Economic evaluation of vehicle related measures

Deliverable 6.3

SafetyCube

Economic evaluation of vehicle related measures

Work package 6, Deliverable 6.3

Please refer to this report as follows:
Martin O. et al (2017). Economic evaluation of vehicle related measures. Deliverable 6.3 of the H2020 project SafetyCube.

Grant agreement No 633485 - SafetyCube - H2020-MG-2014-2015/ H2020-MG-2014_TwoStages

Project Coordinator:
Professor Pete Thomas, Transport Safety Research Centre, Loughborough Design School, Loughborough University, Ashby Road, Loughborough, LE11 3TU, UK

Project Start date: 01/05/2015
Duration: 36 months

Organisation name of lead contractor for this deliverable
Cidaut Foundation, Spain

Report Author(s):
Oscar Martin, Cidaut Foundation, Spain
Rachel Talbot, Christos Katrakazas, Loughborough University, United Kingdom
Eleonora Papadimitriou, Apostolos Ziakopoulos, NTUA, Greece
Reakka Krishnakumar, Jacques Saadé, Vuthy PHAN, CEESAR, France
Cecil Mettel, DEKRA Automobil GmbH, Germany
Robert Thomson, SAFER, Sweden

Due date:	**31/12/2017**	**Submission date:**	**09/03/2018**

Project co-funded by the by the Horizon 2020 Framework Programme of the European Union
Version: Draft
Dissemination Level: PU Public

Co-funded by the Horizon 2020
Framework Programme of the European Union

Table of contents

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 (6.3) of work package 6, which is dedicated to the economic evaluation - mainly by means of a cost-benefit analysis - of vehicle 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 (6.2) of work package 6 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.

The major difficulties arose from the estimation of the costs of the measures, the limitation of CBA studies and the identification of target groups. The vehicle related measures are often developed by the vehicle manufacturers and they are reluctant to give their costs. Also, for most of the measures there was not enough information to perform a CBA. This was due the lack of effectiveness figures and CBA studies. That lead 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 9 road-user related road safety measures.

The documentation of these CBAs is added in the Appendix and provides detailed information on the used data and calculations. The principal tools for all the analyses were the literature reviewed and 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 vehicle related measures have a benefit-to-cost ratio (BCR) that is higher than 1. This means that the benefits outweigh the costs and are economically efficient. The conducted calculations show a wide range of benefit-to-cost ratios between 0.03 and 7.8. For three measures, the CBA resulted in a BCR smaller than 1, which means that they are not economically efficient, although there is sufficient proof of their effectiveness.

All CBA listed in D6.3 are example CBA and the only available tool for making comparisons between them is the E^3 calculator, available in the DSS. A simple compilation was made, setting up an arbitrary identical time horizon for the measures with enough information and calculating their respective BCR.This is just meant to illustrate the capacities of the E^3 calculator and comparisons dedicated at supporting decision making should take features such as the variety of local vehicle usages and the array of safety systems lifespans into account.

The most important limitation in using cost-benefit analyses is the dependence on underlying assumptions about the measure effectiveness, the target group and the measure costs. Therefore, the CBAs were accompanied by a sensitivity analysis when possible. Sensitivity analyses were performed using different rates of effectiveness of the measure in preventing crashes, and different values for measure costs. A best and worst case scenarios were 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 three measures.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 10 economic evaluations conducted, side effects of countermeasures were only available for AEB city and ESC but are generally hardly reported or quantified.

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.

List of Abbreviations

ABS	Advanced Braking Systems
AEB	Autonomous Emergency Braking
BCR	Benefit-to-cost ratio
CARE	Community database on Accidents on the Roads in Europe
CBA	Cost-Benefit Analysis
CBR	Cost-Benefit Ratio
CBS	Combined Braking Systems
CEA	Cost-Effectiveness Analysis
CI	Confidence interval
CRS	Child Restraint System
CUA	Cost-utility Analysis
CMF	Crash Modification Factor
DSS	Decision Support System
EBA	Emergency Braking Assistance
ESC	Electronic Stability Control
E3	Economic Efficiency Evaluation
NPV	Net Present Value
PDO	Property Damage Only
PPP	Purchasing Power Parity
PR	Percentage Reduction
PTW	Powered Two Wheeler
QALY	Quality Adjusted Life Years
ROR	Run-off-road
TCS	Traction Control Systems
VRU	Vulnerable Road User(s)
WP	Work Package
WTP	Willingness To Pay
YLD	Years Lived with Disability
YLL	Years of Life Lost

1 Introduction

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 at:

1. developping 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. applying 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. developing an operational framework to ensure the project facilities can be accessed and updated beyond the completion of SafetyCube
4. enhancing 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 6

The purpose of work package 6 was to analyse data and to implement developed methodologies (WP3) concerning accident risk factors and road safety measures related to the vehicle point of view. It examines accident risks and safety measures concerning all types of road users (passenger cars, heavy goods vehicle, powered two wheelers ...) 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) were used in order to:

- Identify and rank risk factors related to the road use
- Identify measures for addressing these risk factors
- Assess the effect of measures

The work on vehicle-related risks and measures in road traffic was done according to the methodologies and guidelines developed in WP3 (Martensen et al., 2017) being thus consistent with work packages dealing with human (WP4) and infrastructure (WP5) related risks and measures.

All main results of WP6 were integrated into the DSS and linked with each other (risk factors and measures) and with outcomes of other work packages (WPs 4, 5, and 7).

PURPOSE OF THIS DELIVERABLE

This deliverable reports the work carried out within task 6.3 of the SafetyCube project. The aim of task 6.3 is to assess the economic efficiency of road safety measures that are identified as effective in task 6.2 (Jaensch, Leopold et al, 2017). The focus is on measures targeting vehicles – in contrast to measures targeting road infrastructure or road users. Based on the methodology developed in WP3, an economic evaluation of the selected 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, and the literature reviewed.

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 6.3 is the assessment of a variety of vehicle related measures in terms of economic efficiency. 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/.

RELATION TO OTHER SAFETY CUBE WORKPACKAGES AND OUTPUTS

Deliverable 6.3 is fed with the vehicle measures identified as effective in Deliverable 6.2.The main results of deliverable 6.3 include a variety of systematically analysed vehicle measure findings regarding costs and benefits. These findings will be used to elaborate on deliverables 6.4 and 6.5.
The results of the deliverable 6.3 are documented and integrated in a similar form as the measure 'synopses' which were prepared as part of Task 6.2 and presented in Deliverable 6.2. The CBAs will be incorporated into the Safety Cube DSS and linked to corresponding road safety benefits of these measures. The CBAs presented in the report, however, form individual documents appended to this one and will be made available separately through the DSS.
Similar analyses of measures cost-effectiveness were carried out within Tasks 4.3 (Road user behaviour) and Task 5.3 (Infrastructure), in accordance to the Systems approach that spans the whole SafetyCube project.

2 Method

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 was 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 it prevents per unit cost of implementing the measure.
The necessary information to conduct 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 useful to determine how to reach a specific policy target (e.g. reducing the number of crashes) at the lowest cost.

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 including 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 injuries), 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.

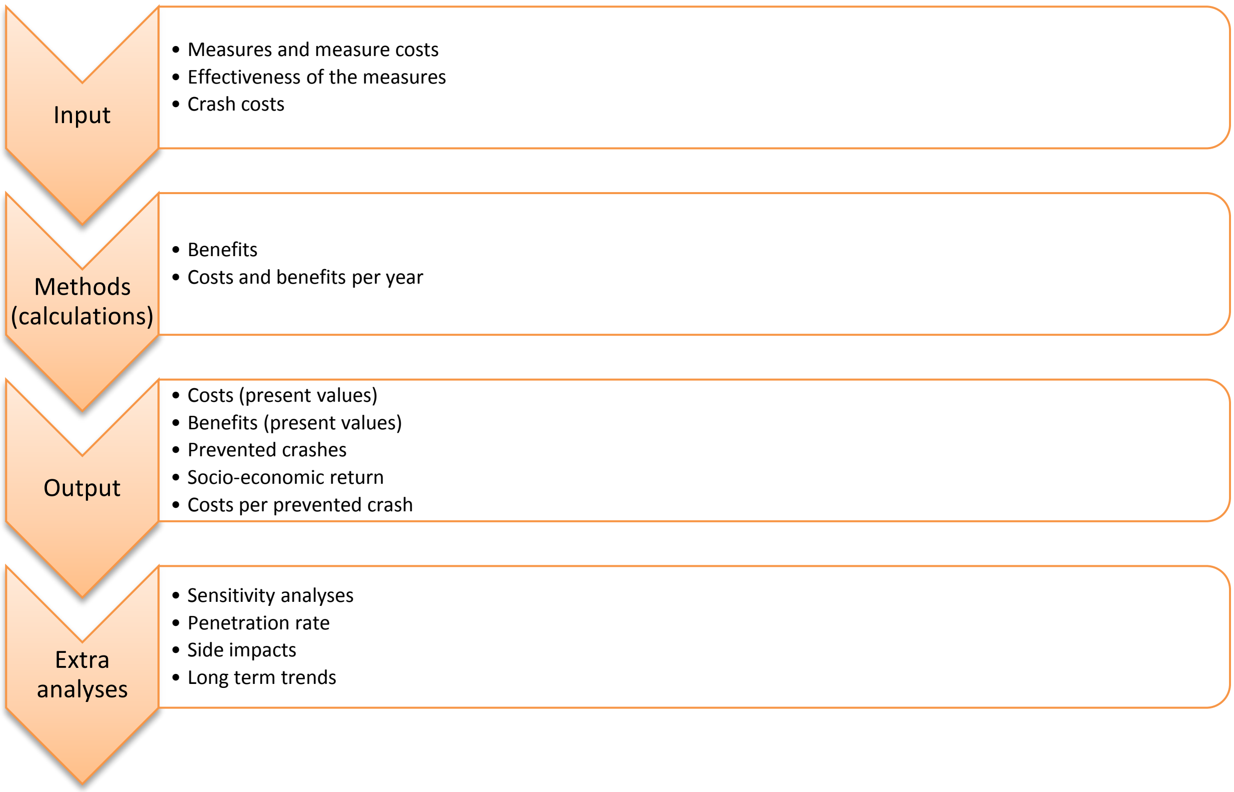
THE ECONOMIC EFFICIENCY EVALUATION TOOL

Within the SafetyCube-project an Economic Efficiency Evaluation (E^3) calculator was developed. This tool is aimed at making CBA easier to undertake. 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 was used to address CBAs for 9 vehicle-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.



2.1.4 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 measures can have different effects depending on the level of injury considered and can thus lead to different benefits because the monetary value differs for each injury level.

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 once, while the maintenance cost is a recurrent cost and should be expressed on a yearly basis. These costs differ per country. They have to be updated to 2015 since this is the year in which the costs of crashes (benefits), which 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.

2.1.5 Method

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

$$Benefits = \sum_{s}^{1} TargetCrashes_s * Effectiveness_s * CrashCosts_s$$

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 transformed into monetary values by multiplying the cost per crash by the number of prevented crashes.

2.1.6 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.

2.1.7 Other analyses

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

DATA COLLECTION PROCEDURE

The first step of the method used to collect data for cost-benefit analyses was firstly to do a literature review of the SafetyCube vehicle measures taxonomy identified in Task 6.2. This allowed to identify available data sources and/or existing published CBAs that could be used as a basis for SafetyCube CBAs. However, there was not enough information to perform a CBA for some of the vehicle measures.

In general, there were four options for conducting a CBA on the selected measures:

a) An estimate from meta-analysis. This was the preferred option. When a meta-analysis with confidence intervals of the estimate of the measure was available, as such an estimate is considered highly reliable and transferable. Information from the literature review was added if needed, to update costs or target group information.

b) Adjustment of an existing CBA: if a reliable CBA was available, it was adjusted at least in two ways: first, with the improved SafetyCube crash costs estimates, and second, with the update of all figures and estimates to the reference year 2015.
c) If only costs and some effectiveness estimation were available a CBA was calculated using the E3 calculator according to the previously established methodology.
d) If only costs information was available, "break even" estimation was calculated using the E3 calculator tool.

After executing the CBA, all results and assumptions were summarized in a two page synopsis document. All synopses are included in Appendix A.

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.

SELECTED MEASURES

3.1.1 Selection criteria

Following a common method, systematic information on the safety effects of 47 traffic safety measures addressing the vehicle were studied Task 6.2. 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).

46 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, 17 measures were assigned a green code (e.g. Seat belt (effectiveness) SBR and Load limiter included, Frontal airbag,...), 19 were given a light green code (e.g. PTW airbag, Regulations,...) and 10 were given a grey code (e.g. Rollover protection system, Emergency stop signal,...).

For the purpose of the cost-benefit analyses, measures that turned out to have a green or light green code in D6.2 were selected in a first step. Measures with a grey 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
Seat belt (effectiveness) SBR and Load limiter included	Green	Yes
Frontal Airbag	Green	No
Side Airbag	Green	No
Anti-Whiplash	Green	No
Child Restraint System – 'CRS'	Green	Yes
Child Restraint System – 'Booster seats'	Green	No
PTW protective clothing	Green	No
PTW protective clothing - Helmet	Green	Yes
Cyclist protective clothing	Green	No
Cyclist protective clothing - Helmet	Green	No
Emergency Braking Assistance system	Green	Yes
Autonomous Emergency Braking AEB (City, interurban)	Green	Yes
Autonomous Emergency Braking AEB (Pedestrians & cyclists)	Green	Yes
EuroNCAP (Full Width & ODB)	Green	No
Electronic Stability Control (ESC)	Green	Yes
Daytime running lights	Green	No
Braking system PTW (ABS, Combined braking system, …) ABS (PTW)	Green	Yes
Directive 96/79/CEE et ECE.R94	Light green	No
Directive 96/27/CEE et ECE.R95	Light green	No
Regulation UN R135 (Pole side-impact protection)	Light green	No
EuroNCap (MBD & Pole)	Light green	No
Vehicle inspection	Light green	No
ECE R100 (Battery electric vehicle safety)	Light green	No
PTW Airbag	Light green	Yes
Underrun protection	Light green	No
Pedestrian protection - 'active technology'	Light green	No
Pedestrian protection - 'vehicle shape'	Light green	No
Pedestrian regulation	Light green	No
Blind Spot Detection	Light green	No
AEB for trucks	Light green	No
Vehicle to Vehicle communication	Light green	No
Event Data Recorder	Light green	No
Alcohol Interlock (ALC)	Light green	No
Intelligent Speed adaptation + Speed Limiter + Speed regulator	Light green	No
eCall	Light green	No
Rescue Data Sheet & Rescue code	Light green	No

3.1.2 Selected measures per category

Crashworthiness

Cost-benefit analyses of this type of measures have been carried out for Child Restraint Systems (CRS), Seat belt (effectiveness) SBR and load limiter included, Helmet usage and performance and PTW airbag.

Active safety/Adas

Within the measure category "Active safety/Adas" effectiveness was examined for Emergency Braking Assistance system, Autonomous Emergency Braking AEB (City, interurban), Autonomous

Emergency Braking AEB (Pedestrians & cyclists), braking systems PTW (ABS, Combined braking system …) and Electronic Stability Control (ESC)

Tertiary safety

There was not enough information to perform CBA for any of the Tertiary safety measures identified in D6.2

UNIT OF ANALYSIS

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

- One vehicle equipped with the system, which was used in the cost-benefit analysis for, AEB_city, AEB_ped, EBA, ESC, motorcycle airbag and motorcycle ABS, TCS.
  One child who belongs to families owning a car who is correctly restricted, this was used for the child restraint system CBA.
- One rider equipped with a helmet was used for the motorcycle helmet CBA.

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

TIME HORIZON

The time horizon in the cost-benefit analyses should equal as much as possible the real lifetime of the measure. The nature of the vehicle measures is very different and subsequently the time horizon used varies from 1 year to 20 years.

The applied time horizon for the measures AEB_ped and seat belt remainder is 1 year. For child restraints was assumed to be 4 years in order to take into account the expected duration of usage. 8 years was set as the time for AEB_city, 12 years for ESC and the applied time horizon for EBA was 20 years.

For PTW helmet the two studies defined a different time horizon. The UNECE (2016) study analyses the data over a period of 12 years whereas the NHTSA (2015) study analyses the data from one year (2013).

The time horizon used is taken from the studies which performed the CBA. Additionally, a sensitivity analysis was done based on varying time horizons, when possible. CBAs have been calculated using the European life expectancy for a vehicle. The lifespan for a vehicle was set as 12 years by Nieuwenhuis, P. et al., but a recent study for the European Commission – DG Climate Action set this figure to 14 years approximately. In the present section, an arbitrary value of 13 years was set for example sake. As vehicle lifespans are intimately linked with the dynamics of each individual country's economy, this should not be understood as an average, nor transferred from one country to another..

Table 2 shows the applied time horizon for each of the selected measures.

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[1] (in EUR EU-2015 PPP)
Seat belt (effectiveness) SBR and Load limiter included	One car equipped with a seat belt remainder	1	€60	-	€60
Child Restraint System – 'CRS'	One child using correctly CRS	4	€214	-	€214
Helmet + reflective equipment + lighting (usage + performance)	One motorcyclist using a helmet	1	€46	-	€46
Helmet + reflective equipment + lighting (usage + performance)	One motorcyclist using a helmet	12	€46		€46
Emergency Braking Assistance system	One vehicle equipped with EBA system	20	€529	-	€529
Autonomous Emergency Braking AEB (City, interurban)	One vehicle equipped with AEB city system	8	€216.5	-	€216.5
Autonomous Emergency Braking AEB (Pedestrians & cyclists)	One vehicle equipped with AEB pedestrian system	1	€216.5	-	€216.5
Braking system PTW (ABS, Combined braking system …)	One motorcycle equiped with ABS	13	€400	-	€400
	One motorcycle equiped with TCS	11	€364	-	€365

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

Electronic Stability Control (ESC)	One vehicle equipped with ESC system	12	€146.9	-	€146.9
PTW airbag	One PTW with airbag	11	€2196.92	-	€2196.92

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 of the safety effect of the measure was 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.

If a meta-analysis was not available, an absolute minimum requirement for a cost-benefit analysis was 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).

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)
Seat belt (effectiveness) SBR and Load limiter included	One car equipped with a seat belt remainder	Fatalities reduction: 24%		
Child Restraint System – 'CRS'	One child using correctly CRS	Children fatalities reduction: 81% Children KSI reduction: 69% Children slight injury reduction: 25%	Children fatalities reduction: 57% Children KSI reduction: 64% Children slight injury reduction: 16%	Children fatalities reduction: 92% Children KSI reduction: 73% Children slight injury reduction: 32%
Helmet + reflective equipment + lighting (usage + performance)	One motorcyclist using a helmet	Reduction of 42% of fatalities and 69% of injury accidents		

Measure	Unit of analysis	Crash effects (best estimates)	Crash effects (lower limit)	Crash effects (upper limit)
Helmet + reflective equipment + lighting (usage + performance)	One motorcyclist using a helmet	Reduction of 50% of fatalities		
Emergency Braking Assistance system	One vehicle equipped with EBA system	Fatal injuries reduction: 8% Serious injuries reduction: 8% Slight injuries reduction: 8% PDO reduction: 8%	Fatal injuries reduction: 4% Serious injuries reduction: 4% Slight injuries reduction: 4% PDO reduction: 4%	Fatal injuries reduction: 16% Serious injuries reduction: 16% Slight injuries reduction: 16% PDO reduction: 16%
Autonomous Emergency Braking AEB (City, interurban)	One vehicle equipped with AEB city system	Fatal injury crashes reduction: 50% Serious injury crashes reduction: 50% Slight injury crashes reduction: 5% PDO only crashes reduction:5%	Fatal injury crashes reduction: 25% Serious injury crashes reduction: 25% Slight injury crashes reduction: 0% PDO only crashes reduction:0%	Fatal injury crashes reduction: 75% Serious injury crashes reduction: 75% Slight injury crashes reduction: 10% PDO only crashes reduction:10%
Autonomous Emergency Braking AEB (Pedestrians & cyclists)	One vehicle equipped with AEB pedestrian system	Fatal injuries reduction: 14.1% Serious injuries reduction: 8.8% Slight injuries reduction: 9.36%	Fatal injuries reduction: 6.3% Serious injuries reduction: 4% Slight injuries reduction: 4%	Fatal injuries reduction: 20.8% Serious injuries reduction: 13.6% Slight injuries reduction: 19.4%
Braking system PTW (ABS, Combined braking system …)	One motorcycle equipped with ABS	Fatal motorcycle crashes: 32% Serious motorcycle crashes: 29% Slight injuries motorcycle crashes: 18%	Fatal motorcycle crashes: 25% Serious motorcycle crashes: 24% Slight injuries motorcycle crashes: 14%	Fatal motorcycle crashes: 39% Serious motorcycle crashes: 35% Slight injuries motorcycle crashes: 22%
	One motorcycle equipped with TCS	20% of all motorcycle crashes.		
Electronic Stability Control (ESC)	One vehicle equipped with ESC system	Fatal injuries reduction: 25.5% Serious or slight injuries reduction: 25.5% PDO reduction: 25.5%	Fatal injuries reduction: 16.6% Serious or slight injuries reduction: 6.6% PDO reduction: 25.5%	Fatal injuries reduction: 70% Serious or slight injuries reduction: 54.8% PDO reduction: 41.1%
PTW airbag	One motorcycle equipped with	Fatal crash reduction: 1% Serious and slight		

Measure	Unit of analysis	Crash effects (best estimates)	Crash effects (lower limit)	Crash effects (upper limit)
	an airbag	crash reduction: 1%		

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).

3.1.3 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.

3.1.4 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.

3.1.5 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

Country	Total costs estimated on the basis of value transfer	Country	Total costs estimated on the basis of value transfer
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
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 9 measures a CBA was conducted or updated. Some of the CBAs were conducted using SafetyCube's E^3 calculator and the rest estimated through a metaanalysis. 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.

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[2] 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. As the selected measures reflect measures that had a green ('effective' or a light green ('probably effective') colour code in the measure synopsis, negative values don't occur.

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.

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. Although the cost estimates for most measures were find, it is still worthwhile to look at break-even costs as they indicate for every measure at what point – given an assumed effect on traffic safety – it starts to become cost-effective.

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.

[2] 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
Seat belt (effectiveness) SBR and Load limiter included	One car equipped with a seat belt remainder	€60	1.40		€80
Child Restraint System – 'CRS'	Norway, 90% 90% of all children who belong to families owning a car are correctly restricted	214 EUR /child restraint	3.4	389,612,640	€717
Helmet + reflective equipment + lighting (usage + performance)	One motorcyclist using a helmet	€46	2.2		€353
Emergency Braking Assistance system	One vehicle equipped with EBA system	€529	3		€1500
Autonomous Emergency Braking AEB (City, interurban)	One vehicle equipped with AEB city system	€216.5	0.6		€130
Autonomous Emergency Braking AEB (Pedestrians & cyclists) – High effectiveness	One vehicle equipped with AEB pedestrian system	€216.5	1.5		€325
Braking system PTW (ABS, Combined braking system …)	One motorcycle eqquiped with ABS	€400	7.8	90,270,625,483	€3135
	One motorcycle eqquiped with TCS	€325	1.7		€511
Electronic Stability Control (ESC)	One vehicle equipped with ESC system	€146.9	5.7	148,736,168,292	€853
PTW airbag	One PTW with airbag	*2196.92*	0.03		61

Table 6: BCR and CBA comparison table (with same time horizon where possible)

Measure	**Unit of analysis**	**Total costs per unit of analysis** (in EUR EU-2015 PPP)	**Crash effects (best estimates)**	**BCR Best estimate**	**BCR estimation common time horizon 13 years**	**Area of implementation of the studies**
Seat belt (effectiveness) SBR and Load limiter included	One car equipped with a seat belt remainder	€60	Fatalities reduction: 24%	1.40	-	Europe Australia
Child Restraint System – 'CRS'	Norway, 90% 90% of all children who belong to families owning a car are correctly restricted	214 EUR /child restraint	Children injuries reduction: 14%	3.4	2.4	Norway
Helmet + reflective equipment + lighting (usage + performance)	One motorcyclist using a helmet	€46	Reduction of 42% of fatalities and 69% of injury accidents	2.2	-	UNECE countries and USA study
Emergency Braking Assistance system	One vehicle equipped with EBA system	€529	Fatal injuries reduction: 8% Serious injuries reduction: 8% Slight injuries reduction: 8% PDO reduction: 8%	3	2.1	Europe
Autonomous Emergency Braking AEB (City, interurban)	One vehicle equipped with AEB city system	€216.5	Fatal injury crashes reduction: 50% Serious injury crashes reduction: 50% Slight injury crashes reduction: 5% PDO only crashes reduction:5%	0.6	1.0	USA data. Europe estimation
Autonomous Emergency Braking AEB (Pedestrians & cyclists) – High effectiveness	One vehicle equipped with AEB pedestrian	€216.5	Fatal injuries reduction: 14.1%	1.5	16.9	UK and Germany data. EU-27 except Bulgaria

Measure	**Unit of analysis**	**Total costs per unit of analysis** (in EUR EU-2015 PPP)	**Crash effects (best estimates)**	**BCR Best estimate**	**BCR estimation common time horizon 13 years**	**Area of implementation of the studies**
	system		Serious injuries reduction: 8.8% Slight injuries reduction: 9.36%			and Lithuania estimations
Braking system PTW (ABS, Combined braking system …)	One motorcycle eqquiped with ABS	€400	Fatal motorcycle crashes: 32% Serious motorcycle crashes: 29% Slight injuries motorcycle crashes: 18%	7.8	7.8	Europe, Australia and USA
	One motorcycle eqquiped with TCS	€325	20% of all motorcycle crashes.	1.7	-	Australia
Electronic Stability Control (ESC)	One vehicle equipped with ESC system	€146.9	Fatal injuries reduction: 25.5% Serious or slight injuries reduction: 25.5% PDO reduction: 25.5%	5.7	6.1	Europe
PTW airbag	One PTW with airbag	*2196.92*	Fatal crash reduction: 1% Serious and slight crash reduction: 1%	0.03	-	Australia

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.

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.

Table 6 presents the results. BCR values above 1 indicate a favourable benefit-to-cost ratio. They are indicated in green. BCR values below 1 are indicated in red and indicate situations in which costs exceed the assumed benefits. The closer to zero, the stronger is the distortion between costs and benefits. For only 7 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 7: BCR ratios in 3 scenarios with varying effect estimates

Measure	Benefit-to-cost ratio (best estimate)	Benefit-to-cost ratio (worst case lower 95% CI limit)	Benefit-to-cost ratio (best case upper 95% CI limit)
Child Restraint System – 'CRS'	3.4	2.5	3.8
Emergency Braking Assistance system	3	2.6	3.9
Autonomous Emergency Braking AEB (City, interurban)	0.6	0.2	1.1
Braking system PTW ABS	7.8	6.3	9.5
Electronic Stability Control (ESC)	5.7	4.3	8.1

VARIATION IN THE ESTIMATES OF THE MEASURE COSTS

For vehicle related measures, the costs of measures have much variation or are 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. The costs of the systems implemented in the vehicles depend on the manufacturer and the costs of programmes as EuroNCAP, are generally unknown.

These huge variations are an important source of uncertainty that can be considered 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. For example, PTW ABS costs estimation varies from the OEMs estimation 700€ to 200€ estimation in a German study.

The costs of the AEB systems were retrieved from a study made for NHTSA (2012). The CRS system costs were obtained from the Handbook of Road Safety (Elvik, Hoye, Vaa, & Sorensen, 2009), where it is reported that the unit cost of a child restrain is about 2,000 NOK. For the EBA system, DG TREN (2006) did not find any cost, so they tested a range of values from 200 € per vehicle to 1000 €. Baum et al. (2007) stated that the cost of equipping a car with ESC is 130 € (it is a mean cost in EU-25) and this cost was verified by experts from eIMPACt project in 2006. UNECE (2016) stated that the cost for a motorcycle helmet (conformal with UN regulation 22) can vary between 46€ and 600+€ in many European countries. And the only cost found for PTW Airbag is the difference in retailer price of the same PTW with and without airbag, which is 2196.92€.

The next table shows the best estimate for CBR and a CBR estimation if the cost of the measure is increase by 100% (double price) and another CBR estimation if the price is halved (-50%).

Table 8: BCR ratios in three scenarios with varying measure costs

Measure	**Benefit-to-cost ratio** (best estimate)	**Benefit-to-cost ratio** (worst case +100% cost)	**Benefit-to-cost ratio** (best case -50% cost)
Child Restraint System – 'CRS'	3.4	1.7	6.7
Emergency Braking Assistance system	3	1.5	6.0
Autonomous Emergency Braking AEB (City, interurban)	0.6	0.3	1.3
Braking system PTW ABS	7.8	3.9	15.7
Electronic Stability Control (ESC)	5.7	2.9	11.2

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.

CRS, PTW ABS and the ESC are the only three measures that remain remain consistently efficient over the 1 threadshold in these scenarios. The other measures are clearly more susceptible to varying combinations of measure costs and effectiveness estimates

Table 9: 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)	Benefit-to-cost ratio (best case)
Seat belt (effectiveness) SBR and Load limiter included	1.40	0.5	3.5
Child Restraint System – 'CRS'	3.4	1.3	7.5
Helmet + reflective equipment + lighting (usage + performance)	2.2	1	4.3
Emergency Braking Assistance system	3	0.7	31.2
Autonomous Emergency Braking AEB (City, interurban)	0.6	0.2	1.1
Autonomous Emergency Braking AEB (Pedestrians & cyclists) - High effectiveness	1.5	0.15	7.3
Braking system PTW ABS	7.8	4.8	20.5
Electronic Stability Control (ESC)	5.7	1.5	13.4

6 Discussion & Conclusion

DISCUSSION

6.1.1 Results obtained

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 noticed 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 CRS, AEB city and PTW airbag, is the BCR below 1. In the case of the PTW airbag, the cost of the system is too high and the accidents which can contribute to mitigate are very few which leads to a very poor BCR of 0.03. The BCR of the cost efficient measures shows some variability with a range between 0.03 and 7.8.

Second, it was shown that the BCR are sensitive to changes in the underlying assumptions. For four measures, it was possible to evaluate the consequences of a variation in the effectiveness estimate. However, three out of four measures remained cost efficient. Next to that, the effect of a variation of the measure costs was inquired. This could be done for four measures, all of them were consistent even with the change of their costs.

Finally, a worst case scenario and a best case scenario analysis were performed. In the worst case scenario, decreased effectiveness and increased costs were assumed. With these assumptions BCR only remained above 1 for three measures:

- PTW braking systems ABS
- Electronic Stability Control ESC
- Child Restraint Systems CRS

For some measures such as AEB pedestrian and Seatbelt (effectiveness) SBR and Load limiter included, the BCR is close to 1, which means that costs and benefits are balanced. Any detrimental change in measure costs or effectiveness would lead to costs exceeding the benefits.
The highest BCR, 7.8, resulted for PTW ABS. For this measure the costs are low and the effectiveness is quite high, in spite of the estimate has being conservative (some studies gave more potential to this measure).

6.1.2 Description of the 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 allowed to provide feedback that has been used to gradually improve it. Thanks to the availability of the tool, CBAs could be executed for 9 different measures.

LIMITATIONS AND FUTURE WORK

By far the most important limitation of using cost-benefit analysis is its dependence on underlying assumptions that are not always straightforward to assess. The examples show that the assumptions on three elements have a great impact:

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

Most importantly, the scarse and fragmentary information available in the literature resulted in several cases for **a combination of information sources to be used for a single CBA**. In particular, a safety effect from a meta-analysis, being the most reliable effectiveness estimate, needed to be combined with measure cost information from another source, and applied for a customised case (unit of implementation and target group or number of crashes / casualties affected). Although every effort was made by SafetyCube experts to use as consistent sources as possible, and limit the number of different sources to be combined in a CBA, in several cases this could simply not be avoided in order to produce a CBA estimate. Even in these cases, particular caution was put on the transparent and substantiated combination of information.

In other words, the **flexibility provided by the E^3 tool**, which allows to transfer any cost value from any country to another (EU countries, USA, Canada, Australia) was exploited as much as possible, but with particular care to properly combine related information.

Multiple examples can be given of CBA that – according to the assumptions made – easily change from highly beneficial to vastly inefficient or vice versa. These uncertainties were the main arguments to execute a series of sensitivity analyses. These clearly showed what can be the 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. However, this was not eventually the case, as the documented information was often poor, fragmentary and unreliable.

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 assumptions made 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.

The number of CBA on vehicle 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 9 conducted economic evaluations.

In general we strongly recommend to avoid relying on existing CBA results and transfer them to a different context, but in any particular case to complement the available information with the case-specific information on the measures target group, the likely safety effects, the measure costs and the circumstances in which they are applied.

The E^3 Calculator from the SafetyCube DSS is explicitly designed to meet this need, by allowing users to **customise any input value of the existing examples on the basis of more case-specific information**, or to perform one's own CBA with new data.

References

Ajzen, I. (1988). Attitudes, personality and behaviour. Open University Press.

Alfaro, J.L., Chapuis, M., Fabre, F. (Eds.) (1994). Socio-economic cost of road accidents: final report of action COST 313. Commission of the European Community, Brussels.

Elvik, R., Hoye, A., Vaa, T. & Sorensen, M. (2009). The handbook of road safety measures. 2nd edition. Bingley: Emerald.

Hatakka, M., Keskinen, E., Gregersen, N.P., Glad, A. & Hernetkoski, K. (2002). From control of the vehicle to personal self-control, broadening the perspectives to driver education. Transportation Research Part F, 5(3), 201-215.

Høye, A., (2013). Still red light for red light cameras? An update. Accident Analysis and Prevention, 55, 77–89.

Martensen, H. et al. (2017). Methodological framework for the evaluation of road safety measures. Deliverable Number 3.3 of the H2020 project SafetyCube.

NCHRP (2008). Effectiveness of Behavioral Highway Safety Countermeasures. National Cooperative Highway Research Program Report 622. https://doi.org/10.17226/14195.

Prochaska, J. (2007). B5 Stages of Change – Phasen der Verhaltensänderung, Bereitschaft und Motivation. In Kerr, J.; Weitkunat, R. und Moretti, M. (Hrsg.): ABC der Verhaltensänderung. Urban Fischer, 118-132.

The Automotive Industry and the Environment, Nieuwenhuis, P. and Wells, P.2003. Woodhead Publishing Lte.

Daniels, S., Aigner-Breuss, E., Kaiser, S., Goldenbeld, C., Katrakazas, C., Schoeters, A., Ziakopoulos, Usami, D.S., Bauer, R., Papadimitriou, E., Weijermars, W., Rodriguez Palmeiro, A. & Talbot (2017). Economic evaluation of road user related measures. Deliverable 4.3 of the H2020 project SafetyCube

Daniels S., Papadimitriou E. (Eds) (2017). Economic evaluation of infrastructure related measures, Deliverable 5.3 of the H2020 project SafetyCube.

Appendix A: Documentation of cost-to-benefit analyses

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

1. Autonomous Emergency Braking (city, inter-urban)
2. Autonomous Emergency Braking (AEB) for pedestrians
3. Child restraints
4. Emergency Braking Assistance system (EBA)
5. Electronic Stability Control (ESC)
6. PTW Helmet
7. Seatbelt and Seatbelt Reminders
8. PTW Airbag
9. PTW braking systems (ABS, TCS)

CBA Autonomous Emergency Braking (city, inter-urban)

Reakka Krishnakumar, CEESAR, September 2017

ABSTRACT

(Grover et al. 2008) conducted a Cost – Benefit – Analysis (CBA) of the Autonomous Emergency Braking System. The SafetyCube Economic Efficiency Evaluation (E^3) Calculator was used to perform our own CBA. The resulting best estimate of the benefit-cost ratio (BCR) is 0.6 which means that the costs outweigh the benefits. The BCR is sensitive to changes in the underlying assumptions as it is shown by the sensitivity analysis.

INPUT INFORMATION

Case studied: (Grover et al. 2008) reported reductions of fatalities and serious injuries from front to rear shunt accidents (M1 vehicle front collides with any vehicle rear) between 25% and 75% and reduction of slight injury accidents between 0% and 10%.

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

Measure Costs: The costs of the AEB system reported in the study (NHTSA 2012) were used in the present paper. The estimated prices vary between 269 and 304 US dollars (2011 prices). These costs were converted in euros by using 2015 exchange rate (0.92), then updated to 2015 by applying the inflation conversion value (1.08) and finally the values were converted to EU averages by multiplying them by the PPP conversion value (0.76)[3].

*Min 269 *0.92*1.08*0.76 = 203 euros*

*Max 304 *0.92*1.08*0.76 = 230 euros*

Time horizon: The applied time horizon for the measure is 8 years.

Area/Unit of implementation: All costs and effects are expressed per vehicle equipped with AEB system. The vehicle stock considered in EU-25 is about 220 million vehicles (M1).

Number of cases affected: The affected number of casualties was retrieved from (Grover et al. 2008). The study contains an estimate number of the effect of the system separately for each severity class: serious injury, slight injury and fatal injury. The number of PDO crashes is derived from the SafetyCube calculator. It assumed that the AEB effectiveness for PDO crashes is equivalent to AEB effectiveness for slight injury accidents.

Side effects: (Grover et al. 2008) considered the congestion benefit by avoiding accidents and/or reducing the severity. In the study congestion benefit cost was provided for Germany (2005). This cost was updated to 2015 value by applying the inflation conversion value of 1.15 and then the value was converted to EU averages by multiplying by the PPP conversion value of 1.03.

*Side effects cost in 2015 = 34,678,670.10*1.15*1.03= 41,076,884.70 euros*

[3] This inflation rate is taken from SafetyCube estimates (see SafetyCube Deliverable 3.2)

RESULTS

Table 1 provides the input values and the result estimated benefit-to-cost ratio for AEB system. It shows a B/C ratio of 0.6. This means that the costs outweigh the benefits.

Table 1 Input values and B/C ratio for the 'best estimate' scenario

Scenario	Input values	B/C ratio
Best estimate	Horizon: 8 years	0.6
	Number of units implemented: 220,000,000	
	Fatal injury crashes reduction: 50[4]%	
	Serious injury crashes reduction: 50%	
	Slight injury crashes reduction: 5%	
	PDO only crashes reduction:5%	
	Implementation cost: 216.5[5] €/vehicle	
	Annual cost: no recurrent cost	
	Affected nr. of crashes per year: Fatalities: 709 Ser. Inj. 12453 Slight inj.: 506805 PDO: 4275899.8	
	Side effects costs (congestion benefit): 41,076,884.70€	

SENSITIVITY ANALYSIS

We used the upper and lower values for each parameter according to the information available from the two studies (Grover et al. 2008) and (NHTSA 2012) to run a sensitivity analysis. The values represent a (much) lower than expected and a (much) higher than expected effect respectively. Then the effect is calculated with lowest and highest measure costs. Table 2 presents the results.

Table 2 Sensitivity analyses

Scenario	Input values	B/C ratio
Low measure effect	Horizon: 8 years	0.2
	Number of units implemented: 220,000,000	
	Fatal injury crashes reduction: **25**%	
	Serious injury crashes reduction: **25**%	
	Slight injury crashes reduction: **0**%	
	PDO only crashes reduction: **0**%	
	Implementation cost: 216.5 €/vehicle	
	Affected nr. of crashes per year: Fatalities: 709 Ser. Inj. 12453 Slight inj.: 506805 PDO: 4275899.8	
	Side effects costs (congestion benefit): 20,538,442.40€	
High measure effect	Horizon: 8 years	1.1
	Number of units implemented: 220,000,000	
	Fatal injury crashes reduction:**75**%	
	Serious injury crashes reduction: **75**%	
	Slight injury crashes reduction: **10**%	
	PDO only crashes reduction: **10**%	
	Implementation cost: 216.5 €/vehicle	
	Affected nr. of crashes per year: Fatalities: 709 Ser. Inj. 12453	

[4] Average reduction of crashes derived from the study (Grover et al. 2008).

[5] Average cost of the AEB system derived from the study (NHTSA 2012): (203+230)/2 = 216.5 euros

	Slight inj.: 506805 PDO: 4275899.8 Side effects costs (congestion benefit): 61,615,327.10€	
Low measure cost	Horizon: 8 years Number of units implemented: 220,000,000 Fatal injury crashes reduction:50% Serious injury crashes reduction:50% Slight injury crashes reduction: 5% PDO only crashes reduction: 5% Implementation cost: **108.25 €/vehicle** Affected nr. of crashes per year: Fatalities: 709 Ser. Inj. 12453 Slight inj.: 506805 PDO: 4275899.8 Side effects costs (congestion benefit): 41,076884.70€	1.3
High measure cost	Horizon: 8 years Number of units implemented: 220,000,000 Fatal injury crashes reduction:50% Serious injury crashes reduction: 50% Slight injury crashes reduction: 5% PDO only crashes reduction: 5% Implementation cost:**430 €/vehicle** Affected nr. of crashes per year: Fatalities: 709 Ser. Inj. 12453 Slight inj.: 506805 PDO: 4275899.8 Side effects costs (congestion benefit): 41,076884.70€	0.3

We defined a 'worst case' scenario as a combination of a worst expected effect and a highest expected measure cost. Also an 'ideal case' scenario is defined which is a combination of a better expected effect and a lower expected measure cost. The results of the CBA for these scenarios are presented in Table 3.

Table 3 CBA for worst case and best case scenarios

Combined Scenario	**Input values**	**B/C ratio**
	Horizon: 8 years Number of units implemented: 220,000,000 Fatal injuries reduction: 25% Serious injury crashes reduction: 25% Slight injury crashes reduction: 0% PDO only crashes reduction: 0% Implementation cost: 230 €/vehicle Affected nr. of crashes per year: Fatalities: 709 Ser. Inj. 12453 Slight inj.: 506805 PDO[6]: 4275899.8 Side effects costs (congestion benefit): 20,538,442.40€	0.2
Best case	Horizon: 8 years Number of units implemented: 220,000,000	1.1

	Fatal injuries reduction:75%	
	Serious reduction: 75%	
	Slight injury crashes reduction :10%	
	PDO only crashes reduction: 10%	
	Implementation cost: 203 €/vehicle	
	Affected nr. of injuries per year: Fatalities: 709 Ser. Inj. 12453 Slight inj.: 506805 PDO[7]: 4275899.8	
	Side effects costs(congestion benefit) : 61,615,327.10€	

REFERENCES

Grover et al. 2008. "Automated Emergency Brake Systems: Technical Requirements, Costs and Benefits."

NHTSA. 2012. "Cost & Weight Analysis of Forward Collision Warning System (FCWS) and Related Braking Systems for Light Vehicles." Vol. NHTSA Tech.

CBA Autonomous Emergency Braking (AEB) for pedestrians

Jacques Saadé, CEESAR, September 2017

ABSTRACT

The SafetyCube Economic Efficiency Evalutaion (E[3]) calculator was used to estimate the benefit-cost ratio (BCR) of the Autonomous Emergency Braking for pedestrians (AEB pedestrian). Benefit data and target population were taken from Edwards et al. (2014) while AEB cost was taken from a report by NHTSA (2012). BCR analysis suggest that the pricing might be too high, depending on country, but also that break-even costs are in the range used for sensitivity analysis..

INPUT INFORMATION

Case studied: Edwards et al. (2014) studied the potential benefit of AEB pedestrian in reducing fatal, serious, and slight injuries among all pedestrian casualties in the UK and Germany and then estimated the benefit for the European Union 27 member states except Bulgaria and Lithuania. Since it was impossible to assess with certainty why UK and German data were so different, we performed two CBA, one for each country.**Table 1** and **Table 2** sum up the effectiveness values we took from Edwards et al. to calculate the benefit-cost ratio and to undertake the sensitivity analysis.

Table 10 Reduction of pedestrian casualty estimates that were used in the cost-benefit analysis (Germany).

	Mean (%)	Minimum (%)	Maximum (%)
Fatal injuries	6.7	2.75	10.3
Serious injuries	9.7	3.8	15.6
Slight injuries	8.6	2.9	13.7

Table 2 Reduction of pedestrian casualty estimates that were used in the cost-benefit analysis (UK).

	Mean (%)	Minimum (IC 5%)	Maximum (IC 95%)
Fatal injuries	14.1	6.3	20.8
Serious injuries	8.8	4.0	13.6
Slight injuries	9.36	4.0	19.4

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

Measure Costs: The costs of the AEB system reported in a study made for NHTSA (2012) were used in the present analysis. It was supposed that the detection system includes a camera and a radar. The estimated prices vary between 269 and 304 US dollars (2011 prices) depending on the supplier. The prices include sensors, image processors and ECUs, structural components, visual displays, and wiring and electrical architecture. The costs were converted to euros by taking into account the 2015 exchange rate (0.92) and then converted to EU-28 values by multiplying with the corresponding PPP conversion value (0.76). Inflation was accounted for by applying the inflation conversion value from 2011 to 2015 (1.08). For 2015, this results in a price range from 203 to 230 €

that would be used for the sensitivity analysis. The mean value of 216.5 € will be used to estimate the benefit-cost ratio.

Time horizon: Based on the literature reviewed, the applied time horizon for the measure is 1 year.

Area/Unit of implementation: The number of new passenger cars registered in Europe per year is 12.5 million (Edwards et al. 2014).

Number of cases affected: In Edwards et al. (2014), the percentage of reduction in casualties were expressed as a percentage of the number of pedestrian casualties (fatal, serious, and slight injuries). The number of cases affected would be the number of pedestrian casualties in Europe. Edwards et al. (2014) took the average values from 2008 to 2010 which means 6,770 killed, 39,663 seriously injured, and 116,873 slightly injured pedestrians. This figure is very optimistic because not all the pedestrian casualties occur when passenger cars hit pedestrians.

Penetration rate: The system is considered to be applied on all new units (100% of 12.5 million).

Side effects: No side effect could be found or evaluated. We considered that side effects are negligible.

RESULTS

Germany

	Best estimate scenario	Worst scenario	Best scenario
Efficiency on fatal injury (%)	6.7	2.75	10.3
Efficiency on serious injury (%)	9.7	3.8	15.6
Efficiency on slight injury (%)	8.6	2.9	13.7
Cost per unit (€) SafetyCube WP4 values	216.5	433	108.25
Benefit-cost ratio	0.77	0.059	3.9

UK

	Best estimate scenario	Worst scenario	Best scenario
Efficiency on fatal injury (%)	14.1	6.3	20.8
Efficiency on serious injury (%)	8.8	4.0	13.6
Efficiency on slight injury (%)	9.36	4.0	19.4
Cost per unit (€) SafetyCube WP4 values	216.5	433	108.25
Benefit-cost ratio	1.5	0.15	7.3

REFERENCES

Edwards, M., Nathanson, A. & Wisch, M., 2014. Estimate of Potential Benefit for Europe of Fitting Autonomous Emergency Braking (AEB) Systems for Pedestrian Protection to Passenger Cars. *Traffic Injury Prevention*, 15, pp.S173–S182. Available at: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84907248659&doi=10.1080%2F15389588.2014.931579&partnerID=40&md5=8fdf43dcbfede78ae823625bd1bc5387.

NHTSA, 2012. *Cost & Weight Analysis of Forward Collision Warning System (FCWS) and Related Braking Systems for Light Vehicles*, Ricardo Inc.

CBA Child restraints

Christos Katrakazas, LOUGH November 2017

ABSTRACT

Latest effectiveness data available (Hoye, A., 2013) regarding the effects of child restraints were used. The SafetyCube Economic Efficiency Evaluation (E3) Calculator was used. The resulting best estimate of the benefit-cost ratio (BCR) is 3.4 which means that the costs tend to exceed the benefits. The sensitivity analysis proved this measure to be very robust with a BCR exceeding 1 even in the worse scenario.

INPUT INFORMATION

Cases studied: Hoye, A (2013) reports a reduction of 81% (95% CI [-92%; -57%] of fatalities, 69% (95% CI [-73%; -64%] of KSI and 33% (95% CI [-32%; -16%] of slight injuries, as an effect of the use of child restraints.

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

Measure Costs: The reported costs were obtained from the Handbook of Road Safety (Elvik, Hoye, Vaa, & Sorensen, 2009), where it is reported that the unit cost of a child restrain is about 2,000 NOK. This cost applies to Norway in 2005 and was updated to 2015 values by applying the inflation conversion value of 1.38. Subsequently the values are converted to EU averages (in EUR) by multiplying with the PPP conversion value of 0.08.

Time horizon: 4 years was assumed to be the time horizon for child restraints in order to take into account the expected duration of usage for child restraints.

Area/Unit of implementation: All costs were expressed according to the assumption that 90% of all children who belong to families owning a car are correctly restricted. The total number of such children in Norway is 860,000. Hence, 774000 units were taken into account.

Number of cases affected: The number of prevented casualties was retrieved from the available study. No side effects were taken into account.

RESULTS

Table 1 provides the input values used for benefit-to-cost ratio and sensitivity analyses

Table 11 Reduction in casualties estimates that were used in the cost-benefit analysis.

	Mean (%)	Minimum (%)	Maximum (%)
Fatal injuries	81	57	92
Serious injuries	64.5	63	65.8
Slight injuries	25	16	32

SENSITIVITY ANALYSIS

The available meta-analysis does provide confidence intervals regarding the number of prevented casualties. Therefore, a sensitivity analysis was conducted.

	Best estimate scenario	Worst scenario	Best scenario
Efficiency on fatal injury (%)	81	57	92
Efficiency on serious injury (%)	64.5	63	65.8
Efficiency on slight injury (%)	25	16	32
Cost per unit (€) SafetyCube WP4 values	214	428	107
Benefit-cost ratio	3.4	1.3	7.5

REFERENCES

Hoye, A. (2013), *Trafikksikkerhetshåndboken*, "*4.13 Sikring av barn i bil", Tabell 4.13.2.* https://tsh.toi.no/doc685.htm

Elvik, R., Hoye, A., Vaa, T., & Sorensen, M. (2009). *The handbook of road safety measures 2nd Edition*. Emerald Group Publishing Limited.

CBA Emergency Braking Assistance system (EBA)

Vuthy PHAN, CEESAR, October 2017

ABSTRACT

DG TREN (2006) conducted a Cost-Benefit-Analysis of Emergency Brake Assistance system (EBA). We performed our own CBA using the SafetyCube Economic Efficiency Evaluation (E3) and the information available in DG TREN (2006). The resulting best estimate of the benefit-cost ratio (BCR) is 3 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.

INPUT INFORMATION

Case studied: DG TREN (2006) reported reductions of 8% of fatalities, seriously and slightly injured persons in EU-25.

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

Measure Costs: DG TREN (2006) did not find any cost of EBA and tested a range of values from 200 € per vehicle to 1000 €. The break-even cost is 460 € per vehicle in 2005 (EU-25 price).
Considering inflation, this cost, from 2005, has to be up-dated to the 2015 price-level. This inflation rate is taken from SafetyCube estimates (see SafetyCube Deliverable 3.2).

*EBA total cost in 2015 = 460 * 1.15 = 529 €*

1.15 is the EU-28 inflation rate considered to update EBA cost from 2005 to 2015.

There is no correction for price-level (to level price from one country to EU-28) as the cost given by DG TREN (2006) is already a EU-25 cost.

Time horizon: The applied time horizon for the measure is 20 years.

Area/Unit of implementation: All costs and effects are expressed per vehicle equipped with EBA. The car stock considered in EU-25 is 213.1 million cars (2003 reference).

Number of cases affected: The affected number of casualties was retrieved from DG TREN (2006) The study contains separate estimates of the effect on the total number of slightly or seriously or fatally injured road user. The number of affected PDO crashes is derived from SafetyCube calculator that predicts PDO target population according to injury target population. We made the hypothesis that EBA effectiveness for PDO crashes would be equivalent to EBA effectiveness for slight injured road users.

Penetration rate: DG TREN (2006) considered two EBA market penetration scenarios. In the first one, the penetration increases from 5% to 20% and in the second one, the penetration increases from 5% to 100%

Side effects: No side effect has been considered by DG TREN (2006).

RESULTS

Table 1 provides the input values and the result estimated benefit-to-cost ratio for EBA. It shows a B/C ratio of 3. This means that the benefits tend to largely exceed the costs.

Table 1 Input values and B/C ratio for the scenario using DG TREN parameters

Scenario	Input values	B/C ratio
Best estimate	Horizon: 20 years Number of units implemented: 213,100,000 cars (European fleet) Fatal injuries reduction: 8% Serious injuries reduction: 8% Slight injuries reduction: 8% PDO reduction: 8% Implementation cost: 529 €/vehicle Annual cost: no recurrent cost Affected nr. of injuries per year: Fatalities: 24,843 Serious injuries: 240,021.5 Slight injuries: 2,365,225.5 PDO: 19,955,342 Side effects : no side effect	3

SENSITIVITY ANALYSIS

We used upper and lower values for each parameter according to the information availability in the literature. When it was possible, we changed one parameter value (the other parameter values were the ones presented in table 1). In the table below, a green arrow upwards (↑) indicates that a value lower/higher than the estimate makes is more likely that the measure is evaluated as being economically efficient. A red arrow downwards (↓), indicates that a lower/higher value makes it less likely that the measure is evaluated as being economically efficient.

Table 2: Sensitivity analyses

	DG TREN (2006) values	Lower value			Higher value		
		Value	Source	B/C	Value	Source	B/C
Costs							
Implementation costs per unit	529	102.573	VSS (2013)	15.6 ↑	1150	DG TREN (2006)	1.4 ↓
Annually recurrent costs per unit							
Total costs (initial + annual costs for all years) per unit							
Affected number of cases per year (target group)							
Fatal	24843						
Serious	240021.5						
Slightly injured	2365225.5						
PDO	19955342						
Injuries (slight/serious)							
Casualties (slight/serious/fatal)							
Effectiveness (percentage reduction in target group)							
Fatalities / fatal crashes	8.0%	4.0%	DG TREN (2006)	2.7 ↓	16%	DG TREN (2006)	3.6 ↑
Serious injuries / serious injury crashes	8.0%	4.0%	DG TREN (2006)	2.6 ↓	16	DG TREN (2006)	3.8 ↑
Slight injuries / slight injury crashes	8.0%	4.0%	DG TREN (2006)	2.7 ↓	16	DG TREN (2006)	3.7 ↑
PDO	8.0%	4.0%	DG TREN (2006)	2.6 ↓	16.0%	DG TREN (2006)	3.9 ↑
Injuries (slight/serious)							
Casualties (slight/serious/fatal)							
Penetration rate							
Pentration rate before implementation		5%	DG TREN (2006)	2.9 ↓	5%	DG TREN (2006)	3 ~
Penetration rate after implementation		20%	DG TREN (2006)		100%	DG TREN (2006)	
Side effects							
Description of side effects							
Annual cost side effects							
Total cost of side effects							

The cost sensitivity of the measure was also analyzed using the SafetyCube methodology. We assessed the effects of a price variation of +100% (worst case) and -50% (best case).

Scenario	Input values	B/C ratio
Best case Reduction of price 50%	Horizon: 20 years Number of units implemented: 213,100,000 cars (European fleet) Fatal injuries reduction: 8% Serious injuries reduction: 8% Slight injuries reduction: 8% PDO reduction: 8% Implementation cost: 264.9 €/vehicle Annual cost: no recurrent cost Affected nr. of injuries per year: Fatalities: 24,843 Serious injuries: 240,021.5 Slight injuries: 2,365,225.5 PDO: 19,955,342 Side effects : no side effect	6
Scenario	**Input values**	**B/C ratio**
Worst case Increasing the price 100%	Horizon: 20 years Number of units implemented: 213,100,000 cars (European fleet) Fatal injuries reduction: 8% Serious injuries reduction: 8% Slight injuries reduction: 8% PDO reduction: 8% Implementation cost: 1058 €/vehicle Annual cost: no recurrent cost Affected nr. of injuries per year: Fatalities: 24,843 Serious injuries: 240,021.5 Slight injuries: 2,365,225.5 PDO: 19,955,342 Side effects : no side effect	1.5

We defined a 'worst case' scenario as a combination of a much worse than expected effect and a higher than expected measure cost. The results of the CBA for these scenarios are reflected in Table 3.

Table 3 CBA for worst case and best case scenarios

Combined Scenario	Input values	B/C ratio
Worst case	Horizon: 20 years Number of units implemented: 213,100,000 cars (European fleet) Fatal injuries reduction: 4% Serious injuries reduction: 4% Slight injuries reduction: 4% PDO reduction: 4% Implementation cost: 1150 €/vehicle Annual cost: no recurrent cost Affected nr. of injuries per year: Fatalities: 24,843 Serious injuries: 240,021.5 Slight injuries: 2,365,225.5 PDO: 19,955,342 Side effects : no side effect	0.7
Best case	Horizon: 20 years Number of units implemented: 213,100,000 cars (European fleet)	31.2

	Fatal injuries reduction: 16% Serious injuries reduction: 16% Slight injuries reduction: 16% PDO reduction: 16% Implementation cost: 103 €/vehicle Annual cost: no recurrent cost Affected nr. of injuries per year: Fatalities: 24,843 Serious injuries: 240,021.5 Slight injuries: 2,365,225.5 PDO: 19,955,342 Side effects : no side effect	

REFERENCES

DG TREN (2006) - COWI, Cost–benefit assessment and prioritisation of vehicle safety technologies. Final Report, Economic assistance activities, Framework Contract TREN/A1/56-2004, Consultancy within Engineering, Environmental Science and Economics (COWI A/S), Kongens, Lyngby, 2006
https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/projects_sources/vehicle_safety_technologies_final_report.pdf

VSS (2013) - Regulation Impact Statement for Brake Assist Systems - Vehicle Safety Standards Branch, Department of Infrastructure and Regional Development, Canberra, Australia – Report DoIT VSS 02/2012

CBA Electronic Stability Control (ESC)

Vuthy PHAN, CEESAR, September 2017

ABSTRACT

Baum et al. (2007) conducted a Cost-Benefit-Analysis (CBA) of Electronic Stability Control. We performed our own CBA using the SafetyCube Economic Efficiency Evaluation (E3) and the information available in Baum et al. (2007). The resulting best estimate of the benefit-cost ratio (BCR) is 13.9 which means that the benefits tend to exceed the costs. The BCR is sensitive to changes in the underlying assumptions as is shown by the sensitivity analysis but the ratios still remain over 1 (that means that ESC benefits are higher than ESC costs).

INPUT INFORMATION

Case studied: Baum et al. (2007) reported a reduction 25.5% of fatalities and injured persons in EU-25 single vehicle crashes.

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

Measure Costs: Baum et al. (2007) stated that the cost of equipping a car with ESC is 130 € (it is a mean cost in EU-25). This cost was verified by experts from eIMPACt project in 2006. Baum et al. (2007) added too that there is normally no recurrent cost per ESC.
Considering inflation, this cost, from 2006, has to be up-dated to the 2015 price-level. This inflation rate is taken from SafetyCube estimates (see SafetyCube Deliverable 3.2).

*ESC total cost in 2015 = 130 * 1.13 = 146.9 €*

1.13 is the EU-28 inflation rate considered to update ESC cost from 2006 to 2015.

There is no correction for price-level (to level price from one country to EU-28) as the cost given by Baum et al. (2007) is already a EU-25 cost.

Time horizon: The applied time horizon for the measure is 12 years.

Area/Unit of implementation: All costs and effects are expressed per vehicle equipped with ESC. The car stock considered in EU-25 is 212 million cars, in 2002 (Baum et al. (2007)).

Number of cases affected: The affected number of casualties was retrieved from Baum et al. (2007). The study contains an estimate of the effect on the total number of injured people and a separate estimate on the effect on the number of fatalities. The number of affected PDO crashes is derived from SafetyCube calculator that predicts PDO target population according to injury target population. We made the hypothesis that ESC effectiveness for PDO crashes would be equivalent to ESC effectiveness for slight or serious injured road users.

Penetration rate: no information available

Side effects: Baum et al. (2007) considered that there are savings in accident costs, property damage and congestion in injury accidents; that is to say in total 11,000€ per injury accident.

*Side effects cost in 2015 = 11,000 * 1.13 = 12,430€*

1.13 is the EU-28 inflation rate considered to update side effects cost from 2006 to 2015.

There is no correction for price-level (to level price from one country to EU-28) as the cost given by Baum et al. (2007) is already a EU-25 cost.

RESULTS

Table 1 provides the input values and the result estimated benefit-to-cost ratio for ESC. It shows a B/C ratio from 5.7 (including side-effects) to 5.8 (excluding side-effects). This means that the benefits tend to largely exceed the costs.

Table 1 Input values and B/C ratio for the scenario using Baum et al. parameters

Scenario	**Input values**	**B/C ratio**
Best estimate	Horizon: 12 years Number of units implemented: 212,000,000 cars (European fleet) Fatal injuries reduction: 25.5% Serious or slight injuries reduction: 25.5% PDO reduction: 25.5% Implementation cost: 146.9 €/vehicle Annual cost: no recurrent cost Affected nr. of injuries per year: Fatalities: 15,642 Serious or slight injuries: 372,815 PDO: 2,746,274 Side effects - savings in accident costs, property damage and congestion in injury accidents: 951,330,050€	Excluding side-effects: 5.8 Including side-effects: 5.7

SENSITIVITY ANALYSIS

We used upper and lower values for each parameter according to the information availability in the literature. When it was possible, we changed one parameter value (the other parameter values were the ones presented in table 1). In the table below, a green arrow upwards (↑) indicates that a value lower/higher than the estimate makes is more likely that the measure is evaluated as being economically efficient. A red arrow downwards (↓), indicates that a lower/higher value makes it less likely that the measure is evaluated as being economically efficient.

Table 2: Sensitivity analyses

	Baum et al. (2007) values	Lower value				Higher value			
		Value	Source	B/C w/ side-effects	B/C w/o side-effects	Value	Source	B/C w/ side-effects	B/C w/o side-effects
Costs									
Implementation costs per unit	146.9					328.93	Elvik R., Vaa T., Hoye A, Sorensen M.; (2009), Pthe handbook of road safety measures. Second edition.	2.6 ↓	2.6 ↓
Annually recurrent costs per unit									
Total costs (initial + annual costs for all years) per unit									
Affected number of cases per year (target group)									
Fatal	15642								
Serious									
Slightly injured									
PDO	2746274								
Injuries (slight/serious)	372815								
Casualties (slight/serious/fatal)									
Effectiveness (percentage reduction in target group)									
Fatalities / fatal crashes	25.5%	16.6%	eIMPACT Socio-economic Impact Assessment of Stand-alone and Co-operative Intelligent Vehicle Safety Systems (IVSS) in Europe. Report type Deliverable D4	4.7 ↓	4.8 ↓	70%	Høye, Alena. 2011. "The Effects of Electronic Stability Control (ESC) on crashes—An Update."	10.7 ↑	11.1 ↑
Serious injuries / serious injury crashes									
Slight injuries / slight injury crashes									
PDO	25.5%					41.1%	Chouinard, Aline, and Jean-François Lécuyer. 2011. "A Study of the Effectiveness of Electronic Stability Control in Canada." Accident Analysis & Prevention 43 (1): 451–60.	6.2 ↑	6.4 ↑
Injuries (slight/serious)	25.5%	6.6%	eIMPACT Socio-economic Impact Assessment of Stand-alone and Co-operative Intelligent Vehicle Safety Systems (IVSS) in Europe. Report type Deliverable D4	4.3 ↓	4.4 ↓	54.8%	Chouinard, Aline, and Jean-François Lécuyer. 2011. "A Study of the Effectiveness of Electronic Stability Control in Canada." Accident Analysis & Prevention 43 (1): 451–60.	7.9 ↑	8.1 ↑
Casualties (slight/serious/fatal)									
Side effects									
Description of side effects									
Annual cost side effects									
Total cost of side effects	*951330050*	1.5E+08	eIMPACT Socio-economic Impact Assessment of Stand-alone and Co-operative Intelligent Vehicle Safety Systems (IVSS) in Europe. Report type Deliverable D4	5.8 ↑	5.8 ~				

The cost sensitivity of the measure was also analyzed using the SafetyCube methodology. We assessed the effects of a price variation of +100% (worst case) and -50% (best case).

Scenario	**Input values**	**B/C ratio**
Best case Reduction of price 50%	Horizon: 12 years Number of units implemented: 212,000,000 cars (European fleet) Fatal injuries reduction: 25.5% Serious or slight injuries reduction: 25.5% PDO reduction: 25.5% Implementation cost: 73.45 €/vehicle Annual cost: no recurrent cost Affected nr. of injuries per year: Fatalities: 15,642 Serious or slight injuries: 372,815 PDO: 2,746,274 Side effects - savings in accident costs, property damage and congestion in injury accidents: 951,330,050€	11.2
Scenario	**Input values**	**B/C ratio**
Worst case Increasing the price 100%	Horizon: 12 years Number of units implemented: 212,000,000 cars (European fleet) Fatal injuries reduction: 25.5% Serious or slight injuries reduction: 25.5% PDO reduction: 25.5%	2.9

	Implementation cost: 293.8 €/vehicle Annual cost: no recurrent cost Affected nr. of injuries per year: Fatalities: 15,642 Serious or slight injuries: 372,815 PDO: 2,746,274 Side effects - savings in accident costs, property damage and congestion in injury accidents: 951,330,050€	

We defined a 'worst case' scenario as a combination of a much worse than expected effect and a higher than expected measure cost. The CBA results of these scenarios are reflected in Table 3.

Table 3 CBA for worst case and best case scenarios

Combined Scenario	Input values	B/C ratio
Worst case	Horizon: 12 years Number of units implemented: 212,000,000 cars (European fleet) Fatal injuries reduction: 16.6% Serious or slight injuries reduction: 6.6% PDO reduction: 25.5% Implementation cost: 328.93 €/vehicle Annual cost: no recurrent cost Affected nr. of injuries per year: Fatalities: 15,642 Serious or slight injuries: 372,815 PDO: 2,746,274 Side effects - savings in accident costs, property damage and congestion in injury accidents: 145,000,000€	Excluding side-effects: 1.5 Including side-effects: 1.5
Best case	Horizon: 12 years Number of units implemented: 212,000,000 cars (European fleet) Fatal injuries reduction: 70% Serious or slight injuries reduction: 54.8% PDO reduction: 41.1% Implementation cost: 146.9 €/vehicle Annual cost: no recurrent cost Affected nr. of injuries per year: Fatalities: 15,642 Serious or slight injuries: 372,815 PDO: 2,746,274 Side effects - savings in accident costs, property damage and congestion in injury accidents: 951,330,050€	Excluding side-effects: 13.9 Including side-effects: 13.4

REFERENCES

Chouinard, A., Lécuyer, J. (2011). "A Study of the Effectiveness of Electronic Stability Control in Canada." Accident Analysis & Prevention 43 (1): 451–60

Baum, H., Grawenhoff, S., Greiβler, T. (2007). Cost-Benefit-Analysis of the Electronic Stability Program (ESP). Zeitschrift für Verkehrswissenschaft; Heft 2007/3.

eIMPACT Socio-economic Impact Assessment of Stand-alone and Co-operative Intelligent Vehicle Safety Systems (IVSS) in Europe. Report type Deliverable D4

Elvik R., Vaa T., Hoye A, Sorensen M. (2009); The handbook of road safety measures. Second edition.

Høye, A. (2011). "The Effects of Electronic Stability Control (ESC) on crashes—An Update."

CBA PTW Helmet

Cecil Mettel, DEKRA Automobil GmbH, December 2017

ABSTRACT

A benefit-analysis regarding the effects of motorcycle helmets in the USA (NHTSA, 2015) and a meta-analysis of the worldwide cost-benefit of motorcycle helmets (UNECE, 2016) was revisited. For the NHTSA paper the SafetyCube Economic Efficiency Evaluation (E3) calculator was used. The resulting best estimate of the benefit-cost ratio (BCR) is between 1.2 and 4.3 depending on the country, which means that the benefits tend to exceed the costs.

INPUT INFORMATION

Case studied: UNECE (2016) reported that helmets are effective in reducing serious (head) injuries in motorcyclists who crash by 69% and death by 42%.

Crash costs: The United Nations Motorcycle Helmet study applies the iRAP (International Road Assessment Programme) economic appraisal model parameters.

The NHTSA study (2015) uses another table, which estimates the economic cost with 1,381,645 $ per fatality.

Measure Costs: UNECE (2016) stated that the cost for a motorcycle helmet (conformal with UN regulation 22) can vary between 50 and 600+ $ in many European countries. In China, the Philippines, Thailand, Vietnam, and Venezuela, motorcycle helmets are considered luxury goods that are primarily sold to foreigners and a small group of wealthy local consumers. Helmets manufactured in China but sold in the United States are sold at 8 $; yet, because of ineffective helmet-wearing enforcement, cultural and other factors, even bicycle helmets are not readily available in China at this relatively low price.
Considering that helmets sold as low as 50 $ fulfil UN ECE R 22 and high-end helmets are designed primarily to provide additional comfort, the estimated measure cost is 50 $ per helmet.

Motorcycle helmet cost in 2017 = 46€

Time horizon: UNECE (2016) study analyses the data over a period of 12 years.

The NHTSA (2015) study analyses the data from one year (2013).

Area/Unit of implementation: All costs and effects are expressed per vehicle. The motorcycle stock considered in USA is 8.4 million motorcycles, in 2013 (NHTSA 2013 (2015)).

Number of cases affected: The affected number of casualties was retrieved from NHTSA (2015) and UNECE (2016). The NHTSA study contains an estimate of the current effect on the total number of fatalities and a separate estimate with a 100 % helmet wearing rate. The UNECE study uses different publications to make an estimation for the current situation and a future situation in 2020.

Penetration rate: Varies considerably depending on the respective country. It depends on mandatory laws and general culture.

Side effects: There might be a disadvantage if low-cost helmets are used, which don't fit safety standards. They could give a feeling of false safety.

RESULTS

Table 1 provides the result estimated benefit-to-cost ratio for motorcycle helmets given in the UNECE paper. It shows a B/C ratio from 1.2 to 4.3, depending on country. This means that the benefits tend to exceed the costs.

Table 1 B/C ratio for the scenario using UNECE parameters

Scenario	Input values	B/C ratio
Worst Case	Horizon: 12 years Number of units implemented: unknown (worldwide fleet) Fatal injuries reduction: 42% Serious or slight injuries reduction: 69% Implementation cost: varies Annual cost: no recurrent cost Affected nr. of injuries per year: Fatalities: 122,000 to 250,000 Serious injuries: 1,600,000 to 5,000,000 Side effects – no known side effects	Low income countries: 1 Middle income countries: 4 High income countries: 1.2
Best Case	Horizon: 12 years Number of units implemented: unknown (worldwide fleet) Fatal injuries reduction: 42% Serious or slight injuries reduction: 69% Implementation cost: varies Annual cost: no recurrent cost Affected nr. of injuries per year: Fatalities: 250,000 Serious injuries: 5,000,000 Side effects – no known side effects	Low income countries: 2.2 Middle income countries: 4,3 High income countries: 1.2

In the worst case scenario it's estimated, that the benefit will just break-even with the costs in low income countries, because there might be a disadvantage if low-cost helmets are used, which don't fit safety standards. They could give a feeling of false safety.
The B/C ratio for high income countries is relative low, because it is estimated with a maximum purchases of highest-end, most expensive, helmets.

Table 2 provides the input value and the result estimated break-even cost for motorcycle helmets in the USA. It shows that even if only the benefit of fatality reduction is considered the break-even cost is 384 $. Compared to the price for helmets in the EU-25, the benefit is significantly exceeding the cost.

Table 2 Break-even cost using NHTSA parameters

Scenario	**Input values**	**Break-even**
Worst Case	Horizon: 1 year Number of units implemented: 8404687 (USA fleet) Fatal injuries reduction: 50% Implementation cost: 50 $/vehicle Annual cost: no recurrent cost Affected nr. of injuries per year: Fatalities: 4,668 Side effects – no known side effects	Break-even cost: 384 Dollar

REFERENCES

NHTSA, 2015 – National Highway Traffic Safety Administration.2015. "Estimating lives and costs saved by motorcycle helmets with updated economic cost information". U.S. Department of Transportation NHTSA. URL: https://www.nrd-nhtsa.dot.gov/Pubs/812206.pdf

UNECE, 2016 – UNECE. 2016. "The United Nations Motorcycle helmet study". United Nations economic commission for Europe. URL: https://www.unece.org/fileadmin/DAM/trans/publications/WP29/United_Nations_Motorcycle_Helmet_Study.pdf

NHTSA, 2013 – National Highway Traffic Safety Administration. 2015. "Traffic Safety Facts. 2013 Data". U.S. Department of Transportation NHTSA

CBA Seatbelt and Seatbelt Reminders

Robert Thomson, SAFER, January 2018

ABSTRACT

Seatbelts are a proven road safety countermeasure. The fitment of seatbelts in passenger cars and heavy vehicles like trucks and buses are mandatory in countries participating in the United Nations – Economic Commission of Europe Vehicle Regulation (UN-ECE) activities. Seatbelt Reminders, devices that detect the presence of a passenger in a designated seating position and issues an audible and visual warning if the belt is not fastened, have previously been optional equipment and have been encouraged in consumer testing programs. Rulemaking activities will soon require that seatbelt reminders are mandatory for all passenger car seats and at least the driver and front seat passenger of commercial vehicles. Cost benefit analyses to assess future implementations of these systems are not necessary as there are essentially all vehicles have seatbelts and vehicles without seatbelt reminders will be phased out of the fleet. This legislation has been implemented as both systems have positive benefits on road safety. Estimates of benefit/cost ratios of seat belt reminders using assumed wearing rates, seatbelt effectiveness, and costs for 1005-2003 produced a result of 1.6 for the European Union. A similar study in Australia in indicated a cost benefit ratio ranging from 0.8-1.40 depending on the type of system and number of passengers addressed.

There are no SafetyCube E3 tool calculations for these 2 cases as future CBAs would not be applicable for legislated measures. Summaries of the previous CBAs are provided below.

Seatbelt reminders are a parallel measure to seatbelt enforcement and the reader is referred to the Seatbelt Enforcement CBA.

CASE INFORMATION

Case studied 1: The ETSC report from 2003 (ETSC 2003) provided an estimate of the number of lives saved in Europe using audible seatbelt reminders. The study assumed a unit cost of 60€ to fit the vehicles. The study assumed that 483 lives per/year could be saved using seatbelt usage rates and effectiveness estimates from other studies. The estimate includes a benefit to society beyond the fatalities avoided using estimates for injury severity reductions for non-fatality crashes. The study assumed 20 Million new vehicles were sold per year and used a 5% discount factor. The estimates were based on 1990-2000 data for costs, road trauma estimates, and safety technologies

Case studied 2: Researchers in Australia performed a CBA for seatbelt reminders using 3 different implementation strategies. Each system was more aggressive in warning when passengers were unbelted. The CBA used the Harm reduction model developed by Monash University which quantifies road trauma costs using the type and number of injuries. Similar to the ETSC study (ETSC 2003), the study used other empirical data to estimate new seatbelt usage rates and seatbelt effectiveness in crashes. The effectiveness of the systems ranged from 10%-40%. The cost to implement the systems ranged from $10 (Aus) for the simplest system for the driver only to $165 (AUS) for the complex system equipped for all passengers. The costs and benefits were based on Australian data from 2002.

RESULTS

Table 1 summarizes the two studies reviewed

Table 1

Scenario		B/C ratio
Europe (2003)	Best estimate – Society Benefit	1.4
Australia (2003)	Worst case: Best Case	0.8 1.4

Table 3 CBA for worst case and ideal case scenarios

Combined Scenario	Input values	B/C ratio
Worst case	Fatalities reduction by using seat belt: 53% Serious injury reduction by using seat belt: 53% Impl. cost: Annual cost: 133,102,800 NOK	0.5
Ideal case	Fatalities reduction by using seat belt: 66% Serious injury reduction by using seat belt: 66% Impl. cost: Annual cost: 133,102,800 NOK	3.5

REFERENCES

European Transport Safety Council (ETSC), 2003, COST EFFECTIVE EU TRANSPORT SAFETY MEASURES, ISBN: 90-76024-16-2, http://archive.etsc.eu/documents/costeff.pdf

Filde, B., Fitzharris, M., Koppel,S., Vulcan, P., Brooks, C., 2003, Benefits of Seat Belt Reminder Systems, Annu Proc Assoc Adv Automot Med. 2003; 47: 253–266.

CBA PTW Airbag

Oscar Martin, Cidaut Foundation, December 2017

ABSTRACT

Anderson et al. (2011), conducted a study to estimate the potential benefits of some of the safety technologies emerging for passenger vehicles, trucks and motorcycles. Within this study they performed a Cost – Benefit – Analysis (CBA) of the PTW in vehicle Airbag. The resulting best estimate of the benefit-cost ratio (BCR) is 0.03 which means that the costs outweigh the benefits. The study reviewed also gives break-even analysis estimation, being the unit cost of 61 Euro.

INPUT INFORMATION

Case studied: (Anderson et al. 2011) reported reductions of fatalities and serious injuries from frontal collisions between motorcycles and passenger vehicles. Ten percent of fatal motorcycle crashes and about 2% of motorcycle injury crashes fall into this category of crash. The study assumed that about ten percent of these crashes might be avoided with an airbag.

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

Measure Costs: The costs of the PTW Airbag estimated in Anderson et al. (2011) study were used in the present paper. The estimated price was 6000 Australian dollars (2011 prices). These costs were converted in euros by multiplying 2015 exchange rate (0.69), after were updated to 2015 by applying the inflation conversion value (1.08) and then the values were converted to EU averages by multiplying with the PPP conversion value (0.76)[8].

$$6000 * 0.69 * 1.08 * 0.49 = 2196.92 \text{ euro}$$

Time horizon: The applied time horizon for the measure is 11 years.

Area/Unit of implementation: All costs and effects are expressed per vehicle equipped with PTW in-vehicle Airbag. The vehicle stock considered in EU-28 is about 33 million of PTW (mopeds + motorcycles). However, there was not enough information to replicate the study with European data, so the results are based on historical crash data and vehicle fleet from New South Wales (Australia).

Number of cases affected: The affected number of casualties was retrieved from (Anderson et al. 2011). The study contains an estimate number of the effect of the system for fatal crashes and injury accidents.

Side effects: There are no side effects described in (Anderson et al. 2011). However, side effects are named in the literature reviewed, especially from the second impact (rider on ground).

[8] This inflation rate is taken from SafetyCube estimates (see SafetyCube Deliverable 3.2)

RESULTS

Table 1 provides the input values and the result estimated benefit-to-cost ratio for PTW in vehicle Airbag system reported in the Anderson et al., study. It shows a B/C ratio of 0.03. This means that the costs outweigh the benefits.

Table 1 Input values and B/C ratio for the 'best estimate' scenario

Scenario	Input values	B/C ratio
Best estimate	Injury reduction (fatal, serious, slight): 1% Motorcycle accidents NSW Prevented casualties: • Fatal: 7 x 11 years= 77 • injured: 49 x 11 years=539 Implementation cost: *2196.92* EUR /PTW Airbag	0.03

SENSITIVITY ANALYSIS

The available meta-analysis does not provide confidence intervals regarding the number of prevented casualties. Therefore, a sensitivity analysis could not be conducted.

REFERENCES

Anderson et al. 2011. "Analysis of crash data to estimate the benefits of emerging vehicle technology.", Report: CASR 094, Center for Automotive Safety Research, University of Adelaide, http://casr.adelaide.edu.au/publications/researchreports

CBA PTW braking systems (ABS, TCS)

Oscar Martin, CEESAR, December 2017

ABSTRACT

To perform the Cost-Benefit Analysis (CBA) of the Powered Two Wheelers (PTW) it has been used 4 studies. Alena Høye (2016) conducted a meta-analysis of the effectiveness of PTW Advanced Braking Systems (ABS) and Combined Braking systems (CBS). Also three CBA studies were use.The SafetyCube Economic Efficiency Evaluation (E3) Calculator was used to perform our own CBA. The resulting best estimate of the benefit-cost ratio (BCR) is 7.8 which means that the benefits outweigh the costs. The BCR is sensitive to changes in the underlying assumptions as it is shown by the sensitivity analysis.

The values of CBA found in the literature reviewed vary between 4.0 and 27 for PTW ABS.

For Traction Control Systems (TCS) only one study was found and this study gives an estimate BCR of 1.7.

INPUT INFORMATION

Case studied: The meta-analysis from Alena Høye reported reductions of motorcycles accidents between 24% and 35%, and a best estimate of 29%. Other studies (Rizzi et al., Teoh) gave a greater around 40% of all accidents. This reduction is higher for more severe accidents. The estimation is a reduction of a 32% for kill or seriously injured accidents.

Anderson et al., estimated an effectiveness of 25% for the TCS, and that it will affect to 20% of all motorcycle crashes.

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

Measure Costs: The costs of the PTW ABS system reported in the different studies vary between 185 and 525 euro. The costs from the Australian study were converted in euros by multiplying 2015 exchange rate (0.69), after were updated to 2015 by applying the inflation conversion value (1.08) and then the values were converted to EU averages by multiplying with the PPP conversion value (0.46)[9].

For TCS price there was only one estimation of 365 euro.

Time horizon: The applied time horizon for the measure varies between the studies from 11 years to 13.2 years.

Area/Unit of implementation: All costs and effects are expressed per vehicle equipped with PTW ABS or TCS system. The vehicle stock considered in EU-25 is about 33 million vehicles.

Number of cases affected: The affected number of casualties was retrieved from the literature reviewed. The studies contain an estimate number of the effect of the system separately for each severity class: serious injury, slight injury and fatal injury. The number of PDO crashes is derived from the SafetyCube calculator. It assumed that the PTW ABS effectiveness for PDO crashes is equivalent to PTW ABS effectiveness for slight injury accidents.

[9] This inflation rate is taken from SafetyCube estimates (see SafetyCube Deliverable 3.2)

No side effects were described.

RESULTS

Table 1 provides the input values and the result estimated benefit-to-cost ratio for AEB system. It shows a B/C ratio of 7.8. This means that the costs outweigh the benefits.

Table 1 Input values and B/C ratio for the 'best estimate' scenario

Scenario	Input values	B/C ratio
Best estimate	Horizon: 13 years	7.8
	Number of units implemented: 33,000,000	
	Fatal injury crashes reduction: 32[10]%	
	Serious injury crashes reduction: 29%	
	Slight injury crashes reduction: 18%	
	PDO only crashes reduction:18%	
	Implementation cost: 400[11] €/vehicle	
	Annual cost: no recurrent cost	
	Affected nr. of crashes per year: Fatalities: 1351 Ser. Inj. 15313 Slight inj.: 15088	

For PTW TCS there was only one study which gave a best estimate of BCR 1.7

SENSITIVITY ANALYSIS

We used the upper and lower values for each parameter according to the information available from the two studies to run a sensitivity analysis. The values represent a lower than expected and a higher than expected effect respectively. Then the effect is calculated with lower and higher measure costs. Table 2 presents the results.

Table 2 Sensitivity analyses

Scenario	Input values	B/C ratio
Low measure effect	Horizon: 13 years	6.3
	Number of units implemented: 33,000,000	
	Fatal injury crashes reduction: **25**%	
	Serious injury crashes reduction: **24**%	
	Slight injury crashes reduction: **14**%	
	PDO only crashes reduction: **14**%	
	Implementation cost: 400 €/vehicle	
	Affected nr. of crashes per year: Fatalities: 1351 Ser. Inj. 15313 Slight inj.: 15088	
High measure effect	Horizon: 13 years	9.5
	Number of units implemented: 33,000,000	
	Fatal injury crashes reduction: 39%	
	Serious injury crashes reduction: **35**%	
	Slight injury crashes reduction: **22**%	
	PDO only crashes reduction: 22%	
	Implementation cost: 400 €/vehicle	
	Affected nr. of crashes per year: Fatalities: 1351	

[10] Average reduction of crashes derived from the study (Grover et al. 2008).
[11] Average cost of the AEB system derived from the study (NHTSA 2012): (203+230)/2 = 216.5 euros

	Ser. Inj. 15313 Slight inj.: 15088	
Low measure cost	Horizon: 13 years	15.7
	Number of units implemented: 33,000,000	
	Fatal injury crashes reduction: 32%	
	Serious injury crashes reduction: **29%**	
	Slight injury crashes reduction: **18%**	
	PDO only crashes reduction: **18%**	
	Implementation cost: 200 €/vehicle	
	Affected nr. of crashes per year: Fatalities: 1351 Ser. Inj. 15313 Slight inj.: 15088	
High measure cost	Horizon: 13 years	3.9
	Number of units implemented: 33,000,000	
	Fatal injury crashes reduction: 32%	
	Serious injury crashes reduction: **29%**	
	Slight injury crashes reduction: **18%**	
	PDO only crashes reduction: **18%**	
	Implementation cost: 800€/vehicle	
	Affected nr. of crashes per year: Fatalities: 1351 Ser. Inj. 15313 Slight inj.: 15088	

We defined a 'worst case' scenario as a combination of a worst expected effect and a highest expected measure cost. Also an 'ideal case' scenario is defined which is a combination of a better expected effect and a lower expected measure cost. The results of the CBA for these scenarios are presented in Table 3.

Table 3 CBA for worst case and best case scenarios

Combined Scenario	**Input values**	**B/C ratio**
	Horizon: 13 years	4.8
	Number of units implemented: 33,000,000	
	Fatal injury crashes reduction: 25%	
	Serious injury crashes reduction: **24%**	
	Slight injury crashes reduction: **14%**	
	PDO only crashes reduction: **14%**	
	Implementation cost: 525€/vehicle	
	Affected nr. of crashes per year: Fatalities: 1351 Ser. Inj. 15313 Slight inj.: 15088	
Best case	Horizon: 13 years	20.5
	Number of units implemented: 33,000,000	
	Fatal injury crashes reduction: 39%	
	Serious injury crashes reduction: **35%**	
	Slight injury crashes reduction: **22%**	
	PDO only crashes reduction: **22%**	
	Implementation cost: 185€/vehicle	

	Affected nr. of crashes per year: Fatalities: 1351 Ser. Inj. 15313 Slight inj.: 15088	

REFERENCES

Motorcyclists Safety, Alena Høye, Norway 2016, TØI Report 1517/2016

Anderson et al. 2011. "Analysis of crash data to estimate the benefits of emerging vehicle technology.", Report CASR-094, Centre for Automotive Safety Researh, University of Adelaide, Australia

Approval and market surveillance of two- or three-wheeled vehicles and quadricycles, DIRECTORATE GENERAL FOR INTERNAL POLICIES, POLICY DEPARTMENT A: ECONOMIC AND SCIENTIFIC POLICY, European Parliament, 2012

Cost -Benefit Analysis for ABS of motorcycles, Baum et al., 2008, **BASt-Bericht F 68**