data. In the present report, the information on the individual analyses was listed in synoptic tables that allow to compare the results for different measures. It was tried as much as possible to express the outcomes (BCR, break-even costs) per unit in order to enable comparisons between the different measures.

First of all, it can be notices that most of the effective measures have a BCR (benefit-to-cost ratio) above 1 which means that the benefits outweigh the costs. Only for mandatory eye-sight testing, the BCR is 0.5. The BCR of the cost efficient measures shows a high variability with a range between 1 and 125.1.

Second, it was shown that the BCR are sensitive to changes in the underlying assumptions. For five measures, it was possible to evaluate the consequences of a variation in the effectiveness estimate. However, four out of five measures remained cost efficient. Next to that the effect of a variation of the measure costs was inquired. This could be done for ten measures, for which two measures became cost inefficient when assuming higher costs.

Finally, a sensitivity analysis with applying two scenarios: a worst case, where decreased effective decreased effectivenessand increased measure costs are assumed, the BCR only remained above 1 for three measures:

- Drink-driving checkpoints and breath testing
- Alcohol interlocks
- Seatbelt campaigns,

For some measures such as speed enforcement, the BCR is 1, which means that costs and benefits are balanced. Any detrimental change in measure costs or its effectiveness would lead to costs exceeding the benefits.

The highest BCR, 125.1, resulted for graduated driver licensing. For this measure the costs are quite low (mainly administrative costs to implement the measure). With its high ratio and very low costs, even an 100% increase of measure costs results in a clearly positive benefit-to-cost ratio.

The only (updated) CBA that is resulting in a BCR below 1, and therefore is economically not efficient, is on mandatory eyesight testing for drivers between 45 and 69 years old.

6.2 THE FOLLOWED APPROACH

The economic evaluation has principally been done by executing cost-benefit analyses. In cost-benefit analyses, the crash costs enter as benefits (because they are prevented) and the costs for measures are compared to them. For countermeasures, the costs are mostly direct costs (i.e. resources used to implement the measure).

One of the major advantages of CBA is that all elements are monetarised and therefore can be compared in various ways. In the SafetyCube project a common method was established to estimate average crash costs for different injury levels for all European countries. The resulting numbers easily allow to monetarise effects on crashes or injuries as long as quantitative estimates are available on the size of the effects.

The principal tool for all the above-mentioned analyses was the Economic Efficiency Evaluation (E^3) calculator that has been developed in the SafetyCube project. A major advantage of this tool is that it enables to standardise the input and output information. The use of the tool in its test phase also enabled to provide feedback that has been used to gradually improve it. Thanks to the availability of the tool, CBAs could be executed for 11 different measures. In one case, break-even costs were calculated.

6.3 LIMITATIONS OF CBA

By far the most important limitation of using cost-benefitanalysis is its dependence on underlying assumptions that are not always straightforward to assess. The executed examples show that mainly the assumptions on three elements can play a decisive role:

- Assumptions about the effectiveness of the measures
- Assumptions about the costs of the measures
- Assumptions about the size of the target group

Numerous examples can be given of CBA that – according to the assumptions made – easily change from highly beneficial to vastly inefficient or vice versa. These sensitivity analyses clearly showed what can be the (sometimes huge) consequences of changing some basic assumptions on measure costs or effectiveness.

The reader should realise that the dependency on all these assumptions is not as such a weakness of the method but rather a weakness of the data that are usually available. In this regard, one can observe that in a number of the executed CBA the most uncertain elements appeared to be the ones that could have been expected to be the easiest to collect: the measure costs and the target numbers of crashes. One could expect that much knowledge on these elements should be available as they represent phenomena that are relatively straightforward to observe in the real world and therefore to collect data about.

Clearly, no CBA should just be copied to any situation. Given the above-mentioned limitations, any reader should use CBA values critically and make sure to check thoroughly any of the made assumptions before inferring results about the CBA values for other applications.

In general, it is recommended in any particular case to complement the available information with specific information on the measure's target group, likely effects, the measure costs and the circumstances in which they are applied.

All together the number of CBA on road safety measures in the scientific literature so far is very limited and much further work is needed to systematically assess costs and benefits of road safety measures. It not just deserves recommendation to carry out this work but also to publish it more systematically in the scholarly literature. Moreover, very little information can be found on (quantifed) side effects of measures, which were not considered in the 12 conducted economic evaluations.

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List of Abbreviations

BAC	Blood Alcohol Concentration
BCR	Benefit-to-cost ratio
CARE	Community database on Accidents on the Roads in Europe
CBA	Cost-Benefit Analysis
CBR	Cost-Benefit Ratio
CEA	Cost-Effectiveness Analysis
GDL	Graduated Driver Licensing
CMF	Crash Modification Factor
DSS	Decision Support System
DUI	Driving Under the Influence
EVT	Education and Voluntary Training
PDO	Property Damage Only
PPP	Purchasing Power Parity
RLC	Red light Camera
VRU	Vulnerable Road User(s)
WP	Work Package

Appendix A: Documentation of cost-to-benefit analyses

This appendix includes the documentations of all the cost-benefit analyses that are available in October 2017. These will also be available through the final version of the DSS. Cost-benefit analyses are provided for the following topics:

1. Law and enforcement – General police enforcement of speeding
2. Law and enforcement – DUI checkpoints, selective and random breath testing
3. Law and enforcement – Seatbelt use
4. Fitness to drive assessment and rehabilitation – Alcohol interlock
5. Education and voluntary training – Hazard perception training
6. Law and enforcement – Red light cameras
7. Formal pre-license training – Graduated driver licensing
8. Fitness to drive assessment and rehabilitation – Mandatory eyesight test
9. Education and voluntary training – Child pedestrian training
10. Awareness raising and campaigns – Seatbelt use
11. Awareness raising and campaigns – Booster seat use
12. Awareness raising and campaigns – Drink-driving

Cost-benefit analysis
Seatbelt enforcement

Davide Shingo Usami, CTL, September 2017

ABSTRACT

An existing evaluation study on effects of seatbelt enforcement in Norway (Elvik et al., 2009) was revisited. The SafetyCube Economic Efficiency Evaluation (E^3) Calculator was used. The resulting best estimate of the benefit-to-cost ratio (BCR) is 1.4 which means that the benefits exceed the costs. The BCR is sensitive to changes in the underlying assumptions as it is shown by the sensitivity analysis. Except for two cases, the worst case scenario and the doubling of measure costs, where the lowest effectiveness estimate is combined with the highest cost, the BCR remains higher than 1.

INPUT INFORMATION

Case studied: The study by Elvik et al. (2009) was updated mainly with results from a recent meta-analysis study (Hoye, 2015) on the effects of seatbelt use on the number of fatalities and severely injured in light vehicles. The latter reports a reduction of 60% (95% CI [-66%; -53%] of the risk of being seriously/fatally injured for front seat occupants and 44% (95% CI [-58%; -27%] for back seat occupants. Since seatbelt use among rear seat occupants in Norway is unknown, the potential effect of increasing seatbelt use on rear seats could not be calculated.

Crash costs: The updated SafetyCube estimates for 2015 for Europe were used (see SafetyCube Deliverable 3.2).

Measure Costs: The estimated annual cost of seatbelt control by police officers in Norway is NOK 60,000,000 (Elvik, 2017; 2010 prices). These costs apply to Norway and are updated to 2015 values by applying the inflation conversion value of 1.11. Violator expenses for traffic tickets were not considered in the analyses. Subsequently the values are converted to EU averages by multiplying with the PPP conversion value of about 0.08.

Time horizon: The applied time horizon for the measure is one year.

Area/Unit of implementation: All costs and effects refer to the whole country. The study considers an increase by factor two of seatbelt enforcement.

Number of cases affected: The affected number of casualties (i.e. the number of unbelted car occupants injured in road accidents) was estimated based on car casualties data retrieved from the Statistics Norway (2015 values) and the wearing rates (or penetration rate) among non-crash involved car occupants. Crash risks were assumed the same among belted and unbelted drivers[1]. Seatbelt use rates are taken from Elvik et al. (2009).

Penetration rate: The study reports different usage rates for urban (87%) and rural areas (93%) in Norway for the period 2004 to 2006. Since the majority of fatal and serious crashes occur in rural roads (93% based on Elvik et al., 2009) the usage rates in rural roads are considered. This value is also closer to the seatbelt usage rates in Norway in 2013 equal to 96.9% (Hoye, 2015). A meta-analysis by Hoye (2009) reports a significant increase of the percentage of seatbelt use of 19% (95% CI [11%; 28%]) after increasing the level of enforcement leading to a 100% usage rate. As this value is unrealistic for several reasons[2], it is assumed that increased enforcement would increase the usage rates for seatbelts from 94% to 96%. Minor injuries were considered not affected by the measure.

[1] The formula included in the E^3 Calculator does not take into account risk in different groups of road users
[2] See Elvik et al. (2009)

RESULTS

Table 1 provides the input values and the resulting estimated benefit-to-cost ratio for seatbelt enforcement. It shows a BCR of 1.4. This means that the benefits tend to exceed the costs slightly.

Table Input values and BCR ratio for the 'best estimate' scenario

Scenario	Input values	BCR
Best estimate	Fatalities reduction by using seatbelt: 60% Serious injury reduction by using seatbelt: 60% Slight injury crashes reduction: 0% PDO only crashes reduction: 0% Annually recurrent cost: €5,173,139 Affected nr. of crashes per year: Fatalities: 75 (Statistics Norway, 2015) Ser. Inj. 308 Slight inj.: 0 PDO: 0	1.4

SENSITIVITY ANALYSIS

We used the upper and lower limits of the 95% confidence intervals of reduction of the risk of being seriously/fatally injured for front seat occupants (Hoye, 2016) to run a sensitivity analysis. The values represent a (much) lower than expected and a (much) higher than expected effect respectively. Subsequently the effect is calculated for cases in which the measure costs are lower or higher than estimated. Table 2 presents the results.

Table 2 Sensitivity analyses

Scenario	Input values	BCR
Low measure effect	Fatalities reduction by using seatbelt: 53% Serious injury reduction by using seatbelt: 53%	1.1
High measure effect	Fatalities reduction by using seatbelt: 66% Serious injury reduction by using seatbelt: 66%	1.8
Low measure cost (-50%)	Impl. cost: Annual cost: €2,586,570	2.8
High measure cost (+100%)	Impl. cost: Annual cost: €10,346,278	0.7

We define a 'worst case' scenario as a combination of a much worse than expected effect (i.e. the lower limit of the 95% CI) and a higher than expected measure cost (i.e. the estimated cost +100%). Also, an 'ideal case' scenario is defined which is a combination of a much better than expected effect (upper limit of the 95% CI) and a lower than expected measure cost (estimated cost -50%). The results of the CBA for these scenarios are reflected in Table 3.

Table 3 BCR for worst case and ideal case scenarios

Combined Scenario	Input values	BCR
Worst case	Fatalities reduction by using seatbelt: 53% Serious injury reduction by using seatbelt: 53% Impl. cost: Annual cost: €10,346,278	0.5
Ideal case	Fatalities reduction by using seatbelt: 66% Serious injury reduction by using seatbelt: 66% Impl. cost: Annual cost: €2,586,570	3.5

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Cost-benefit analysis
Alcohol Interlock Program

Annelies Schoeters, Vias institute, September 2017

ABSTRACT

An existing cost-benefit analysis on the effect of an alcohol interlock program in the Netherlands (SWOV, 2009) is revisited. The SafetyCube Economic Efficiency Evaluation (E^3) Calculator was used. The resulting best estimate of the benefit-to-cost ratio (BCR) is 10.9 which means that the benefits substantially exceed the costs. The sensitivity analysis shows that while the BCR is sensitive to changes in the underlying assumptions, the ratio remains higher than 1, which means that the measure remains economically efficient.

INPUT INFORMATION

Case studied: The cost-benefit analysis by SWOV (2009) provides an estimate of the effect of a compulsory alcohol interlock program for serious offenders on the number of fatalities. The alcohol interlock program that was examined is a program which lasts minimally 2 years, with the possibility of extending the program one time for 6 months. With the current inclusion criteria, it is calculated that 4,500 serious offenders would participate each year. Two approaches are used to calculate the number of prevented fatalities. The first approach uses the size of the population of serious offenders; the second approach uses the percentage of recidivisms. Since a SafetyCube synopsis (Nieuwkamp et al., 2017) provides us with a meta-analysis estimate for the effect of alcohol interlocks on the reduction of recidivism, we chose to use the second approach. This approach predicts a prevention of 2.8 fatalities of the Dutch population.

Crash costs: The updated SafetyCube estimates for 2015 for the EU were used (see SafetyCube Deliverable 3.2)

Measure Costs: The cost-benefit analysis by SWOV (2009) contained information on the measure costs. These were estimated at €1,600 annually recurrent costs (€1,000: supervision, installation & removal; €200 administrative costs; €400: mentoring). The implementation costs are included in the annually recurrent costs. Updating the costs to 2015 and correcting for Purchasing Power Parities[1] (PPP) results in an annually recurrent cost of €1,534.

Time horizon: The applied time horizon for the measure is 2 years and 3 months. The minimal compulsory period is two years. It is estimated that half of the participants will extend the program for six months.

Area/Unit of implementation: Participation of a serious offender in an alcohol interlock program.

Number of cases affected: The affected number of casualties was retrieved from SWOV (2009). It was estimated that alcohol-related accidents in which the driver had a Blood Alcohol Concentration (BAC) exceeding 1.3 g/l resulted each year in 150 road fatalities. In total 100,000 serious offenders are responsible for these accidents. Depending on the number of offenders that participates in an alcohol interlock program, the effectiveness in terms of prevented fatalities increases. There are no effectiveness estimates given for serious injuries, slight injuries or Property Damage Only (PDO) crashes. Assuming that drink-driving with a BAC exceeding 1.3 g/l has the same effect on fatalities, serious injuries, slight injuries and PDO crashes, we can calculate the number of prevented

[1] Purchasing Power Parities are the rates of currency conversion that equalize the purchasing power of different currencies, they are price relatives that show the ratio of the prices in national currencies of the same good or service in different countries (EU/OECD,2012).

casualties/crashes for other severity categories using the ratio of the number of serious injuries, slight injuries and PDO crashes per fatality in the Netherlands.

No side effects were taken into account.

RESULTS

Table 1 provides the input values and the resulting estimated benefit-to-cost ratio for the alcohol interlock program. It shows a BCR of 10.9. This means that the benefits substantially exceed the costs.

Table 1 Input values and BCR for the 'best estimate' scenario

Scenario	Input values	BCR
Best estimate	Prevented fatalities: 5.6 (SWOV, 2009) Prevented serious injuries: 145.3 (assumption) Prevented slight injuries: 2250.0 (assumption) Prevented PDO crashes: 7976.6 (assumption) Implementation cost: / Annual cost: €1,534 / alcohol interlock program Number of units implemented: 4,500	10.9

SENSITIVITY ANALYSIS

The number of prevented fatalities calculated by SWOV (2009) is based on the assumption that an alcohol interlock reduces recidivism by 75%. This is the same effectiveness estimate as found in the synopsis (Nieuwkamp et al., 2017). There is no 95% confidence interval, but according to the authors "there is consensus in the scientific literature that an alcohol interlock can improve road safety by reducing the risk of drink driving by 40 to 95% while installed". We will use these values as lower and upper limits to run a sensitivity analysis. Subsequently the effect is calculated for cases in which the measure costs are lower or higher than estimated. Table 2 presents the results.

Table 2 Sensitivity analyses

Scenario	Input values	BCR
Low measure effect	Prevented fatalities: 3.0 Prevented serious injuries: 77.5 Prevented slight injuries: 1,200.0 Prevented PDO crashes: 4,254.2	5.8
High measure effect	Prevented fatalities: 7.1 Prevented serious injuries: 184.1 Prevented slight injuries: 2,850.0 Prevented PDO crashes: 10,103.6	13.8
Low measure cost (-50%)	Impl. cost: / Annual cost: €767 /program	21.7
High measure cost (+100%)	Impl. cost: / Annual cost: €3,068 /program	5.4

We define a 'worst case' scenario as a combination of a much worse than expected effect (i.e. the reduction rate of recidivism of 40%) and a higher than expected measure cost (i.e. the estimated cost +100%). Also, an 'ideal case' scenario is defined which is a combination of a much better than expected effect (the reduction rate of recidivism of 95%) and a lower than expected measure cost (estimated cost -50%). The results of the CBA for these scenarios are reflected in Table 3.

Table 3 CBA for worst case and ideal case scenarios

Combined Scenario	Input values	BCR
Worst case	Prevented fatalities: 3.0 Prevented serious injuries: 77.5 Prevented slight injuries: 1,200.0 Prevented PDO crashes: 4,254.2 Impl. cost: /	2.9

	Annual cost: €3,068 /program	
Ideal case	Prevented fatalities: 7.1 Prevented serious injuries: 184.1 Prevented slight injuries: 2,850.0 Prevented PDO crashes: 10,103.6 Impl. cost: / Annual cost: €767 /program	27.5

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Cost-benefit analysis
Hazard perception training

Christos Katrakazas, Loughborough University, September 2017

ABSTRACT

Two existing evaluation studies on cost-benefit effects of hazard perception training in the UK (Crundall, Andrews, Van Loon, & Chapman, 2010) and in Spain (Di Stasi, Contreras, Cándido, Cañas, & Catena, 2011) were used for this report. The SafetyCube Economic Efficiency Evaluation (E^3) Calculator was used. A benefit-to-cost ratio (BCR) was not possible to be calculated as neither of the papers included cost estimates. Although there is evidence that hazard perception training is generally low-cost (e.g. Vlakveld et al., 2011; White, Cunningham & Titchener, 2011), because the corresponding financial requirements concern the acquisition of a driving simulator or a PC, no estimates are given even in official reports such as Grayson & Sexton (2002). However, as figures for prevented crashes were given in Crundall, Andrews, Van Loon & Chapman (2010) and Di Stasi et al. (2011) break-even cost could be calculated.

INPUT INFORMATION

Cases studied: The first available paper (Crundall et al., 2010) reports that 2.25 injury accidents were prevented in a total of 24 drivers as an effect of the implementation of hazard perception training, while the corresponding figure in the second paper (Di Stasi et al., 2011) was 21 in a total of 17 drivers.

Crash costs: The updated SafetyCube estimates for 2015 for UK and Spain were used (see SafetyCube Deliverable 3.2)

Measure Costs: -

Time horizon: 1 year (assumed)

Area/Unit of implementation: All costs and effects are expressed per training intervention, and hence one (1) unit of implementation was taken into account.

Number of cases affected: -

RESULTS

Table 1 provides the input values and the result estimated break-even cost for hazard perception training.

Table 1 Input values and Break-even cost for the available studies

Study	Input values	Break-even cost
Crundall et al., 2010	Prevented crashes • Injuries (slight/serious): 2.25/24 drivers	**£120,155 or** **£5,006.46 /trained driver**
DiStasi et al., 2011	Prevented crashes • Injuries (slight/serious): 21/17	**€682,438 or** **€40,143.41 /trained driver**

SENSITIVITY ANALYSIS

Due to the limited number of studies and the absence of cost figures, a sensitivity analysis was not conducted.

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Cost-benefit analysis

Red light cameras

Charles Goldenbeld, SWOV, and Stijn Daniels, VIAS institute, September 2017

ABSTRACT

To perform a cost-benefit analysis (CBA) on red light cameras, safety estimates from a meta-analysis on international red light camera studies (Høye, 2013) were used, and information on the costs of operating a red light cameras (i.e. costs of purchase, installation, maintenance of cameras and cost of administrative and judicial processing of red light offenders) were obtained from Belgian authorities.

The SafetyCube Economic Efficiency Evaluation (E^3) Calculator was used. The resulting best estimate of the benefit-to-cost ratio (BCR) of red light cameras is 3.7. This means that in a time span of ten years the (expected) benefits exceed the costs with a ratio of 3.7 to 1.

The first sensitivity analysis checked the effects of two scenario's in which the costs of installation and the recurrent annual costs were either much lower or much higher than the author's estimates. If the measure costs were only 50% of the estimated ones, the BCR would increase to 7.3. If the measure costs were twice as high as the estimated ones, the BCR would decrease to 1.8 which still means that the benefits exceed the costs.

An additional sensitivity analysis was done by using the effect estimates of a European study instead of the meta-analyses by Høye (2013) as it could be argued that the latter is mainly reflecting effects from US and Australian studies. Using the results of De Pauw et al. (2014) yielded slightly different results with an estimated BCR of 4.2.

INPUT INFORMATION

Case studied: It was decided to use Belgium as a case for the safety effect of red light cameras since it was expected (and confirmed) that Belgian authorities were able to deliver reliable information on costs of red light camera operations. There were two 'good' studies available on the safety effects of red light cameras. A general meta-analysis on international red light camera studies by Høye (2013), and a meta-analysis restricted to 253 intersections in Belgium by De Pauw et al. (2014). Table 1 summarises the characteristics, strengths and weaknesses and main effect estimates of the two studies.

Table 1. Effect estimates that can be used for the cost benefit analysis.

Study	Study type	Study scope	Relevance for Europe	Strengths/Weaknesses (S/W)	Best effect estimates
DePauw et al., 2014	Meta-analysis	253 intersections; period 2000-2008	High relevance; study conducted in Belgium	**S:** Large scale study 253 intersections with > 3 years before and after period. **W**: No good separate estimate for fatal crashes or serious injury crashes. No correction for regression to the mean.	14% reduction severe crashes (fatal/serious) 5% increase all injury crashes
Høye, 2013	Meta-analysis	29 before-after studies (for specific effect	Moderate relevance; most studies ESA/ Australia; 3 European	**S:** Estimate corrected for regression to the mean.	12% reduction all injury crashes

Study	Study type	Study scope	Relevance for Europe	Strengths/Weaknesses (S/W)	Best effect estimates
		estimates lesser number studies)	studies included in analysis	**W:** No good separate estimate for fatal or serious injury crashes.	3% increase property damage crashes 6% increase all crashes

Crash costs: The updated SafetyCube estimates for 2015 for Europe were used (see SafetyCube Deliverable 3.2)

Measure Costs: Based on (recent) cost information from Belgian authorities (including a scientific study on costs of judicial procedures by Deben, 2006), we used 80,400 € as the one-time costs for purchase and installation of speed red light cameras per intersection. The total annual costs (maintenance, testing and administration) per camera equipped intersection were estimated to (maintenance and testing: 1,020€ + 1,680€ + judicial costs: 1,98€) ≈ 2,900 € (rounded number).

Other costs: There was no reliable information on possible effects of speed red light cameras on emission, driving time, congestion and costs related to these effects.

Time horizon: The applied time horizon for the measure is 10 years, since authorities had reported red light cameras are economically written off after a period of 10 years

Area/Unit of implementation: All costs and effects are expressed per camera equipped intersection. The Belgian study on safety effects of red light cameras evaluated 253 intersections.

Number of cases affected: The red light cameras on 253 intersections impacted upon 774,5 casualty crashes per year (this was number of casualty crashes for the studied 253 intersections in before period (774,5 is average for the two years 800 (year 2000) and 749 (year 2001) (De Pauw et al, 2012; 2014). The E-3 calculator estimated the concomitant number of property damage crashes to be 5398.87.

RESULTS

Table 2 provides the input values and the result estimated benefit-to-cost ratio (BCR) for red light cameras. It shows a BCR of 3.7. This means that in a time span of ten years the (expected) benefits exceed the costs with a ratio of 3.7 to 1.

Table 2 Input values and BCR for the 'best estimate' scenario

Scenario	Input values	BCR
Best estimate	Casualty crashes reduction: 12% PDO only crashes reduction: -3% (increase!) Implementation costs: one time €84.000 /intersection Annual cost: €2,900 /intersection Affected nr. of crashes per year: Casualty crashes: 774.5 (De Pauw et al., 2012, 2014) PDO crashes (estimated by E3 calculator): 5398.87	3.7

SENSITIVITY ANALYSIS

The effects of varying measure costs were checked by assuming two hypothetical scenarios in which the measure costs were either much lower (-50%) or much higher (+100%) as compared with our best estimates. The analysis was run again by substituting the original data by the lower and upper bound values of the measure costs. This generated the following cost-benefit estimates:

- If the measure costs could be reduced to 50% of our best estimate (initial cost = €40,200, recurrent costs €1,450), the net present value increases to 84.8 and the BCR increases to 7.3
- If the measure cost was twice as high as our estimate, the net present value decreases to €44.7 million and the BCR decreases to 1.8. Although the net present value decreases strongly, this also means that the measure remains beneficial.

Additionally, it was checked how much the results would differ in case the underlying effect estimates become different. Therefore, the CBA was performed again with the effect estimates from De Pauw et al. (2014) instead of those from Høye (2013). Whereas we preferred the meta-analysis by Høye as it is by far the most elaborate, it is also heavily dominated by US and Australian studies that are not necessarily valid for European countries. As the study by De Pauw et al. (2014) is entirely based on European data, we considered it useful to run a sensitivity analysis of the CBA with the estimates of the benefits resulting from this study (see Table 3 for input values in both analyses).

Table 3 Sensitivity analysis: Change in input values dependent upon choice of best estimate study

Main analysis with effectiveness estimates from Høye (2013)

Affected number of cases per year (target group)			
Fatal			
Serious			
Slightly injured			
PDO	5398.87	5398.87	5398.87
Injuries (slight/serious)			
Casualties (slight/serious/fatal)	*774.5*	774.5	774.5
Effectiveness (percentage reduction in target group)			
Fatalities / fatal crashes			
Serious injuries / serious injury crashes			
Slight injuries / slight injury crashes			
PDO	-3%	-3%	-3%
Injuries (slight/serious)			
Casualties (slight/serious/fatal)	*12%*	12%	12%

Sensitivity analysis with effectiveness estimates from De Pauw et al. (2014)

17	***Affected number of cases per year (target group)***	
18	Fatal	20.18
19	Serious	123.32
20	Slightly injured	631
21	PDO	5039
22	*Injuries (slight/serious)*	
23	*Casualties (slight/serious/fatal)*	
24		
25	***Effectiveness (percentage reduction in target group)***	
26	Fatalities / fatal crashes	14%
27	Serious injuries / serious injury crashes	14%
28	Slight injuries / slight injury crashes	-5%
29	PDO	-5%
30	*Injuries (slight/serious)*	
31	*Casualties (slight/serious/fatal)*	

The sensitivity analysis led to the following results:

- The estimated BCR with the data from De Pauw et al. (2014) is 4.2 coming very close to the estimate (3.7) based on the effectiveness estimates from Høye (2013).
- The net present value of the benefits is €86.7 million instead of €71.5 million in the previous calculation. The net present value of the costs is logically the same as the one for the estimates from Høye (2013).
- The break-even cost per unit of the measure is €448,000 (€388,000 previously), a difference of 15%.
- The number of prevented crashes differs between both calculations as the provided input information differed. The difference is related to the effect estimates that are different in both scenario's.

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Cost-benefit analysis
Graduated driver licensing

Christos Katrakazas, Loughborough University, September 2017

ABSTRACT

An evaluation study on cost-benefit effects of graduated driver licensing (GDL) in the USA (National Academies of Sciences Engineering and Medicine; & Transportation Research Board, 2008) was revisited. The SafetyCube Economic Efficiency Evaluation (E^3) Calculator was used. The resulting best estimate of the benefit-to-cost ratio (BCR) is 125.1 which means that the benefits tend to exceed the costs considerably. The sensitivity analysis indicates that this is also the case even with an 100% increase in measure costs.

INPUT INFORMATION

Cases studied: The available report (National Academies of Sciences Engineering and Medicine; & Transportation Research Board, 2008) demonstrates a reduction of 20% of fatal and injury casualties for 16-year-old drivers, as an effect of the implementation of graduated driver licensing in an average US-state (600 fatalities per year) .

Crash costs: The updated SafetyCube estimates for 2015 for Europe was used (see SafetyCube Deliverable 3.2)

Measure Costs The estimated implementation cost in this paper is $150,000 and corresponds to the administrative cost of implementing the GDL law in the state of Oregon, USA. This cost applies to USA in 2006 and was updated to 2015 values by applying the inflation conversion value of 1.16. Subsequently the values are converted to EU averages (in €) by multiplying with the PPP conversion value of 0.76.

Time horizon: In the study from the USA the applied time horizon for the measure is assumed to be one year. It was decided to use one year as a horizon because prevented crashes and effectiveness measures in the papers were all given on an annual basis.

Area/Unit of implementation: All costs and effects are expressed per training intervention, and hence one (1) unit of implementation was taken into account.

Number of cases affected: The study from the USA contains an estimate of the effect on the total number of deceased people in the age group (i.e. 20% reduction). The affected number of cases is 12 fatal crashes among 16-year-old drivers per state. Other than in the study in question, the European fatality-to-injury ratio was used and thus, 926.441 slight and severe injuries, as suggested by the E^3 calculator, were included in the calculation (3,318 in the US study). No side effects were taken into account.

RESULTS

Table 1 provides the input values and the estimated benefit-to-cost ratio for GDL. For the 'best estimate' scenario the figures from the USA study were used, as these were considered more complete. For the best estimate scenario, the cost-benefit ratio was estimated at 125.1. This means that the benefits tend to exceed the costs considerably.

Table 1 Input values and BCR for the 'best estimate' scenario

Scenario	Input values	BCR
Best estimate	Fatal injury casualties reduction: 20% Slight/serious injury casualties reduction: 20% Implementation cost: €132,620 Affected no. of crashes per year: Fatalities: 12 Injuries (slight/serious): 926.441	125.1

SENSITIVITY ANALYSIS

For the reported estimate of effectiveness, no confidence interval is indicated. Therefore, the sensitivity analysis was run only with an 100% increase and a 50% decrease in measure costs. Table 2 presents the corresponding results.

Table 2 Sensitivity analysis

Scenario	Input values	BCR
Low measure cost (-50%)	Impl. costs: €231,990 (one-time) No annual costs	250.3
High measure cost (+100%)	Impl. costs: €927,960 (one-time) No annual costs	62.6

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National Academies of Sciences Engineering and Medicine & Transportation Research Board. (2008). *Effectiveness of Behavioral Highway Safety Countermeasures*. *National Cooperative Highway Research Program (NCHRP) Report 622*. https://doi.org/10.17226/14195

Cost-benefit analysis
Mandatory eyesight tests

Annelies Schoeters, Vias institute, September 2017

ABSTRACT

An existing cost-benefit analysis on the effect of mandatory eyesight testing in Norway (Vlakveld et al., 2005) is revisited. The SafetyCube Economic Efficiency Evaluation (E^3) Calculator was used. The resulting best estimate of the benefit-to-cost ratio (BCR) is 0.5 (excluding side-effects) which means that the costs exceed the benefits and the measure is not economically efficient. Taking into account the side effects (on mobility, commercial transport and the environment) the measure becomes even less efficient with a BCR of 0.2.

INPUT INFORMATION

Case studied: The cost-benefit analysis by Vlakveld et al. (2005) in the framework of the European research programme IMMORTAL provides an estimate of the effect of different types of mandatory eyesight testing in different countries. We take the example of mandatory visual acuity tests for drivers between 45 and 69 years old in Norway since this example contains the best detailed information. The measure consists of a visual acuity test that has to be taken every 10 years by all drivers between 45 and 69 years old, and of a treatment (glasses) for those who fail and can be treated. It is predicted that each year 121,453 drivers will take the test. Of the drivers that fail the test, approximately 19,235 can be treated with glasses. The remaining part will lose their driving license. It is estimated that this measure prevents 0.49 fatalities and 20.6 injured casualties.

Crash costs: The updated SafetyCube estimates for 2015 for the EU were used (see SafetyCube Deliverable 3.2)

Measure Costs: The cost-benefit analysis by Vlakveld et al. (2005) contained information on the measure costs in Norway. It was estimated that the visual acuity test costs €25 per person and the treatment costs €125 per person. Assuming that 80% of those who fail the test will get treatment, the average cost per tested person is €45. The year in which the costs are expressed is not explicitly mentioned. Since the study was conducted in 2005, we assume the price year to be 2004. Updating to 2015 results in €67 and updating to the European price level (by dividing by 1,437; an update using the exchange rate is not necessary since the costs are already expressed in EUR) results in €47. There are no implementation costs mentioned, but since the time horizon is only 1 year, the annual costs will be included as 'implementation costs' because the calculator will discount the value for the annual costs for one year.

Time horizon: The applied time horizon for the measure is 1 year.

Area/Unit of implementation: A visual acuity test for drivers between 45 and 69 years old and a treatment (glasses) if necessary and possible.

Number of cases affected: The number of prevented fatalities is estimated at 0.49 and the number of prevented injuries is estimated at 20.6. Based on the Norwegian accident rates, found in the E^3 tool, the number of prevented PDO crashes is estimated at 152.

Side effects: The study calculated the side effects in terms of environmental benefits, (negative) mobility benefits and (negative) commercial benefits. These are €4,000,000 environmental benefits, €12,400,000 mobility costs, €700,000 commercial transport costs. In total, the side effects account for - €12,700,000. The year in which the costs are expressed is not explicitly mentioned. Since the study was conducted in 2005, we assume the price year to be 2004. Updating to the price level of

2015 results in €19,050,000 and updating to the European price level (by dividing by 1,437) results in €13,256,784.97.

RESULTS

Table 1 provides the input values and the resulting estimated benefit-to-cost ratio for the mandatory visual acuity test. It shows a BCR of 0.5. This means that the costs exceed the benefits and the measure is not economically efficient.

Table 1 Input values and BCR for the 'best estimate' scenario

Scenario	Input values	BCR
Best estimate	Prevented fatalities: 0.49 Prevented serious/slight injuries: 20.6 Prevented PDO crashes: 152 (assumption) Implementation cost: €47 / tested person Annual cost: / Number of units implemented: 121,453	0.5

SENSITIVITY ANALYSIS

The effect is calculated for cases in which the measure costs are lower or higher than estimated. Table 2 presents the results. The measure is sensitive to changes in the cost. At a lower cost (-50%) the BCR become 1.5 which means that the benefits exceed the costs.

Table 2 Sensitivity analysis

Scenario	Input values	BCR
Low measure cost (-50%)	Impl. cost: €16 /program Annual cost:/	1.5
High measure cost (+100%)	Impl. cost: €94 /program Annual cost: /	0.3

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Vlakveld, W., Wesemann, P., Devillers, E., Elvik, R. & Veisten, K. (2005). Detailed cost-benefit analysis of potential impairment countermeasures.

Cost-benefit analysis
Child pedestrian training

Christos Katrakazas, Loughborough University, September 2017

ABSTRACT

An existing evaluation study on effects of child pedestrian training in the USA (National Academies of Sciences Engineering and Medicine & Transportation Research Board, 2008) was revisited. The SafetyCube Economic Efficiency Evaluation (E³) Calculator was used. The resulting best estimate of the benefit-cost ratio (BCR) is 2.6 which means that the benefits tend to exceed the costs. The BCR is sensitive to changes in the underlying assumptions as it is shown by the sensitivity analysis. However, in both the low-cost and high cost scenarios it is shown that child pedestrian training remains economically efficient.

INPUT INFORMATION

Case studied: The only available report (National Academies of Sciences Engineering and Medicine & Transportation Research Board, 2008) demonstrates a reduction of 12% of fatal and injury casualties among children who undertook child pedestrian training in an average US State (600 fatalities/year).

Crash costs: The updated SafetyCube estimates for 2015 for Europe were used (see SafetyCube Deliverable 3.2)

Measure Costs: The available report also contained cost estimates. The estimated state-wide implementation cost (for an average US state with 600 fatalities/year) in this paper is between $500,000-800,000 (or $1-2/child student). In order to have a single estimation, the average of the upper and lower limit was taken into account (i.e. $650,000). These costs apply to USA in 2006 and are updated to 2015 values by applying the inflation conversion value of 1.16. Subsequently the values are converted to EU averages (in Euros) by multiplying with the PPP conversion value of 0.76.

Time horizon: The applied time horizon for the measure is assumed to be 1 years, as suggested by the available report.

Area/Unit of implementation: All costs and effects are expressed per training intervention, and hence one (1) unit of implementation was taken into account.

Number of cases affected: The affected number of casualties was retrieved from (National Academies of Sciences Engineering and Medicine & Transportation Research Board, 2008).The study contains an estimate of the effect on the total number of deceased and injured people (i.e. 12% reduction). Other than in the study in question, the European fatality-to-injury ratio was used and thus, 140.51 slight and severe injuries, as suggested by the E³ calculator, were included in the calculation (57 in the US study) No side effects were taken into account.

RESULTS

Table 1 provides the input values and the result estimated benefit-to-cost ratio for the measure. It shows a BCR of 2.6. This means that the benefits tend to exceed the costs.

Table 1 Input values and BCR for the 'best estimate' scenario

Scenario	Input values	BCR
Best estimate	Fatal injury casualties reduction: 12% Slight/serious injury casualties reduction: 12% Implementation cost: €574,689 Affected nr. of crashes per year: Fatalities: 1.82 Injuries(slight/serious): 140.51	2.6

SENSITIVITY ANALYSIS

We used the upper and lower limits of the cost estimates in the available report to run a sensitivity analysis. The effect is calculated for cases in which the measure costs are lower of or higher than the estimated average. Table 2 presents the results.

Table 2 Sensitivity analyses

Scenario	Input values	BCR
Low measure cost (based on the study)	Impl. cost: \$500,000 = (€442,068) No annual costs	3.4
High measure cost (based on the study)	Impl. cost: \$800,000 = (€707,309) No annual costs	2.1
Low measure cost (-50%)	Impl. costs: €287,344 (one-time) No annual costs	5.3
High measure cost (+100%)	Impl. costs: €1,149,377 (one-time) No annual costs	1.3

REFERENCES

National Academies of Sciences Engineering and Medicine & Transportation Research Board. (2008). Effectiveness of Behavioral Highway Safety Countermeasures. National Cooperative Highway Research Program (NCHRP) Report 622. https://doi.org/10.17226/14195

Cost-benefit analysis
Seatbelts campaign

Eva Aigner-Breuss, KFV, September 2017

ABSTRACT

An exemplary cost-benefit analysis (CBA) for seatbelt campaigns was conducted using as a basis the evaluation study on a Dutch seatbelt campaign (Tamis, 2009). The SafetyCube Economic Efficiency Evaluation (E^3) Calculator was used. The resulting best estimate of the benefit-to-cost ratio (BCR) is 44.6 which means that the benefits exceed the costs. The sensitivity analysis indicates that even when calculating a worst case scenario, the benefits outweigh the costs.

INPUT INFORMATION

Case studied: The evaluation study on a Dutch seatbelt campaign (Tamis, 2009) was chosen, because it has good quality and the campaign itself was conducted with the principles of CAST (Delhomme et al., 2009), which is assumed to be best practice for designing and evaluating road safety campaigns. Further it is a European example. The campaign does not prevent crashes but aims at increasing the use of seatbelts, and seatbelts in turn prevent or reduce injuries in a crash.

The campaign results in an 1.8% increase of seatbelt use of all car occupants (from 93.8% to 95.6%: measured 2008 before the campaign and after the campaign).

Crash costs: The updated SafetyCube estimates for 2015 for Europe were used (see SafetyCube Deliverable 3.2)

Measure Costs: Tamis (2009) reports that the campaign costs €490,000. These costs covered concept development, production (TV and radio spots, billboards, posters and website), dissemination and research (pre-testing of the campaign). No annually recurrent costs are accounted for since the campaign was launched only once. These costs were updated by applying the inflation conversion value of 1.04 (from year 2008 to year 2015 in the Netherlands). Subsequently the values are converted to EU average by multiplying with the PPP conversion value of 0.92.

Time horizon: The applied time horizon for the measure is 1 year, since the campaign lasted less than one year (2008).

Area/Unit of implementation: Effects are expressed for the Dutch seat belt campaign 2008.

Number of cases affected: Tamis (2009) reported as affected numbers of cases for the campaign the fatalities and severely injured car occupants in the Netherlands for the year 2007. For this calculation, the numbers are updated to the year 2015 and retrieved from CARE database. No differentiation between drivers, front passengers and rear passengers could be made, as this data was missing. Further, no side effects were taken into account.

Effectiveness: The effectiveness of seatbelts in cars was retrieved from the handbook of road safety measures (Elvik et al., 2009). The authors report effects for drivers, front seat passengers and back seat passengers separately. For the CBA calculation, the effects for the drivers were used for all car passengers since separate calculation due to missing accident data for different types of car occupants couldn´t be conducted (drivers (cars): fatal (all accidents) -50% (95% confidence intervals: -55, -45), serious injuries (all accidents) -45% (95% confidence intervals: -50, -40). The penetration rate was taken from the campaign evaluation (Tamis, 2009).

RESULTS

Table 1 provides the input values and the result estimated benefit-to-cost ratio for the Dutch seatbelt campaign. It shows a benefit-to-cost-ratio of 42.2. This means that the benefits exceed the costs.

Table 1 Input values and BCR for the 'best estimate' scenario

Scenario	Input values	BCR
Best estimate	Fatal injury crashes reduction: 50% Serious injury crashes reduction: 45% Implementation cost: €468,832 Affected nr. of crashes per year (2015): Fatalities: 214 Serious Injuries: 2,832 Penetration Rate of seat belt usage before the campaign: 93,8% Penetration Rate of seat belt usage after the campaign: 95,6%	42.2

SENSITIVITY ANALYSIS

The upper and lower limits of the 95% confidence intervals of the estimates in Elvik et al. (2009) was used to run a sensitivity analysis. The values represent a (much) lower than expected and a (much) higher than expected effect respectively. Subsequently the effect is calculated for cases in which the measure costs are lower or higher than for the campaign. Table 2 presents the results.

Table 2 Sensitivity analyses

Scenario	Input values	BCR
Low measure effect	Fatal injury crashes reduction: -45% Serious injury crashes reduction: -40%	34.8
High measure effect	Fatal injury crashes reduction: -55% Serious injury crashes reduction: -50%	50.9
Low measure cost (-50%)	Implementation cost: €234,416	84.3
High measure cost (+100%)	Implementation cost: €937,664	21.1

Additionally, a 'worst case' scenario and an 'ideal case' scenario was defined and calculated. The 'worst case' scenario is a combination of a much worse than expected effect (i.e. the lower limit of the 95% CI) and a higher than expected measure cost (i.e. the estimated cost +100%). The 'ideal case' scenario is defined as a combination of a much better than expected effect (upper limit of the 95% CI) and a lower than expected measure cost (estimated cost -50%). The results of the CBA for these scenarios are reflected in Table 3.

Table 3 CBA for worst case and ideal case scenarios

Combined Scenario		Input values	BCR
Worst case		Fatal injury crashes reduction: -45% Serious inj. Crashes reduction: -40% Implementation cost: €937,664	17.4
Ideal case		Fatal injury crashes reduction: -55 % Serious inj. Crashes reduction: -50% Implementation Cost: €234,416	101.9

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Cost-benefit analysis
Booster seat program

Susanne Kaiser, KFV, September 2017

ABSTRACT

An exemplary cost-benefit analysis for booster seat campaigns was conducted using data from NCHRP (2008). The SafetyCube Economic Efficiency Evaluation (E^3) Calculator was used. The resulting best estimate of the benefit-to-cost ratio (BCR) is 4.6 which means that the benefits exceed the costs. The sensitivity analysis indicates that this is also the case even with an 100% increase in measure costs.

INPUT INFORMATION

Case studied: An evaluation study from the US on cost-benefit outcomes of a booster seat program for children aged four to eight in an average US state (NCHRP, 2008) was revisited, updated and complemented with European data. This report calculates with an increase in booster seat use by 13%, an estimated 59% reduction of injuries when using a booster seat compared to the non-use (resulting in an 8% reduction of injuries for the affected cases).

Crash costs: The updated SafetyCube estimates for 2015 for Europe were used (see SafetyCube Deliverable 3.2).

Measure Costs: NCHRP (2008) provide an estimate for the implementation costs of a nationwide (average US state) booster seat program for 4 to 8 year old children. which includes a variety of single activities targeted at children, parents or physicians such as strategy development, community education, newspaper articles, website and newsletter, brochures, flyers, radio and TV public service announcements, discount coupons and citizen advisory groups. This amounts to a range from $300,000 to $800,000. The average of this range was used as a basis to conduct calculations: $550,000. Correcting for inflation by the factor 1.11 (from 2008 to 2015) results in $610,500 and updating the price level (USA to EU-28) by the factor 0.76 in €463,980 one-time investment costs.

Time horizon: The applied time horizon for the measure is one year.

Area/Unit of implementation: All costs and effects are expressed per implementation of one nationwide booster seat program.

Number of cases affected: The affected number of fatalities was used as provided by NCHRP for an average US state: 3.86 children between four and eight not traveling in booster seats (0.643% of 600 fatalities in all groups). Based on this number, the E^3 calculator suggests 295.005 slight or serious injuries. No side effects were taken into account.

Effectiveness: Reported estimates of increased booster seat use due to a campaign or program vary between 12.8% and 28.5% (Aigner-Breuss & Pilgerstorfer, 2017). Durbin et al. (2003, cited from NCHRP, 2008) assume a 59% reduction of injuries when travelling with a booster seat rather than an adult seat belt. For the age group five to nine, Elvik et al. (2009) report a similar estimate for the reduction in all injury categories (-57%). Based on the estimates provided by NCHRP (13% increased use and 59% reduction of injuries compared to non-use), an 8% reduction (13 by 0.59) of injuries for the affected cases due to the countermeasure is assumed and was used for this calculation.

RESULTS

Table 1 provides the input values and the result estimated benefit-to-cost ratio for the booster seat program. It shows a BCR of 4.6. This means that the benefits exceed the costs.

Table 1 Input values and BCR for the 'best estimate' scenario

Scenario	Input values	BCR
Best estimate	Fatalities reduction: 8% Serious and slight injuries reduction: 8% Implementation cost: €463,980 Affected no. of crashes per year (2015): Fatalities: 3.86 Serious + slight injuries: 298.005	4.6

SENSITIVITY ANALYSIS

Taking the range of 12.8 to 28.5% increase of booster seat use into account, the estimate used for this calculation (+13%) can already be described as conservative. A confidence interval was not reported. Therefore, the sensitivity analysis was run only with an 100% increase and a 50% decrease in measure costs. Table 2 presents the corresponding results.

Table 2 Sensitivity analysis

Scenario	Input values	BCR
Low measure cost (-50%)	Implementation. costs: €231,990 (one-time) No annual costs	9.2
High measure cost (+100%)	Implementation costs: €927,960 (one-time) No annual costs	2.3

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Aigner-Breuss, E. & Pilgerstorfer, M. (2017). Synopsis on Awareness raising and campaigns – Child restraint, developed within the H2020 project SafetyCube.

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Cost-benefit analysis
Drink-driving advertising campaign

Susanne Kaiser, KFV, September 2017

ABSTRACT

An existing evaluation study from the US on cost-benefit outcomes of an advertising campaign tackling drink-driving among young drivers (Murry et al., 1996) was revisited. The SafetyCube Economic Efficiency Evaluation (E^3) Calculator was used to update the figures. The resulting best estimate of the benefit-to-cost ratio (BCR) is 2.1 which means that the benefits exceed the costs. A sensitivity analysis with 100% increase and 50% decrease in measure costs suggests that the campaign is not sensitive to changes in the underlying assumptions. An increase of 100% in measure costs, however, results in a BCR of 1, which indicates neither exceeding costs nor benefits.

INPUT INFORMATION

Case studied: The study re-evaluated (Murry et al., 1996), reports incapacitating and fatal highway accidents of 18-24-year-old males in Wichita, Kansas (USA) before and after a paid-media anti-drink-driving campaign, implemented in 1986 (March through August).

Crash costs: The updated SafetyCube estimates for 2015 for Europe were used (see SafetyCube Deliverable 3.2).

Measure Costs: Murry et al. (1996) also provide cost information: $292,000 for planning and evaluation[1], $150,000 for message production and $90,000 for the bought media time. The sum of $532,000 was corrected for inflation (1986 to 2015) with a corresponding online conversion tool[2] since the E^3 Calculator dates back only till 1995. This resulted in $1,134,417.19, which then were corrected for the price level (USA to EU-28 with the value 0.76). The updated costs for the measure in 2015 are €862,157 (one-time investment).

Time horizon: The time horizon for the measure is 8 months, therefore 1 year was applied in the E3 Calculator.

Area/Unit of implementation: All costs and effects are expressed per implementation of one drink-driving campaign.

Prevented casualties: Based on a time series model, Murry et al. (1996) conclude that 15.4 fewer incapacitating and fatal accidents among young males occurred than otherwise expected. This number was applied in the E3 Calculator as prevented casualties, which includes slight, serious and fatal injuries since there is no separate entry field for only serious and fatal. PDO crashes were suggested to be 112 accordingly by the calculator. No side effects were considered.

RESULTS

Table 1 provides the input values and the result estimated benefit-to-cost ratio for the drink-driving advertising campaign. It shows a BCR of 2.1. This means that the benefits exceed the costs.

[1] Costs are not provided for planning and evaluation separately, otherwise evaluation costs would not have been considered here.
[2] https://inflationdata.com/Inflation/Inflation_Calculators/Inflation_Rate_Calculator.asp

Table 1 Input values and BCR for the 'best estimate' scenario

Scenario	Input values	BCR
Best estimate	Incapacitating and fatal crash reduction: 15.4 PDO only crashes reduction: 112 Implementation cost: €862,157 (one-time) No annual cost	2.1

SENSITIVITY ANALYSIS

Murry et al. don't report a confidence interval for the estimate of effectiveness. Therefore, a sensitivity analysis was conducted only for cases in which the measure costs are lower or higher than indicated. Table 2 presents the results.

Table 2 Sensitivity analysis

Scenario	Input values	BCR
Low measure cost (-50%)	Implementation costs: €431,079 (one-time) No annual costs	4.2
High measure cost (+100%)	Implementation costs: €1,724,314 (one-time) No annual costs	1.0

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Cost-benefit analysis
Police enforcement of speeding

Apostolos Ziakopoulos, NTUA, September 2017

ABSTRACT

Existing evaluation studies on the effects of general police enforcement and speeding were analysed, and information was synthesized from several sources. The SafetyCube Economic Efficiency Evaluation (E^3) Calculator was used. The resulting best estimate of the benefit-to-cost ratio (BCR) is 1.0 which means that the benefits tend to match the costs invested. The BCR is sensitive to changes in the underlying assumptions as it is shown by the sensitivity analysis.

INPUT INFORMATION

Case studied: The effects produced by the meta-analysis conducted by Erke et al. (2009) were utilized: They mention a significant 18% reduction of all crashes (95% CI [-23%; -13%]) after speed enforcement measures were implemented.

Crash costs: The updated SafetyCube estimates for 2015 for Europe were used (see SafetyCube Deliverable 3.2).

Measure Costs: The Handbook of road safety measures (Elvik, 2009) estimated the annual costs of speed enforcement in Norway to be roughly NOK 130 million. However, this is too large an area to use with the calculator which requires specific crash reduction data because it is difficult to define proper coverage of police enforcement and speeding. Thus, the study of Goldenbeld & van Schagen (2005) is preferred, which puts the total costs (material costs and salary costs) at about €5 million for the period 1998-2002. A correction for inflation is made to transfer the values to 2015. Therefore, we used the average inflation rate of the years 1998 to 2002 which is 1.27. This results in a total cost of €6,350,000 for 5 years. Updating the price level (from the Netherlands to EU-28) by the factor 0.92 results in €5,842,000. Maintenance costs are considered as incorporated in the implementation costs and for the purpose of the calculator they are considered as 0, so there is no extra discounting of annual costs (which would be unrealistic).

Time horizon: The applied time horizon for the measure is five years, as described in the study by Goldenbeld & Van Schagen (2005).

Area/Unit of implementation: The area that is examined is the one that is defined in the study of Goldenbeld & Van Schagen (2005) and includes 28 above average dangerous road segments of which the 100 km/h speed limit road segments (5) had a total length of 28 km and the 80 km/h segments (23) had a total length of 88 km.

Number of cases affected: Crash mitigation figures are provided by Goldenbeld & Van Schagen (2005). The study estimated a saving of 50 injury crashes in the area of implementation that is defined above. The total number of crashes on these roads after the implementation of the measure remains 204 per year. By summing up the number of actual crashes and the number of prevented crashes, we can define the target group, which are 254 crashes. There were no PDO (property damage only crashes) figures reported in the study; the suggested values of the calculator are used instead. Note that the effectiveness estimate that was calculated in the study of Goldenbeld & Van Schagen (2005) of 21% is disregarded in the CBA in favour of the more general 18% of the meta-analysis (Erke et al., 2009).

RESULTS

Table 1 provides the input values and the result estimated benefit-to-cost ratio for DSL. It shows a BCR of 1.0. This means that the benefits tend to match the costs invested.

Table 1: Input values and BCR for the 'best estimate' scenario

Scenario	Input values	BCR ratio
Best estimate	Injury crashes reduction: 18% PDO only crashes reduction: 18% Total costs: 5,856,879 €/area treated Affected nr. of casualties per year: Injury crashes: 47.6 Affected nr. of PDO[1] crashes per year: 346.15	**1.0**

SENSITIVITY ANALYSIS

We used the upper and lower limits of the 95% confidence intervals of the estimates in Erke et al. (2009) to run a sensitivity analysis. The values represent a considerably lower/higher than expected effect, respectively. Subsequently the effect is calculated for cases in which the measure costs are lower of or higher than estimated. Table 2 presents the results.

Table 2: Sensitivity analyses

Scenario	Input values	BCR ratio
Low measure effect	Injury crash reduction: 13% PDO only crashes reduction: 13% Total costs: €5,856,879 /area treated	**0.7**
High measure effect	Injury crash reduction: 23% PDO only crashes reduction: 23% Total costs: €5,856,879 /area treated	**1.3**
Low measure cost (-50%)	Injury crashes reduction: 18% PDO only crashes reduction: 18% Total costs: €2,928,440 /area treated	**2.0**
High measure cost (+100%)	Injury crashes reduction: 18% PDO only crashes reduction: 18% Total costs: €11,713,759 /area treated	**0.5**

We define a 'worst case' scenario as a combination of a much worse than expected effect (i.e. the lower limit of the 95% CI) and a higher than expected measure cost (i.e. the estimated cost +100%). Also, an 'ideal case' scenario is defined which is a combination of a much better than expected effect (upper limit of the 95% CI) and a lower than expected measure cost (estimated cost -50%). The results of the CBA for these scenarios are reflected in Table 3.

Table 3: CBA for worst case and ideal case scenarios

Combined Scenario	Input values	BCR
Worst case	Injury crash reduction: 13% PDO only crashes reduction: 13% Total costs: €11,713,759 /area treated	**0.4**
Ideal case	Injury crash reduction: 23% PDO only crashes reduction: 23% Total costs: €2,928,440 /area treated	**2.6**

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[1] Crashes obtained as suggested by the calculator

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Cost-benefit analysis

Random breath tests and DUI checkpoints

Apostolos Ziakopoulos, NTUA, October 2017

ABSTRACT

Existing evaluation studies on the effects of random breath tests and DUI (Driving Under the Influence) checkpoints were analysed, and information was synthesized from several sources. The SafetyCube Economic Efficiency Evaluation (E^3) Calculator was used. The resulting best estimate of the benefit-to-cost ratio (BCR) is 7.3 which means that the benefits considerably exceed the costs invested. The BCR is sensitive to changes in the underlying assumptions as it is shown by the sensitivity analysis.

INPUT INFORMATION

Case studied: The original Handbook (Elvik, 2009) mentions a significant 14% reduction in crashes (95% CI [-18%; -11%]) for DUI checkpoints when publication bias is controlled for (this figure is preferred over the uncontrolled one). These figures are general and are going to be utilized for corresponding crash cost numbers.

Crash costs: The updated SafetyCube estimates for 2015 for Europe were used (see SafetyCube Deliverable 3.2).

Measure Costs: The Handbook of road safety measures (Elvik, 2009) estimated the total annual costs of DUI checkpoints for Norway on a national level to be roughly NOK 164 million (1995 prices). This figure included costs for prosecution, licence suspension, new driving tests and licence replacement. However, this is too large an area to use with the calculator which requires specific crash reduction data, because it is difficult to define proper coverage of breath tests and DUI checkpoints. Thus, the figures provided in Mackay et al. (2003) are preferred instead. They set the personnel costs (including overhead) at €100,000 plus €5750 for equipment respectively, and provide that in one person-year, 16,200 tests can be conducted. Furthermore, under an assumption that 2% of the tests are being positive, which is the EU rough average as a whole as cited by Mackay et al., it can be calculated that 324 offenders will be detected in a person-year, with respective administrative costs of €324,000 (€1,000 per offender).

This sets the total costs for random breath testing at €2,652,778 per 100,000 tests (EU price level). This conversion was conducted for compatibility with crash numbers. Correcting for inflation by the factor 1.238 (from 2001 to 2015) results in €3,284,143. Maintenance costs are considered incorporated in the implementation costs and for the purpose of the calculator they are considered as zero.

There are no annual maintenance costs, and publicity costs were considered as zero due to the lack of precise data and an effect that is impossible to capture due to free publicity (journalism, police reports etc.).

Time horizon: The applied time horizon for the measure is 5 years, compatible with the crash data, which is inputted as a 5-year average.

Area/Unit of implementation: The unit of implementation examined is the increase of random-breath tests by 100,000 per year.

Number of cases affected: Crash mitigation figures were obtained from a graph provided in Ferris et al. (2013). Despite being from Australia, it was the only source of crash number data that was located (Mackay et al reference fatalities only). The study reports an average number of alcohol-related traffic crashes per six-month period of 145 at the start and 159 at the end of the Australian random breath testing program which was implemented for the period examined. The joint analysis they provide has a steady trend so it can be argued that there are about 304 relevant crashes per year on approximation for the 5-year period. These are noted as casualty crashes because there is no further detail in the data.

RESULTS

Table 1 provides the input values and the result estimated benefit-to-cost ratio for the measure. It shows a BCR of 7.3. This means that the benefits considerably exceed the costs invested.

Table 1: Input values and BCR for the 'best estimate' scenario

Scenario	Input values	BCR
Best estimate	Crash reduction: 14% Implementation cost: €3,284,143 /100,000 tests Annual cost: €0.00 Affected nr. of casualties per year: Crashes: 304	7.3

SENSITIVITY ANALYSIS

We used the upper and lower limits of the 95% confidence intervals of the estimates of the original Handbook (Elvik, 2009) to run a sensitivity analysis. The values represent a considerably lower/higher than expected effect, respectively. Subsequently the effect is calculated for cases in which the measure costs are lower of or higher than estimated. Table 2 presents the results.

Table 2: Sensitivity analyses

Scenario	Input values	BCR
Low measure effect	Crash reduction: 11%	5.7
High measure effect	Crash reduction: 18%	9.4
Low measure cost (-50%)	Implementation cost: €1,642,072 /100,000 tests Annual cost: €0.00	14.6
High measure cost (+100%)	Implementation cost: €6,568,287 /100,000 tests Annual cost: €0.00	3.7

We define a 'worst case' scenario as a combination of a much worse than expected effect (i.e. the lower limit of the 95% CI) and a higher than expected measure cost (i.e. the estimated cost +100%). Also, an 'ideal case' scenario is defined which is a combination of a much better than expected effect (upper limit of the 95% CI) and a lower than expected measure cost (estimated cost -50%). The results of the CBA for these scenarios are reflected in Table 3.

Table 3: CBA for worst case and ideal case scenarios

Combined Scenario	Input values	BCR
Worst case	Crash reduction: 11% PDO only crashes reduction: 13% Implementation cost: €6,568,287 /100,000 tests Annual cost: €0.00	2.9
Ideal case	Crash reduction: 18% Implementation cost: €1,642,072 /100,000 tests Annual cost: €0.00	18.8

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