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Final Project Report

Deliverable 1.4

SafetyCube

Final Project Report

Work package 1, Deliverable 1.4

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Executive summary

Safety CaUsation, Benefits and Efficiency (SafetyCube) was a European Commission supported Horizon 2020 project running from May 2015 to April 2018. Its main objective was to develop an innovative road safety Decision Support System (DSS) that enables 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. The core of the project was a comprehensive analysis of road safety risks (problems) and measures (solutions), including cost-benefit of measures. The method focused on road users, infrastructure, vehicles and injuries framed within a systems approach. Involvement of road safety stakeholders at the national level, EU level and beyond has be sought at all stages.

The European Road Safety DSS (www.roadsafety-dss.eu) is the first integrated road safety support system developed in Europe. The DSS goes above and beyond existing decision support systems by:

- Providing scientific evidence for both road safety risks and measures
- Taking a holistic approach considering road users, infrastructure, vehicles, and post impact care.
- Presenting a very large number of estimates for risk and measure effects
- Demonstrating the links between risk factors and respective measures.
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- Applying a common ranking system; colour codes are applied to all risks and measures so it is possible to compare the relative risk and effectiveness of risks and measures.
- Providing cost benefit analysis examples for selected measures.
- Providing guidelines for the estimation of MAIS3+ injuries to obtain estimates that are better comparable between countries

The SafetyCube DSS aims to be a reference system for road safety in Europe that is improved and enhanced over time. Its objective is to provide the European and Global road safety community a user friendly, web-based, interactive Decision Support Tool

- To properly substantiate their road safety decisions
- For the actions, measures, programmes, policies and strategies
- To be implemented at local, regional, national, European and international level.

The DSS is intended to be used by a whole range of users including public authorities, industry, researchers and Non-Government Organisations (NGOs).

The main contents of the SafetyCube DSS concern:

- Road accident risk factors and problems
- Road safety measures
- Best estimate of effectiveness
- Economic Efficiency Evaluations (E3 Calculator)
- Serious injuries
- All related analytic background

Taxonomies were created to describe the risk factors and measures relevant to the road user, infrastructure, vehicle and, for measures only, post impact care. These taxonomies provide the framework for the content of the DSS. A two-tier accident scenario taxonomy with eight broad types of crashes and more specific subcategories was also devised.

In total, 1301 individual studies and 211 synopses were included in the DSS as well as 36 Economic Efficiency Evaluation (E3) example analyses. In addition, six accident scenario 'fact-sheets' were created based on in-depth accident data from the French VOIESUR database. Links between risks and measures were made in the DSS at the lowest level of the SafetyCube taxonomy. The relationship between risks and measures is a "one-to-many" relationship, as each risk factor can be addressed by different measures, and each measure may mitigate different risk factors. A holistic approach was taken, meaning that measures from one area e.g. infrastructure could be linked with a risk factor from another e.g. road user. Links were also made in the DSS between the accident scenarios and risk factors and measures.
In reflection of the increasing use of serious injuries as a road safety indicator, SafetyCube also had a particular focus on serious injuries (MAIS3+). The work in this area involved:

- Providing guidelines for estimating the number of serious road casualties
- Examining the impacts and costs of serious road injures
- Investigating the risk factors associated with serious road injuries

The SafetyCube Decision Support System can be freely accessed here: www.roadsafety-dss.eu . A 'Quick guide' has been created to guide users though the DSS. It is strongly recommended that this is read before using the DSS. The Quick guide can be found on the homepage of the DSS and via this web address:
www.roadsafety-dss.eu/assets/data/pdf/A.Quick.Guide.to.the.SafetyCube.DSS.pdf.

All content on the DSS can be accessed via the menu at the top of the screen (Search, Knowledge, Calculator, Methodology, Support). 'Search' provides access to all synopses and individual studies as well as links between risk factors and measures, structured through the SafetyCube taxonomy. 'Knowledge' gives direct access to all synopses, serious injury information and accident scenario fact sheets and 'Calculator' is where the E3 calculator and SafetyCube E3 examples can be found. The 'Methodology' menu option provides information about the SafetyCube project and a link to the project website where project reports can be found. It also provides information about the SafetyCube methodology used to generate content for the DSS, the scope and limitations of content as well as a Glossary that defines key terms that are used within the DSS. Finally, there is information on the quality assurance processes implemented to ensure the content of the DSS met the highest possible scientific standard and was consistent across the different work areas. Finally, the 'Support' menu option provides contact details, another link to the Quick Guide and links to alternative decision support systems.

The DSS is not intended to be a static tool. The intention is that further funding will be sought to develop, expand and update the DSS. The DSS was developed for a very broad range of users and aimed to cover as many topic areas as possible. However inevitably due to this wide-ranging approach and the time constraints of a project with a finite timeline, not all topics could be covered and not all relevant studies could be included. In addition, not all feedback from stakeholders could be incorporated during the SafetyCube project but these could be developed in future versions of the DSS.

Although the SafetyCube project has ended, the individuals involved will continue to promote its work and the DSS. To assist with this a short promotion video was created: www.youtube.com/watch?v=Y-mVUde3knU.The SafetyCube consortium believes that the DSS will be a key tool, assisting in evidenced based policy making both now and in the future.

1 SafetyCube and the Decision Support System

Introducing the SafetyCube DSS

This chapter provides an introduction to the SafetyCube project and the DSS

1.1 SAFETYCUBE PROJECT

Safety CaUsation, Benefits and Efficiency (SafetyCube) was a European Commission supported Horizon 2020 project running from May 2015 to April 2018. Its main objective was to develop an innovative road safety Decision Support System (DSS) that enables 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.

The overall aims of SafetyCube were to:

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

The core of the project was a comprehensive analysis of accident risks and their 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.

The project was divided into eight work areas:

1. Project Management
2. Dissemination and stakeholder engagement
3. Methodology
4. Road User
5. Infrastructure
6. Vehicle
7. Serious Injuries
8. Decision Support System

However, SafetyCube was an integrated project so these work areas were not isolated areas of work. Instead common methodologies were developed and applied in the road user, infrastructure, vehicle and serious injury areas with the common aim of developing the Decision Support System.

Throughout the project efforts were made to engage and consult with stakeholders and potential users of the DSS to guide the content and the development of the system.

1.2 PURPOSE AND CONTENT OF REPORT

This report should be viewed as a summary of the main results of the SafetyCube project. It provides a broad overview without going into specific detail of each project work area. Many reports (deliverables) have been produced during the course of the project and these will be referenced, as appropriate, in the text. In addition a full list of reports and a brief description of their contents can be found in Appendix A.

The report is divided into six chapters. This chapter provides background information relating to the SafetyCube project and the DSS including the development of a set of taxonomies and how evidence based policy making and the system approach has informed the work. Chapter two, 'Analysis of Risks and Measures' focuses on the methodology relating to the work on risk factors and measures and specifically the generation of three key content items of the DSS: synopses, individual study pages and the Economic Efficiency Evaluation (E3) Calculator.

Chapter three, 'Contents of the DSS', states the number of studies, synopses and E3 calculator examples included in the DSS as well as giving some methodological background about the linking or risk factors and measures and the work on accident scenarios. Chapter four, 'Serious Injuries' gives a brief overview about the work on serious (MAIS3+) injuries within the project. Chapter five, Using the DSS', is a practical guide about how to navigate the DSS and find specific content and finally chapter 6, 'Conclusions and the Future' provides brief concluding remarks as well as suggestions about how the DSS could be enhanced and expanded in the future.

1.3 EUROPEAN ROAD SAFETY DECISION SUPPORT SYSTEM (DSS)

The European Road Safety Decision Support System (DSS) is the primary output of the SafetyCube project. It is the first integrated road safety support system developed in Europe. The DSS goes above and beyond existing decision suport systems by:

- Providing scientific evidence for both road safety risks and measures
- Taking a holistic approach considering road users, infrastructure, vehicles, and post impact care.
- Presenting a very large number of estimates for risk and measure effects
- Demonstrating the links between risk factors and respective measures.
- Applying a common ranking system; colour codes are applied to all risks and measures so it is possible to compare the relative risk and effectiveness of risks and measures.
- Providing cost benefit analysis examples for selected measures.
- Providing guidelines for the estimation of MAIS3+ injuries to obtain estimates that are better comparable between countries

The SafetyCube DSS aims to be a reference system for road safety in Europe that is improved and enhanced over time. Its objective is to provide the European and Global road safety community a user friendly, web-based, interactive Decision Support Tool

- To properly substantiate their road safety decisions
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The DSS is intended to be used by a whole range of users including public authorities, industry, researcher and Non-Government Organisations (NGOs).

The main contents of the SafetyCube DSS concern:

- Road accident risk factors and problems
- Road safety measures
- Nest estimate of effectiveness
- Economic Efficiency Evaluations (E3)
- Serious injuries
- All related analytic background

1.4 DEFINING RISKS AND MEASURES

The DSS distinguishes between road safety risks and road safety measures. A risk factor refers to any factor that contributes to either the occurrence of a road accident or the severity (in terms of injury) of an accident. Similarly, a road safety measure refers to any measure that prevents the occurrence of an accident or reduces the chance of fatal or non-fatal injury.

The main areas of focus of the DSS are the road user, infrastructure and vehicle elements of the road traffic system with the addition of post-impact care measures. The first step was to define the lists of risks and measures that were relevant for each of these areas. A group of experts in each element identified these from existing literature and their subject specific knowledge and organised them in three level structures referred to as taxonomies. Although these levels differed depending on the represented element, all had a general topic as the first level followed by subtopics (second level) and then the subtopics were further split into specific risks/measures (level three). Table 1 is an example of part of the road user risk factor taxonomy with its three levels.

Table 1: An extract of the road user risk factor taxonomy

Level 1: main topic	Level 2: subtopic	Level 3: specific topic
Speed choice	Excess speed	Built-up areas
		Rural roads
		Motorways
	Inappropriate speed	Too fast weather-related
		Too fast traffic related
		Too slow
Fatigue	Insufficient (good) sleep	Not enough sleep
		Sleeping disorders
	Long drives	--

This resulted in seven taxonomies, risks and measures for road user, infrastructure and vehicle and measures only for post-impact care. For full versions of the taxonomies please see Annex B.

1.5 EVIDENCE-BASED POLICY MAKING AND THE SAFE SYSTEM APPROACH

The DSS is designed to support evidence-based road safety policy making. Evidence-based policy making refers to the use of objective, scientifically-based evidence in all stages of the policy making process. Policy making is a complex process and particularly in road safety, where resources are often very limited, a number of road safety problems as well as other transport issues will be competing for the same resource. Evidence-based policy making enables policy makers to make justified decisions in this complex reality.

In the case of evidence-based policy making, the identification and prioritisation of risk factors and the selection of countermeasures are based on results from scientific research. This means that the factors that contribute to road risks must be quantified to assess their relative contribution to the occurrence or consequences of road accidents. This also means that the selection of countermeasures is based on the sound evaluation of its safety effects, and from an economic point of view, also on the expected costs. One resource which could assist policy makers in making objective choices about resource allocation is a decision support system (Fancello et al., 2013) and the DSS provides information to the user on all these aspects.

The SafetyCube project and the DSS also aim to follow the principles of the safe system approach. The systems approach considers safety incidents as failures of the social-technical system, resulting from unexpected, uncontrolled relationships between a system's constituent parts (Levenson, 2004). According to Reason (2000), systems theory "concentrates on the conditions under which individuals work and tries to build defences to avert errors or mitigate their effects." The ethos of this approach is that understanding accidents and defining the appropriate measures require the study of the system as a whole, rather than considering its parts in isolation (Rasmussen, 1997).

The road system can be considered to be a socio-technical system, with road users, vehicles and road as the components that interact with each other in order to "produce" transport of people and cargo (Larsson et al., 2010). According to Hughes et al. (2015) systems theory and practices should be thoroughly applied to develop measures that improve the road system as a whole, rather than in isolation. More specifically, this would mean that a 'failure' of one component (e.g. road users) could be compensated by improving another component (e.g. infrastructure) and that a combination of measures has a larger impact than either one separately (e.g. regulation and enforcement). This approach suggests that evaluating the majority of crashes as being due to human error is too simplistic and road safety policies would be more successful if they consider other elements of the system such as infrastructure and vehicles as well as improving road user behaviour. In addition, the Safe System approach, an application of the systems approach to road safety, starts with the ethical imperative that no human being should be killed or seriously injured in a road crash and aims to strengthen all dimensions of road safety, including the organisational levels, and manage them holistically and not as separate parts in "silos" (OECD/ITF, 2016).

As the DSS is grounded in the Safe System approach, risk factors have been identified and evaluated from across the system. Additionally, a large range of measures were considered and all applicable measures have been linked to relevant risk factors (see section 3.2). In practice this means that while a risk factor may originate in one area of the system (e.g. road user behaviour) the range of measures which are applicable to address this may come from all areas of the system (e.g. road user behaviour, infrastructure or vehicle focused). In addition to take account of a key element of a Safe System, the drive to irradiate serious injury as well as fatalities, SafetyCube has had a particular focus on serious injuries (see chapter 4). The DSS includes specific information about injury prevention and, indicates the added value of measures for reducing serious injury.

Please see Filtness et al. (2016) for a more detailed description of evidence-based policy making and the systems approach within the SafetyCube project and the DSS.

1.6 FURTHER READING

SafetyCube reports are available from the SafetyCube project website: https://www.safetycube-project.eu/

Overall background on taxonomy development and the Safe System approach in SafetyCube:

Filtness A., Thomas P., Talbot R., Quigley C., Papadimitriou E., Yannis G., Theofilatos A., Aigner-Breuss E., Kaiser S., Machata K., Weijermars W., Van Schagen I., Hermitte T (2016), The application of systems approach for road safety policy making, Deliverable 8.1 of the H2020 project SafetyCube.

2 Analysing Risks and Measures

Overview of methodology

This chapter describes the methodology behind creating a repository of studies, synopses and the E3 Calculator.

To fulfil its goal of providing an evidence-based policy making tool, a number of methodologies were adopted and created to provide the framework for populating the DSS with high quality scientifically sound data and information. The DSS contains a wide range of information including the findings of individual research studies, summaries of the evidence for risk or effectiveness of measures in specific topic areas, fact sheets relating to specific crash scenarios, a tool for calculating the economic efficiency of measures and links between risks and measures. Certain key methodologies were developed and then used within the road user, infrastructure, vehicle and serious injuries (post-impact care) work areas. These common methodologies ensured that each topic appearing in the DSS was treated in the same way even though a large number of different researchers were involved.

This chapter gives an overview of the methodologies relating to:

- Creating a repository of studies
- Summarising evidence in specific topic area (synopses)
- Economic Efficiency Evaluation tool (E3 Calculator)

Other contents of the DSS, including the crash scenario fact sheets and linking between risks and measures, are described in Chapter 3.

Detailed guidelines about how to select individual studies and analyse and summarise them for each topic can be found in Martensen and Lassarre (2017). The same document contains guidelines for using the E3 Calculator with further information and examples in Martensen et al (2018).

2.1 REPOSITORY OF STUDIES

2.1.1 Literature search

For each of the risk factors and measures in the taxonomies a standardised systematic literature search was conducted to identify potentially relevant papers. The specific literature databases and sources searched depended on the specific area of interest, but generally included Scopus and TRID. Searches were based on well-defined logical strings of keywords and usually a set of terms for the topic was combined with road safety terms (see Table 2 for an example).

Table 2 Example of the search terms for the topic of fatigue

Fatigue	"fatigue*" OR "Sleep*" OR "Tired*" OR "drowsy" OR "drowsiness" OR "alert*" OR "monotony" OR "time on task"
AND	
Road Safety	"road safety" OR "driv*" OR "road" OR "transport" OR "crash" OR "accident" OR "incident" OR "traffic" OR "collision" OR "traffic safety" OR "risk" OR "measure OR "Road Casualties" OR "Road Fatalities"

The appropriate taxonomy level to use for the initial search depended on the topic but generally the second level was the most commonly used with third level terms also being included as keywords in some cases. Unless a topic resulted in very few hits, the following criteria were also used:

- Year published > 1990
- Language = English (sometimes also the native language of the researcher)
- Type of publication = Journal (although respected peer reviewed conference papers were also considered)

If the search resulted in very large numbers of hits further refinement was required such as reducing the number of years examined or limiting the countries included in the results. If very few studies were available the criteria could be widened and other publications such as conference papers or trusted grey literature were considered.

2.1.2 Prioritisation

The resulting lists of potentially relevant studies were then screened to assess their eligibility for further analysis and inclusion in the DSS. The screening was first based on the title, abstract, and then on the full paper. The main criterion for inclusion in the DSS was that a study had to give a quantitative estimate of the size of the risk of the risk factor under consideration or of the effect of the measure under consideration. Preferably, the studies reported at the level of accidents, e.g. accident numbers or injury severity. Second best were studies that reported on safety performance indicators (SPIs). A SPI is an indirect measure of road safety, but a measure that is causally related to the number or severity of accidents. SPIs can be related to road user behaviour (e.g. speeding), to road infrastructure (e.g. the presence of cycle paths), or to vehicle safety (e.g. the presence of airbags).

While the aim was to include as many studies as possible, for some topics the literature search resulted in an unfeasibly high number of studies. In these cases, the **selection of studies for further analysis and eventual inclusion in the DSS was based on the following criteria**:

- **Relevance**: Information about accidents before incidents before observed information before self-reported information.
- **Transferability**: European studies before USA/Australian/Canadian studies before studies from other countries.
- **Publication date**: Recent studies before older studies, though older studies of particular relevance were included.
- **Quality**: Peer reviewed papers before non-peer reviewed papers.
- **Language**: Papers in English before other language papers.

For several risk factors and measures, meta-analyses were available. If that was the case, the most recent meta-analysis was selected and complimented with additional studies published after, and consequently not included in the meta-analysis.

2.1.3 Recording of study characteristics and results

A standardised Excel coding template was created to record the characteristics and results of each study to be included in the DSS. The template allowed the recording of all relevant information for each study in a standardised way for all topics. This both allowed information to be imported in the DSS in a standardised way and for key information to be captured that would allow a meta-analysis to be conducted if appropriate.

The coding template consisted of several sheets requiring the researcher to provide information, mostly in predefined categories, about

- Road safety domain (road user, infrastructure, vehicle, post impact care), risk factor or measure, and the level of the relevant taxonomy.
- The bibliographic features of the study (title, author, year, source, origin) and the study abstract
- Characteristics of the study population (e.g., road user group, age groups)
- Characteristics of the study design (e.g., experimental or observational)
- The type of effect estimator (e.g., Crash Modification Factor, Odds Ratio etc.)
- The numerical results of the study with their confidence intervals or other relevant statistical details (for different subgroups if appropriate)
- The scientific quality of the study (e.g., limitations, biases)

In addition, the researcher had to compile an overall brief summary of the study, including the main findings, as well as an overall assessment of their reliability and usefulness, given the study design and potential biases. Coded studies were cross checked by a second researcher in order to optimize quality.

Figure 2 is an example of a result sheet in the excel template, completed for a study on the effect of bicycle helmets.

☐ Differences between effects	Effect 1	Effect 2	Effect 3	Effect 4	Effect 5
Injury nature	Fracture; Internal; Open Wou	Fracture; Internal; Open Wou	Fracture; Internal; Open Wou	Fracture	Fracture
Injury severities	Moderate	AIS 3	AIS 4	AIS 3	AIS 3; AIS 4
Injury - Cases	Hospital; Head	Hospital; Head	Hospital; Head	Hospital; Head	Hospital; Head
Injury - Controls	Non-Head; Minor head	Non-Head; Minor head	Non-Head; Minor head	Non-Head; Minor head	Non-Head; Minor head
Measure of effect/association	Odds ratio	Odds ratio	Odds ratio	Odds ratio	Odds ratio
Specifications	Odds for wearing a helmet	Odds for wearing a helmet	Odds for wearing a helmet	Odds for wearing a helmet	Odds for wearing a helmet
Estimate	0.5060	0.3790	0.2570	0.4370	0.2170
Standard error of estimate					
Statistic [name(parameters)=x]					
p-value	<0.0001	<0.0001	<0.0001	0.1710	<0.0001
Sample size (x or n1=x1; n2=x2)	n (cyclist casualties)= 6745	n (cyclist casualties)= 6745	n (cyclist casualties)= 6745	n (cyclist casualties)= 6745	n (cyclist casualties)= 6745
Confidence level	0.9500	0.9500	0.9500	0.9500	0.9500
Lower limit	0.3880	0.2670	0.1480	0.1300	0.1320
Upper limit	0.6590	0.5360	0.4480	1.4660	0.3570
Adjustment variables/Covariates	Speed limit; Collision vehicle	Speed limit; Collision vehicle	Speed limit; Collision vehicle	Speed limit; Collision vehicle	Speed limit; Collision vehicle
Conclusion	Significant positive effect on	Significant positive effect on	Significant positive effect on	Non-significant effect on roa	Significant positive effect on

Figure 1 Example of a result sheet of a coded study

The coding template was designed with the aim to accommodate the wide variety and complexity of different study designs. Guidelines provided detailed instructions on how to use the template (Elvik et al., 2015; Martensen & Lassarre, 2017) and coders attended a workshop and/or webinars to practice.

2.2 SYNOPSIS CREATION

Once all the studies in a topic had been recorded in coding templates then the results in terms of road safety were summarised in a short report referred to as a synopsis. The first step was to decide which analysis method was most appropriate to generate an overall assessment of the significance of the risk factor or the effectiveness of the method. Three ways had been defined to analyse and summarise the results (Martensen and Lassarre, 2017), in the decreasing order of priority:

- **Meta-analysis**. A meta-analysis combines the numerical results of multiple studies and yields a weighted average of the risk factor/measure effect from the results of the individual studies. A meta-analysis was performed if there were a sufficiently large number of studies that were comparable in terms of both their research design features and the type of results they produced.
- **Vote-count analysis**. A vote-count analysis compares the share of studies that showed a positive effect, no effect, or a negative effect. This type of analysis was performed if there were a sufficient number of studies but a meta-analysis was not possible due to large differences between studies.
- **Review-type analysis**. In a review-type analysis the results are summarised in a more qualitative way, generally including a qualitative summary table of effects with the related interpretation. This analysis was performed if the number of studies was small or if the studies were so heterogeneous that a vote-count analysis was not meaningful.

In each type of analysis, the most relevant modifying conditions were identified (e.g., a measure that works in urban, but not in rural settings or a factor that is particularly risky for novice drivers). In meta-analysis or vote-count analyses this was addressed by analyses at the relevant sub group level.

The analysis results were then recorded in the synopsis. Each synopsis provided information on the main findings, information from the identified studies and the analysis of these. Additional studies that were more qualitative, e.g. reviews, and therefore could not be recorded in the coding template could also be referred to in the synopses to provide further background or evidence.

Synopses are divided into three sections:

- **Summary**: This section reports the background of the topic concerned, the main results and conclusions based on the analysis. This 2-page section gives a general overview of the topic, avoids technical terms where possible and can be read independently of the rest of the synopsis.
- **Scientific overview**: This section is for the reader who wants additional scientific detail. In 4-5 pages it provides a summary of the study designs and individual effects, usually in table form, as well as any meta-analysis, vote count or descriptive analysis results. Additional background detail and literature may be included here. The limitations and transferability of the results is also discussed to give the user all the necessary information to understand the results and assess their validity.
- **Supporting documentation**: As a minimum this section contains the documentation of the literature search including search terms and prioritisation. It also provides the references for all analysed and mentioned studies and in many cases the studies excluded during the final prioritisation phase are recorded here. If a meta-analysis has been conducted, full documentation would be included in this section. Other more detailed tables of study designs and reported effects may also be in this section.

For some topics, particularly in the vehicle area, few research studies where identified by the structure search, e.g. new in-vehicle technologies. In these cases, 'Abbreviated synopses' were produce which just include summary and supporting documentation sections. Although one or two studies may be reported these reports are predominantly based on qualitative information as well as the knowledge and the expertise of the author(s).

2.2.1 Colour code

In order to give the user of the DSS a quick overview of the evidence for a risk or the effectiveness of a measure, colour codes were developed and applied to each synopsis. Where appropriate a distinction was made between different road user groups. The colour codes used and their definitions can be found in Table 3. The assigned colour code and a short explanation can be found at the beginning of each synopsis and on the relevant DSS pages (see Chapter 5).

Table 3: Risk factors and measure colour codes and definitions

Risk factors		Countermeasures	
RED	Results consistently show an increased risk when exposed to the risk factor concerned.	GREEN	Results consistently show that the countermeasure reduces road safety risk.
YELLOW	There is some indication that exposure to the risk factor increases risk, but results are not consistent.	LIGHT GREEN	There is some indication that the countermeasure reduces road safety risk, but results are not consistent.
GREY	No conclusion possible because of few studies with inconsistent results, or few studies with weak indicators, or an equal amount of studies with no (or opposite) effect.	GREY	No conclusion possible because of few studies with inconsistent results, or few studies with weak indicators, or an equal amount of studies with no (or opposite) effect.
GREEN	Results consistently show that exposure to the presumed risk factor does not increase risk.	RED	Results consistently show that this measure does not reduce road safety risk or may even increase it.

2.3 ECONOMIC EFFICIENCY EVALUATION

[The text used in this section (2.3) was extracted from Yannis and Papadimitriou (2018)]

A separate tool was developed in SafetyCube to evaluate the economic efficiency of measures that were found to be effective: the Economic Efficiency Evaluation (E3) calculator (Martensen et al., 2016, Martensen & Lassarre, 2017). The E3 calculator combines the information about the effectiveness of a measure, i.e. the percentage of accidents or casualties that this measure can prevent, with the costs of the measure. With the calculator two types of analyses can be done, resulting in two types of output. First, there is the *cost-effectiveness analysis.* This analysis calculates the costs for preventing one accident or one casualty. Outcomes for different severities, e.g. costs for preventing a fatal accident versus costs for preventing a serious injury accident, have to be addressed separately. Second, there is the *cost benefit analysis*. This analysis results in a ratio between the monetary value of the benefits of a measure (because of prevented accidents or casualties, jointly for different severities) and the total monetary costs of the measure. This type of information is very helpful for prioritising measures, i.e., getting best value for money.

As the monetary value of prevented accidents or casualties differs across Europe and the DSS aims to allow for cost-benefit analyses at a national level, the E3-calculator database contains information about the costs of accidents and casualties of different severity from all European countries (see Wijnen et al., 2017 for more information).

For the measures, the E3 calculator first requires information about the effectiveness of a measure in terms of the number of (targeted) accidents and resulting casualties prevented for four levels of severity: fatal, serious, slight, and damage-only. The E3 calculator also requires information about the costs of a measure. Here a distinction is made between the initial development and implementation costs and annual maintenance costs. Hence, the time horizon of the measure is also important. Based on this information, the E3 calculator compares the value of all benefits and all costs for each year within the time horizon of the measure, resulting into the following outputs:

- Number of accidents / casualties prevented (per unit of implementation)
- Cost effectiveness: cost per prevented accident / casualty for different severities:
  - per prevented fatality / fatal accident
  - per prevented severe injury / severe accident
  - per prevented slight injury / light accident

- per prevented damage-only accident
- Total benefits
- Benefit-cost ratio (benefits/costs)
- Net effect (benefits – costs)

Figure 3 schematically shows the required input for as well as the output of the E3 calculator.

If no measure costs are entered, the break-even costs are calculated. This shows the costs of a measure assuming a benefit-cost ratio of 1. In other words, the break-even costs indicate how much a measure could maximally cost to still be cost-effective.

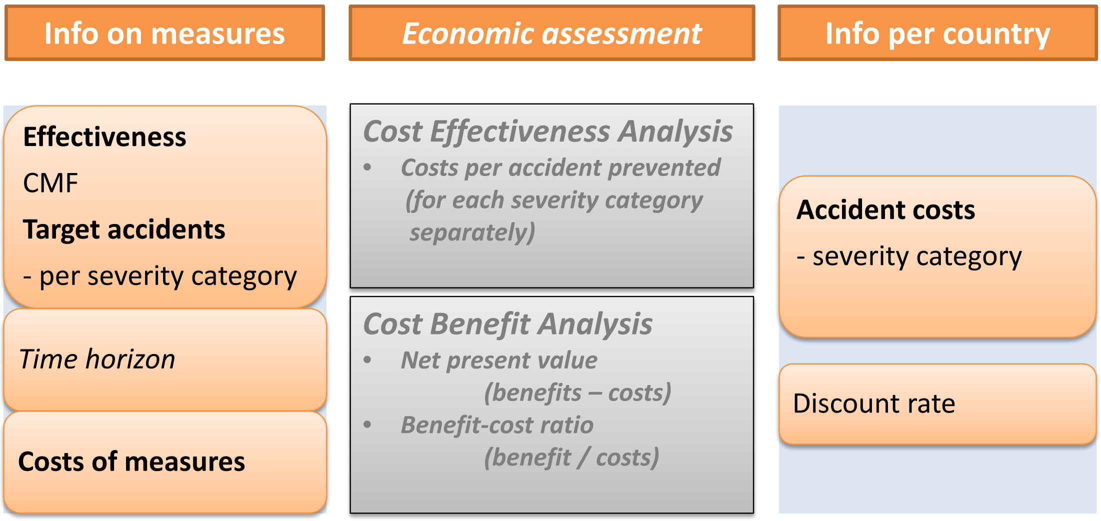


Figure 2: Economic Efficiency Evaluation (E3) calculator

Since both the information on the safety effects of a measure and its costs are uncertain, the E3 calculator provides the option to carry out a sensitivity analysis, giving a range of cost effectiveness and cost benefits under different cost and effectiveness scenarios.

By default, the E3 calculations will be conducted for the country from which effectiveness and cost results are obtained. From there it is possible to transfer the results to any other European country or to the European average. It is also possible to use the calculator for additional analyses, e.g. by change the used values, e.g., of the measure cost estimates.

For each measure in the DSS that was classified as effective and for which a quantitative estimate of the effectiveness was available, an economic efficiency evaluation was performed using an Excel version of the E3 Calculator. The results are summarised in a two-page CBA synopsis document, linked to the measure in the DSS and are also available as examples in the E3 tool of the DSS.

2.4 FURTHER READING

SafetyCube reports are available from the SafetyCube project website: https://www.safetycube-project.eu/

Guidelines for creating the contents of the DSS:

Martensen, H., and Lassarre, S., Eds. (2017), Methodological framework for the evaluation of road safety risk factors and countermeasures, Deliverable 3.3 of the H2020 project SafetyCube.

Overview of E3 Calculator and examples:

Martensen, H., Daniels, S; Van den Berghe W., Wijnen, W., Weijermars, W., Carnis, L., Saadé, J., Elvik, R. (2018), Guidelines for priority setting between measures with practical examples, Deliverable Number 3.5 of the H2020 project SafetyCube.

Detail on the generation of crash costs used in the E3 Calculator:

Wijnen, W., Weijermars, W., Van den Berghe, W., Schoeters, A., Bauer, R., Carnis, L., Elvik, R., Theofilatos, A., Filtness, A., Reed, S., Perez, C., and Martensen, H. (2017), Crash cost estimates for European countries, Deliverable 3.2 of the H2020 project SafetyCube.

Overview of applying the project methodology in the road user, infrastructure and vehicle areas:

Aigner-Breuss, E., Kaiser, S., Usami, D.S., Reed, S. & Weijermars, W. (2017). Inventory of road user related risk factors and safety measures, Deliverable 4.4 of the H2020 project SafetyCube.

Usami, D.S., Papadimitriou, E., Ziakopoulos, A., Quigley, C., Katrakazas, C., Durso C. (Eds.) (2017), Inventory of assessed infrastructure risk factors and measures, Deliverable 5.4 of the H2020 project SafetyCube.

Leopold**, F. (2018)** Inventory of assessed vehicle risk factors and measures**. Deliverable 6.4** of the H2020 project SafetyCube**. [In press, reference subject to change]**

3 Contents of the DSS

A practical guide

This chapter demonstrates how and where the user can find information in the DSS

3.1 SELECTION AND QUALITY OF CONTENT

The taxonomies described in section 1.4 provide the framework for the content of the DSS. Within the SafetyCube project risks were analysed first and then focus switched to measures. Measure taxonomies were created to be exhaustive however care was taken that measures were included that addressed risk factors assigned the colour code 'red' or 'yellow' (see Table 3). It was not possible to address every level three (and occasionally level two) risk/measure on the taxonomy during the SafetyCube project timeframe but priority was given to 'hot topics' for each work area. In total, 1301 individual studies and 211 synopses were included in the DSS. Reports have been written summarising this work (see appendix A) however for the most up-to-date version of the individual synopses please see the online version within the DSS (www.roadsafety-dss.eu). A full list of synopses, their colour code and link to the full document in PDF form can be found within the 'Knowledge' section of the DSS.

The E3 Calculator has been incorporated in the DSS (still under development at the time of writing) and around 35 example analyses are available (exact number yet to be determined). These examples were generated within the individual work areas (road user, infrastructure, vehicle, post-impact care). Measures that were assigned a green or light green colour code (see Table 3) were focused upon and data from existing cost-benefit analyses and synopses were used to provide input date for the E3 Calculator.

In addition, six 'fact sheets' were produced describing fatality and injury rates related to a particular accident scenario and links were created in the DSS between risks and measures and accident scenarios and risks/measures. This additional content and the associated methodologies will be described in the following sections.

3.2 LINKING RISK FACTORS AND ROAD SAFETY MEASURES

[The text in this section (3.2) is an abridged version of that used in Yannis and Papadimitriou (2018) – the full version, with methodological detail, has been reproduced in Appendix C]

In the SafetyCube DSS, all risks considered in the SafetyCube taxonomies are intended to be linked to measures that have the potential of reducing this risk, and vice versa. There is obvious added value in this feature, as it will assist DSS users in:
(a) knowing which risks can be remedied by which types of measures
(b) knowing which types of risks will be reduced by a particular measure.
These links are meant to reflect situations where a user of the system would be looking for effective measures. This means a measure (e.g. winter maintenance) could be linked to a risk-factor (e.g. snow) but in the end turn out not to be effective. The idea behind this is to give users access to an evaluation of the measure whenever they might consider the measure a solution to their problem.

3.2.1 The SafetyCube model for linking risks and measures

The proposed SafetyCube model for linking risk factors and measures is based on the conceptual framework of Elvik (2004) for the causal chain through which road safety measures influence road safety. More specifically, road safety measures may affect risk factors through two mechanisms: one related to 'generic' factors (i.e. which are beyond the user control) and one related to 'circumstantial' factors (i.e. crash-specific conditions), both eventually affecting road safety outcomes.

In the present approach, we extend this model by taking into account elements of the Safe System approach and the Haddon matrix, which in details means: (i) considering separately the system components i.e. road user, infrastructure and vehicle, (ii) considering the crash chain i.e. pre-crash, crash and post-crash separately and (iii) separately considering the road safety outcomes in terms of crash type and severity.

An overview of the proposed model to 'link' road safety measures to risk factors is presented in Figure 4.

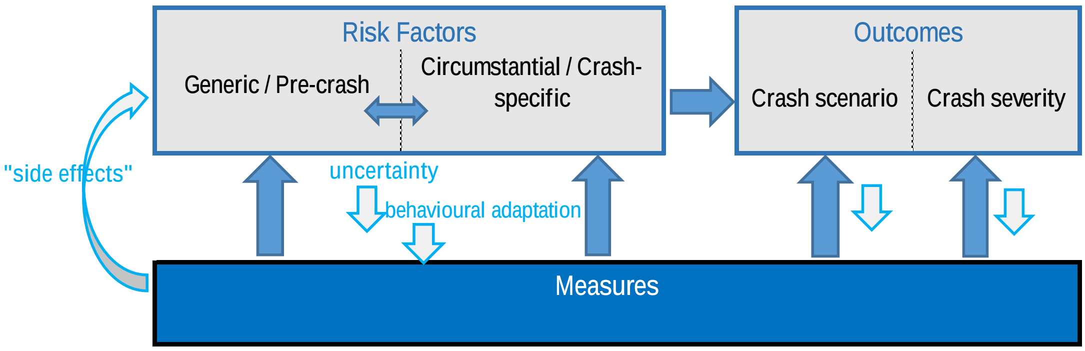


Figure 3: SafetyCube theoretical model for linking road safety risks and measures

3.2.2 Implementation of the links

The steps taken in order to implement the links in the DSS can be summarized as follows:

- The SafetyCube risk factors from the taxonomies were classified according to the above model as generic, circumstantial, or directly affecting the crash outcomes.
- Next, it was tested how the SafetyCube taxonomies conform to the proposed model of chains of risk factors and outcomes. In each case, the implementation started from the circumstantial risk factors and proceeded to linking:
  - related generic risk factors,
  - other related circumstantial risk factors and
  - related crash types.
- Figure 5 demonstrates indicative examples with infrastructure, vehicle and behaviour circumstantial risk factors placed in the centre.
- Accordingly, the SafetyCube measures from the taxonomies were classified as addressing different risks / outcomes in the accident chain.
- Finally, the above models and classifications were exploited to attempt the actual linking of risks and measures.

The links between risks and measures were finally implemented at the lowest level of the SafetyCube taxonomy. The relationship between risks and measures is a "one-to-many" relationship, as each risk factor can be addressed by different measures, and each measure may mitigate different risk factors.

All these elements are integrated in the DSS and considered when checking for measures that should be considered as remedies for a risk factor in question. Moreover, by linking risk factors to measures from different domains, an important aspect of the Safe System approach is emphasized for the user. As an example, when looking for measures linked to a road user related risk like "speeding", the user will be guided to measures that address road users (campaigns, demerit point systems) or infrastructure (speed humps, section control) or the vehicle (ISA, adaptive cruise control).

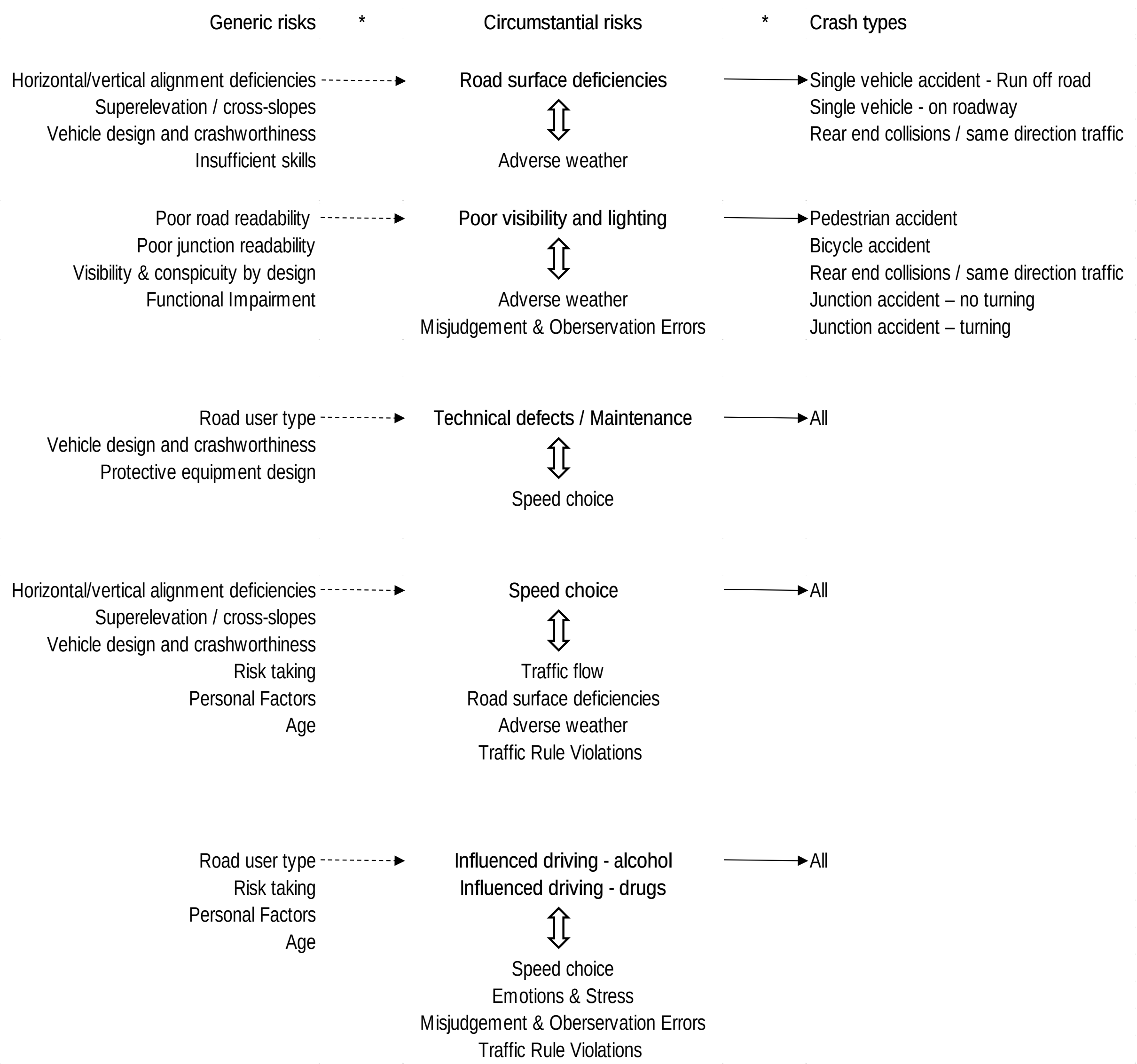


Figure 4: Examples of chains of risk factors and outcomes in SafetyCube taxonomies

3.3 ACCIDENT SCENARIOS IN THE DSS

One of the ways in which effective countermeasures are identified is through the study of road traffic crashes that have occurred. Often these crashes are grouped according to their characteristics. In addition, particularly when looking at vehicle technologies, the aim of a countermeasure can be to prevent a particular type of crash or manoeuvre from occurring rather than being directly aimed at countering the specific factor that cause the vehicle to leave a lane. For example, Lane Departure Warning systems assist in preventing a vehicle from leaving its lane irrespective of why that manoeuvre occurred – the driver could have been drunk, distracted or falling asleep. It was therefore identified that it would be important for users to be able to find information in the DSS from a starting point of accident characteristics or scenarios.

A group of SafetyCube researchers with experience in the investigation and/or analysis of road traffic crashes devised a two-tier accident scenario taxonomy with eight broad types of crashes and more specific subcategories. These accident scenarios and subcategories do not describe what caused the crash, instead they give an indication of the broad type of crash and an indication of the manoeuvres of the vehicles involved at the point of conflict. The eight categories are:

- Pedestrian Accident
- Bicyclist Accident
- Single Vehicle Accident
- Head-On Collision / On-Coming Traffic
- Rear-End Collision / Same Direction Traffic
- Junction Accident (No Turning)
- Junction Accident (Turning)
- Railway Crossing

The sub-categories for the pedestrian scenario are:

- pedestrian crossing road out of crossing path
- pedestrian crossing road on crossing path at straight stretch
- pedestrian crossing road in front of junction
- pedestrian crossing road behind junction
- pedestrian moving along the road
- vehicle reversing
- pedestrian sitting or lying on the ground
- pedestrian – changing mode (e.g. driver getting off the car)
- other pedestrian configuration

See Appendix B for full taxonomy and Filtness et al. (2016) for further information.

Relevant risks and measures were linked to the eight accident scenarios using the methodology described in section 3.2 above and this can be found in the DSS under the heading 'accident categories'.

In addition, six 'fact-sheets' were created and set out key data relating to:

- Pedestrian accident
- Cyclist accident
- Single vehicle accident
- Opposite direction accident
- Same direction accident
- Junction accident

The contents of these factsheets are predominantly based on analyses of the French VOIESUR database and concern injury accidents occurring in France during the year 2011. The Pedestrian and Cyclist accident fact sheets provide overall figures (e.g. WHO[1], CARE[2]) about the prevalence of such crashes as well as information on the types of injuries and share of the sub-scenarios within the VOIESUR database. The other fact sheets only include data from the VOIESUR database and give an indication of the share of accidents assigned to that accident scenario as well as the most common sub-scenarios for each vehicle type. These factsheets can be found in the 'Knowledge' section of the DSS.

3.4 QUALITY ASSURANCE PROCESS

One of the aims of SafetyCube was to populate the DSS with high quality scientific content. A series of quality assurance procedures were put in place during the project to maximise the quality and consistency of the DSS content. This included:

- Detailed guidelines, training of researchers and close cooperation between work areas
- A coordinated peer review process and English language check by a native speaker for each synopsis covering both the content and literature search
- A review of individual study pages and where necessary input data
- Expert review of all E3 examples
- An expert working group to define accident scenarios and all factsheets were reviewed by project partners
- Development of theoretical framework for linking risk factors and measures which was applied by the same researcher in all cases and evaluated by a small group of researchers

3.5 FURTHER READING

SafetyCube reports are available from the SafetyCube project website: https://www.safetycube-project.eu/

Linking risk factors to measures methodology:

Yannis G., Papadimitriou E. (Eds.) (2018), The European Road Safety Decision Support System - A clearinghouse of road safety risks and measures, Deliverable 8.3 of the H2020 project SafetyCube.

Development of Accident Scenarios:

Filtness A., Thomas P., Talbot R., Quigley C., Papadimitriou E., Yannis G., Theofilatos A., Aigner-Breuss E., Kaiser S., Machata K., Weijermars W., Van Schagen I., Hermitte T (2016), The application of systems approach for road safety policy making, Deliverable 8.1 of the H2020 project SafetyCube.

[1] World Health Organisation

[2] European Community Road Accident Database

4 Serious road injuries, analysis and strategy

Serious injuries in SafetyCube

This chapter describes the serious injuries (MAIS3+) work of SafetyCube

Road safety policy making is switching from focusing on reducing the number of fatally injured road users to also taking into account of serious injuries. One of the priorities in the European Commission's Road Safety Programme (EC, 2010) is reducing the number of serious traffic injuries and a target has been set by the EU Transport Ministers to halve the number of serious injuries on the EU roads between 2020 and 2030 (ETSC, 2017). 'Serious injuries' have therefore become an additional road safety indicator. The EU High Level Group on Road Safety has defined serious traffic injures as road casualties with an injury level of MAIS3+. MAIS stands for Maximum AIS which represents the most severe injury obtained by a casualty according to the Abbreviated Injury Scale (AIS®).

In reflection of this, SafetyCube had a particular focus on serious injuries (MAIS3+) with the aim of:

- Providing guidelines for estimating the number of serious road casualties
- Examining the impacts and costs of serious road injures
- Investigating the risk factors associated with serious road injuries

Summaries of the work on these three areas can be found in the 'Knowledge' section of the DSS and a brief extract of these will be given in the following sections.

Apart from the Post-Impact Care measures, the SafetyCube work on serious injuries is stand alone and is not directly connected with the risk and measures work appearing in the DSS. This is because less research has been conducted that examines serious injuries as an outcome – fatal injuries are the predominant focus and those that do include serious injuries do not necessarily use the MAIS3+ definition. The exception to this is the work conducted on risk factors associated with serious road injuries. Reed et al. (2017) provides an overview table in which the identified contributing factors for the specific groups or MAIS3+ casualties were linked to measures included in the DSS. The links were based on a search in the DSS on specific risk factors in relation to the general group of casualties (e.g. cyclists).

4.1 PRACTICAL GUIDELINES FOR DETERMINING THE NUMBER OF SERIOUS ROAD INJURIES (MAIS3+)

The High-Level Group identified three main ways Member States can arrive at data on serious traffic injuries (MAIS ≥ 3):

1. by applying a correction on police data,
2. by using hospital data, and
3. by using linked police and hospital data.

Within SafetyCube, for each of these three ways, practical guidelines have been developed to help countries determining the number of MAIS3+ road casualties. Moreover, it was examined how comparable data from different methods are and how differences in data availability influence on the results.

The estimated number of MAIS3+ casualties is highly influenced by the method applied. Linking of police and hospital data leads to the most reliable estimate, followed by the use of hospital data. However, differences are apparent between countries that apply the same method, this might occur because of differences in the data and/or differences in the operationalization of the method applied. For the time being, one should be careful drawing conclusions when comparing MAIS3+ counts between countries. Further harmonisation is certainly desirable over the next years.

4.2 THE IMPACT AND COSTS OF SERIOUS INJURIES

It is clear that non-fatal serious injuries can have a major impact on the quality of personal, social and working life of a crash survivor as well as on the quality of life of their relatives. Besides these individual consequences, road traffic injuries also pose a burden to society and result in considerable societal costs. Within SafetyCube, physical and psychological consequences of non-fatal road traffic injuries were investigated by means of a literature review and analysis of additional data and studies that the SafetyCube partners had access to.

[The following text was extracted from Weijermars (2017a)]:

The health burden of injuries to society can be expressed in Disability Adjusted Life Years (DALYs). DALYs quantify the loss of healthy life due to (a given) disease or injury in the population. DALYs are calculated by adding the number of years of life lost due to premature mortality (YLL) to time spent in less than perfect health due to morbidity and disability, expressed in healthy year equivalents lost to disability (YLD) (Murray & Acharya, 1997).

Within SafetyCube, the burden of non-fatal injury has been calculated for road traffic casualties in Austria, Belgium, England, The Netherlands, the Rhône department of France, and Spain, applying a method that was developed in the INTEGRIS study (Haagsma et al., 2012). The average burden of injury per MAIS3+ casualty varies between 2.4 YLD in Spain and 3.2 YLD in the Netherlands, with an average of 2.8 YLD per casualty for the six countries/regions together. About 90% of the burden of injury is due to lifelong disabilities that are encountered by between 19% and 33% of the MAIS3+ casualties in Spain and the Netherlands respectively

The burden of injury for an individual casualty depends on the nature of the injury and on the age of the casualty. The average burden per casualty is by far the highest for spinal cord injuries (24.4 – 30.0 YLD). Spinal cord injuries also have a large share in the total burden of injury, as have 'other skull-brain injuries', hip fractures, femur shaft fractures, and fractures in knees and lower legs. The average burden per casualty decreases with age, because life expectancy and thus years lived with permanent disability decreases with age.

The costs related to serious road injuries were analysed by means of a survey among European countries that was developed and distributed in a joint effort with the InDeV project (www.indev-project.eu). The cost components that are most relevant for serious injuries are medical costs, costs related to production loss and human or immaterial costs. In addition, crashes with serious road injuries also induce crash-related costs, including property damage, administrative costs and other costs. 32 European countries (EU28 + Iceland, Norway, Serbia and Switzerland) were included in the survey and crash cost estimates were collected for 30 European countries.

An important explanation for differences in cost estimates between countries is the method that is applied for the estimation of human costs. Human or immaterial costs are the costs relating to loss of quality of life due to the road traffic injuries, including pain, grief and sorrow. The Willingness To Pay (WTP) method is the generally recommended method for the calculation of human costs (Alfaro et al., 1994; Bickel et al., 2006) and results in higher human costs than alternative approaches like the use of financial compensations that are awarded to road casualties in courts of law. Other factors that contribute to differences in costs per seriously injured road traffic casualty between countries are:

- Different cost components being taken into account
- Different definitions of a serious road injury being applied
- Differences in reporting rates of serious road injuries

Human costs constitute the largest share of the total costs related to serious injuries. This is particularly the case for countries that use the WTP method: for these countries the share of human costs varies between 51% and 91%. Medical costs and production loss are the two other main components of the costs related to serious injuries. The share of medical costs in the cost per serious injury varies between 3% and 38%. The share of costs related to production varies between 3% and 58%. Both components have a median share in the total costs of 18% (only taking into account countries that included these components).

4.3 INVESTIGATING THE RISK FACTORS ASSOCIATED WITH SERIOUS ROAD INJURIES

[Text extracted from Weijermars (2017b)]

As a first step, groups of casualties that are of special relevance concerning MAIS3+ injuries were selected. The aim was to identify groups that are not yet covered when focussing on fatalities. Therefore, relevant groups of casualties are those with:

- A relatively large number of MAIS3+ casualties, in relation to fatalities, i.e. a high MAIS3+ to fatality ratio
- Relatively large health impacts, quantified by Years Lived with Disability (YLD) in relation to Years of Life Lost (YLL), i.e. a high YLD to YLL ratio

The selection was based on hospital discharge register data and road fatality registers from a number of countries/regions. Characteristics taken into account were transport mode, age and gender and type of injury. The four main groups of special interest were selected for further in-depth analysis:

- Cyclists: In all countries, cyclists show the highest MAIS3+/fatality ratio and YLD/YLL ratio of all transport modes.
- 0-17 year olds; this age group shows a relatively high MAIS3+/fatality ratio and YLD/YLL ratio. Moreover, the average burden per casualty is relatively high for these casualties, due to a long remaining life expectancy.
- Spinal cord injuries; these injuries always result in long-term disabilities and therefore are a main contributor to years lived with disability of MAIS3+ casualties in all included countries.
- Knee/lower leg fractures; This type of injury has a relatively large share in the burden of injury of MAIS3+ casualties in most of the included countries.

For the selected groups of casualties, the main contributing factors and injury mechanisms were investigated by analysing in-depth collision investigation data from four countries. Due to differences in datasets between the countries and relatively small sample sizes, it was not possible to provide statistically robust results for all the groups of interest across all countries. Therefore, the results should be seen as an indication of relevant risk factors rather than a complete picture of all relevant contributing factors for the selected crash types.

4.4 FURTHER READING

SafetyCube reports are available from the SafetyCube project website: https://www.safetycube-project.eu/

Serious injuries full reports:

Pérez, K., Weijermars, W., Amoros, E., Bauer, R., Bos, N., Dupont, E., Filtness, A., Houwing, S., Johannsen, H., Leskovsek, B. Machata, K., Martin, JL., Nuyttens, N., Olabarria, M., Pascal, L., Van den Berghe, W., (2016), Practical guidelines for the registration and monitoring of serious traffic injuries, D 7.1 of the H2020 project SafetyCube.

Weijermars, W., Meunier, J.-C., Bos, N., Perez, C., Hours, M., Johannsen, H., Barnes, J., et al. (2016), Physical and psychological consequences of serious road traffic injuries, Deliverable 7.2 of the H2020 project SafetyCube.

Schoeters, A., Wijnen ,W., Carnis, L., Weijermars, W., Elvik, R., Johannsen, H., Van den Berghe, W., Filtness, A. and Daniels, S. (2017), Costs related to serious injuries, D 7.3 of the H2020 project SafetyCube.

Reed, S., Weijermars, W, et al. (2017), Identification of key risk factors related to serious road injuries and their health impacts, Deliverable 7.4 of the H2020 project SafetyCube.

5 Using the DSS

A brief practical guide

This chapter will provide a brief overview of how and where to access content in the DSS

The SafetyCube Decision Support System can be freely accessed here: www.roadsafety-dss.eu .

A 'Quick guide' has been created to guide users though the DSS. It is strongly recommended that this is read before using the DSS. The Quick guide can be found on the homepage of the DSS and via this web address:
www.roadsafety-dss.eu/assets/data/pdf/A.Quick.Guide.to.the.SafetyCube.DSS.pdf.

All content on the DSS can be accessed via the menu at the top of the screen (Search, Knowledge, Calculator, Methodology, Support) as shown in Figure 6. 'Search' provides access to all synopses and individual studies as well as links between risk factors and measures. 'Knowledge' gives direct access to all synopses, serious injury information and accident scenario fact sheets and 'Calculator' is where the E3 calculator and SafetyCube E3 examples can be found. These three menu options will be described in more detail in the following sections.

The 'Methodology' menu option provides information about the SafetyCube project and a link to the project website where project reports can be found. It also provides information about the SafetyCube methodology used to generate content for the DSS, the scope and limitations of content as well as a Glossary that defines key terms that are used within the DSS. Finally, there is information on the quality assurance processes implemented to ensure the content of the DSS met the highest possible scientific standard and was consistent across the different work areas.

Finally, the 'Support' menu option provides contact details, another link to the Quick Guide and links to alternative decision support systems.

The technical detail behind the creation of the DSS as well as a more thorough description of its content and associated methodologies is supplied in Yannis and Papadimitriou (2018).

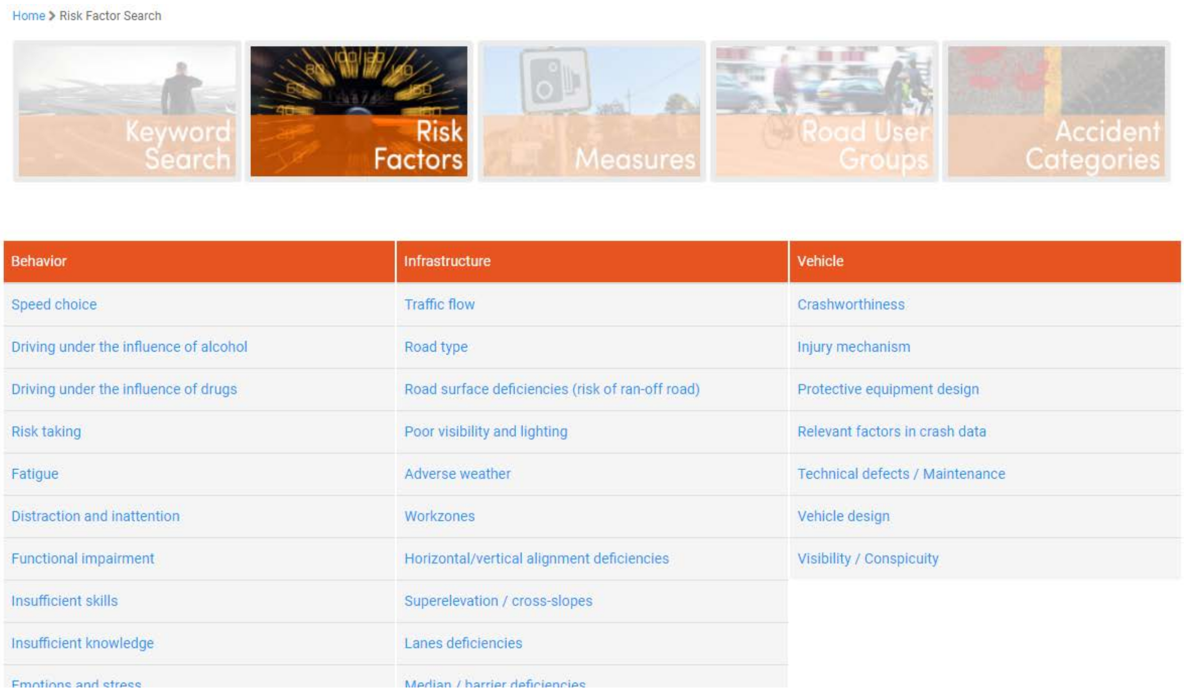
5.1 SEARCH OPTIONS

The structure of the DSS is based on the taxonomies developed for road users, vehicles, infrastructure and post-impact care. All synopses and study pages are linked with the taxonomy (all three levels) which allows them to be searchable on the DSS. On the 'Search' page there are five search options: Keyword search, Risk factors, Measures, Road User Groups and Accident Categories. This page is the home page of the DSS and can be navigated to by clicking on the 'search' tab from the menu at the top of the screen (see Figure 6). Each search option has an introductory video that explains how to use it and what information will be provided.

Figure 5: Home page of DSS (www.roadsafety-dss.eu)

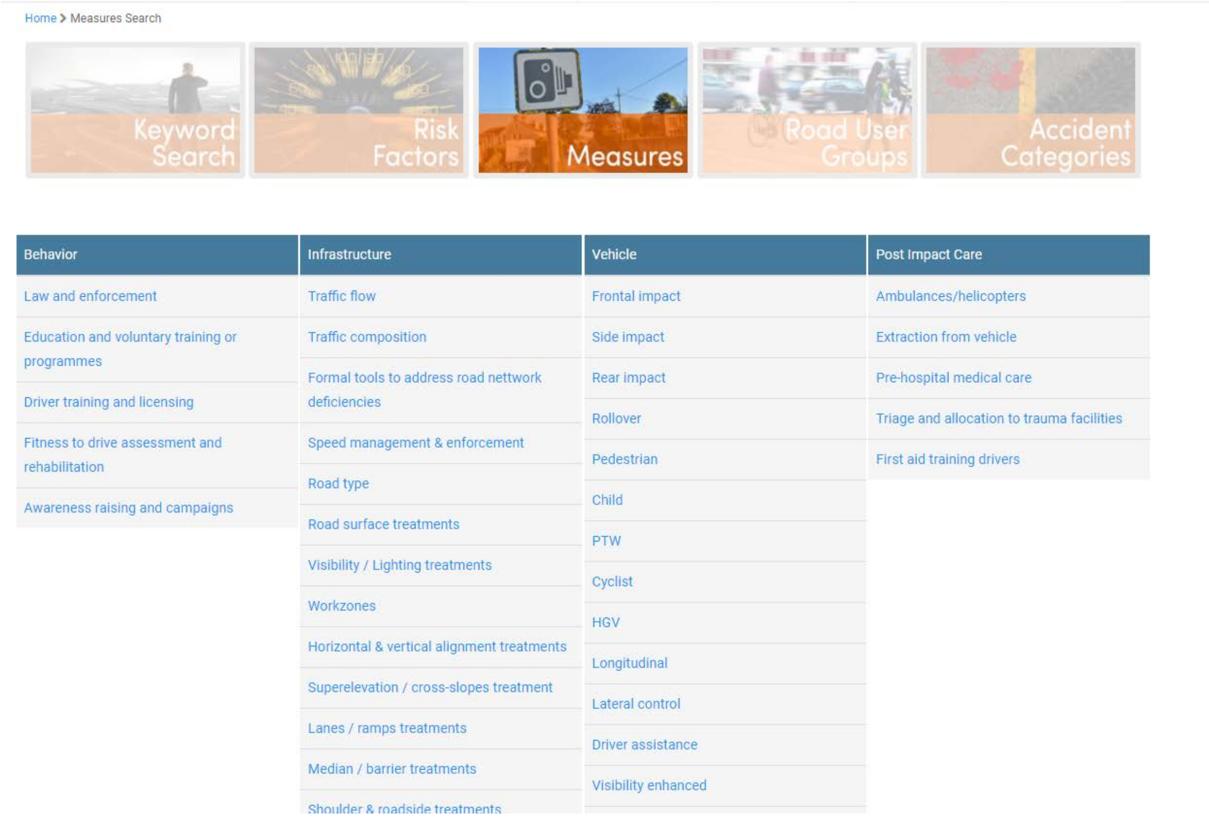
5.1.1 Risk Factors and Measures search options

The primary search options are 'Risk Factors' (Figure 7) and 'Measures' (Figure 8). The Risk Factors page displays the list of taxonomy items that are associated with the 'Behaviour' (road user work area), 'Infrastructure' and 'Vehicle' areas. For behaviour, this is the first level of the taxonomy and for infrastructure and vehicle it's the second level. For the measures search, the resulting list is the first level taxonomy for 'Behaviour' and 'Post Impact Care' and for 'Infrastructure' and 'Vehicle' it's the second. All the synopses and study pages can be accessed through the Risk Factors and Measures search options.



Behavior	Infrastructure	Vehicle
Speed choice	Traffic flow	Crashworthiness
Driving under the influence of alcohol	Road type	Injury mechanism
Driving under the influence of drugs	Road surface deficiencies (risk of ran-off road)	Protective equipment design
Risk taking	Poor visibility and lighting	Relevant factors in crash data
Fatigue	Adverse weather	Technical defects / Maintenance
Distraction and inattention	Workzones	Vehicle design
Functional impairment	Horizontal/vertical alignment deficiencies	Visibility / Conspicuity
Insufficient skills	Superelevation / cross-slopes	
Insufficient knowledge	Lanes deficiencies	
Emotions and stress	Median / barrier deficiencies	

Figure 6: Risk Factors search page



Behavior	Infrastructure	Vehicle	Post Impact Care
Law and enforcement	Traffic flow	Frontal impact	Ambulances/helicopters
Education and voluntary training or programmes	Traffic composition	Side impact	Extraction from vehicle
Driver training and licensing	Formal tools to address road network deficiencies	Rear impact	Pre-hospital medical care
Fitness to drive assessment and rehabilitation	Speed management & enforcement	Rollover	Triage and allocation to trauma facilities
Awareness raising and campaigns	Road type	Pedestrian	First aid training drivers
	Road surface treatments	Child	
	Visibility / Lighting treatments	PTW	
	Workzones	Cyclist	
	Horizontal & vertical alignment treatments	HGV	
	Superelevation / cross-slopes treatment	Longitudinal	
	Lanes / ramps treatments	Lateral control	
	Median / barrier treatments	Driver assistance	
	Shoulder & roadside treatments	Visibility enhanced	

Figure 7: Measures search page

The Road User Group search option allows the user to search for synopses and studies related to the type of road user/vehicle and the Accident Characteristics lists the 8 accident scenarios described in section 3.3 (see Figure 9). When one of the Road User Group or Accident Characteristics categories are selected, the risks and measures associated with that category is displayed (see Figure 10).

Road User Groups
Cyclists
LGV / Van
Bus
Pedestrians
HGV / Truck
PTW
Passenger Car

Accident Scenarios
PEDESTRIAN ACCIDENT
BICYCLIST ACCIDENT
SINGLE VEHICLE ACCIDENT
HEAD-ON COLLISION / ON-COMING TRAFFIC
REAR-END COLLLISION / SAME DIRECTION TRAFFIC
JUNCTION ACCIDENT (NO TURNING)
JUNCTION ACCIDENT (TURNING)
RAILWAY CROSSING

Figure 8: Road User Group and Accident Scenario categories as DSS search options.

Risk Factors			Measures			
Behavior	Infrastructure	Vehicle	Behavior	Infrastructure	Vehicle	Post Impact Care
Inapropriate speed	poor visibility - darkness	Low Star rating (EuroNCap)	Distraction	improvement of existing lightling	Night Vision	Not Applicable
Speeding	high number of conflict points	Visibility, Conspicuity & Blind Spot issue	Protective clothing (excluding helmet)	installation of road lighting	Pedestrian protection (Active bonnet, pedestrian airbag, EuroNCap, ...)	
Drunk driving or drunk riding (cyclists/mopeds)	uncontrolled junction	vehicle shape & Configuration	Children/pre-school, primary school	reduction of speed limit	Pedestrian regulation	
Distraction within vehicle or within the riding or walking situation	misleading or unreadable traffic sign		Adolescents/seconda school	speed cameras		
	absence of marked					

Figure 9: Example of risk factors and measures associated with pedestrian accidents

5.1.2 Keyword Search option

The Keyword Search option allows the user to search for risk factors and measures on the basis of a predefined list of keywords. This is a particularly useful option if it is unclear which taxonomy item the subject would be found within. As the user starts to type in the keyword box (see Figure 11), a list of suggestions from the keyword database appears. The Keyword Search returns the lists of risk factors and measures taxonomy topics, in which the selected keyword is found among the original keywords of one or more of the studies coded under each topic. Once a term is selected, a list of Risk Factors and Measures are displayed in the form shown in Figure 10. Sometimes topics will appear in Keyword Search results that have a title relating to a seemingly different area, however, it is likely that the individual coded studies will have some relevance to the search term as they identify with that key word.

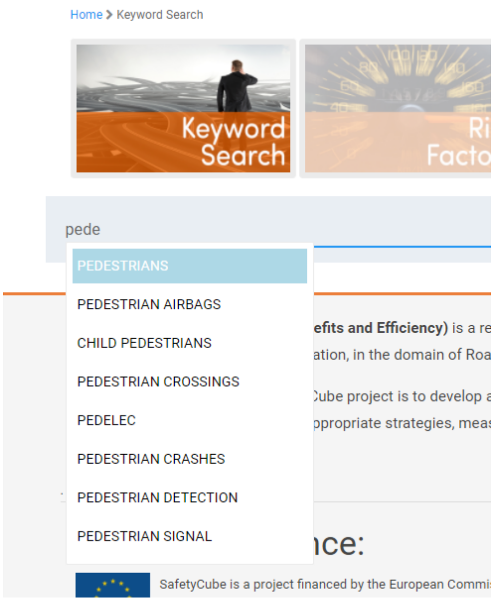


Figure 10: Keyword Search option

Once a specific risk factor or measure has been selected, a search result page is opened (Figure 12). This displays the synopses and a list of studies associated with that risk/measure. The synopses titles, colour code and related text are displayed and the PDF can be downloaded by clicking on the icon. Below the synopses is a table listing the individual studies associate with the topic. A subset of results can be selected by checking the filter boxes on the left-hand side of the screen. There is also an Introductory Video on the search results page which will guide the user about its content and how to use it.

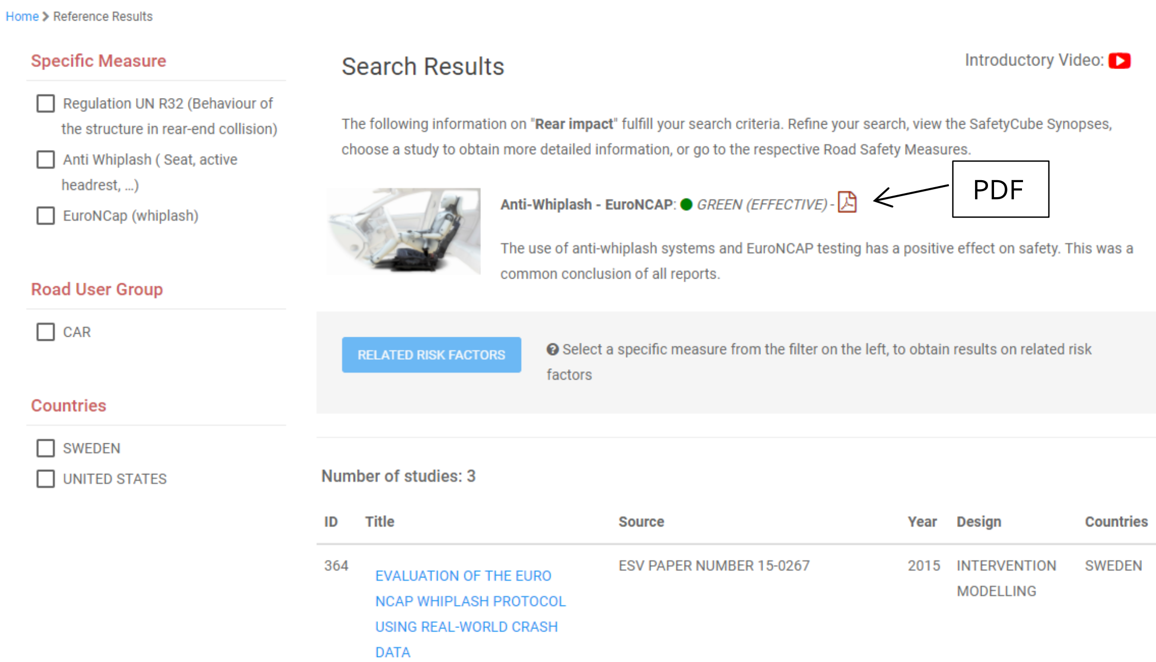


Figure 11: Search Results page for vehicle measures addressing 'Rear impact'

More detail can be found about the studies that appear on the particular search results page by clicking on the study title. This will open the individual study page (Figure 13). The title, other reference information, abstract, summary (written by the SafetyCube researcher) and some information about the study design for the study appears here along with a table summarising information to do with the reported effects and their significance for road safety. Where possible, a link to the original study is provided however this will link to the original publisher and the ability to view will depend on the users' access rights. Another introductory video is available on the individual study pages to guide the user about the content.

Obstructive Sleep Apnea, Health-Related Factors, and Long Distance Heavy Vehicle Crashes in Western Australia: A Case Control Study

Meuleners, L., Fraser, M. L., Govorko, M. H., Stevenson, M. R.

Introductory Video:

Abstract

Study Objectives: To determine the association between obstructive sleep apnea (OSA), health-related factors and the likelihood of heavy vehicle crashes in Western Australia (WA). Methods: This case-control study included 100 long haul heavy vehicle drivers who were involved in a police reported crash in WA during the study period (cases) and 100 long-haul heavy vehicle drivers recruited from WA truck stops, who were not involved in a crash during the past year (controls). Driver demographics, health, and fatigue related characteristics were obtained using an interviewer administered questionnaire. Drivers were tested for OSA using a diagnostic Flow Wizard. Logistic regression was used to determine health-related factors associated with crash involvement among long distance heavy vehicle drivers. Results: Heavy vehicle drivers diagnosed with OSA through the use of the FlowWizard were over three times more likely to be involved in a crash than drivers without OSA (adjusted OR: 3.42, 95% CI: 1.34-8.72). The risk of crash was significantly increased if heavy vehicle drivers reported a diagnosis of depression (adjusted OR: 6.59, 95% CI: 1.30-33.24) or had not completed fatigue management training (adjusted OR: 6.05, 95% CI: 1.80-20.24). Crash risk was 74% lower among older drivers (> 35 years) than younger drivers (adjusted OR: 0.25, 95% CI: 0.08-0.82). Conclusion: The results suggest that more rigorous screening and subsequent treatment of OSA and depression by clinicians as well as compulsory fatigue management training may reduce crashes among heavy vehicle drivers.

http://dx.doi.org/10.5664/jcsm.4594

Summary

Meuleners et al (2015) used a case-control methodology to study the crash risk of OSA among long distance truck drivers in West Australia. Cases were 100 long distance heavy vehicle (>=12 tonnes) drivers (99% male) who were involved in a police-reported crash between Jan 2009 and Nov 2011 during a journey of at least 200km. Controls were 100 long distance heavy vehicle (>=12 tonnes) drivers (98% male) recruited from four truck stops between July 2009 and Nov 2011. Drivers were classed as suffering from OSA if they scored an AHI >17 following a self-administered overnight test with the measuring device 'Flow Wizard'. Logistic regression was used to control for confounding factors and to determine which factors were associated with crash involvement. Factors included in the model were age, BMI, smoking status, diagnosed health conditions, diagnosis of depression , use of prescription medications, use of caffeine to stay awake, regular exercise, completed fatigue training, involved in a crash in previous 5 years, and OSA. The adjusted odds ratio for crash involvement for drivers classed as having OSA was 3.42 (95% Confidence Interval: 1.34-8.72).

Basic Study Information

Topic: RISK FACTOR

Year: 2015

Source: JOURNAL OF CLINICAL SLEEP MEDICINE, 11:413-418

Design: OBSERVATIONAL CASE-CONTROL

Countries: AUSTRALIA

Keywords: HEAVY VEHICLE CRASH RISK FATIGUE DEPRESSION OBSTRUCTIVE SLEEP APNEA

Effects

Effect No	Outcome	Exposure	Group Type	Group	Effect Estimator	Effect Estimator Specifications	Sample	Estimate	Estimate Lower Limit	Estimate Upper Limit	Conclusion Comments
1	CRASH	OBSTRUCTIVE SLEEP APNEA (OSA)	ctrl	NO	ODDS RATIO	ADJUSTED ODDS RATIO FROM LOGISTIC REGRESSION	case = 100; control = 100	3.42	1.34	8.72	SIGNIFICANT NEGATIVE EFFECT ON ROAD SAFETY HGV DRIVERS WITH OBSTRUCTIVE SLEEP APNEA

Figure 12: Individual study page

5.1.3 Links between risk factors and measures and accident scenarios

Information about the risk factors and measures which are linked with the accient scenarios can be accessed through the Accident Categories search option. Once one of the accident scenarios are slected the linked risks and measures appear at the bottom of the screen. This does not open a new page so the user may need to scroll down to view information.

Links between a particular risk factor and the related measures, or vice versa, can be viewed from the Search Results pages. First the user needs to select one of the specific risk factors (top left of page) and then the 'Related Measures' button can be clicked (see Figure 14). The results will be given in a separate page as shown in Figure 15.

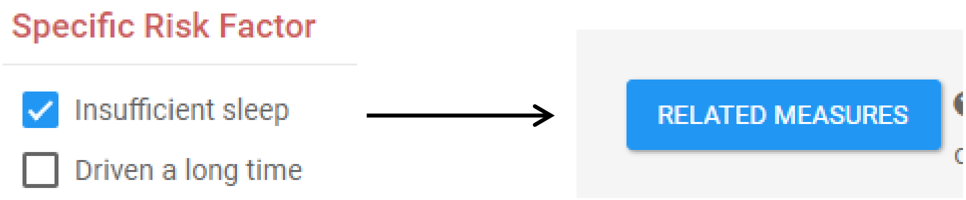


Figure 13: Viewing related risk factors/measures

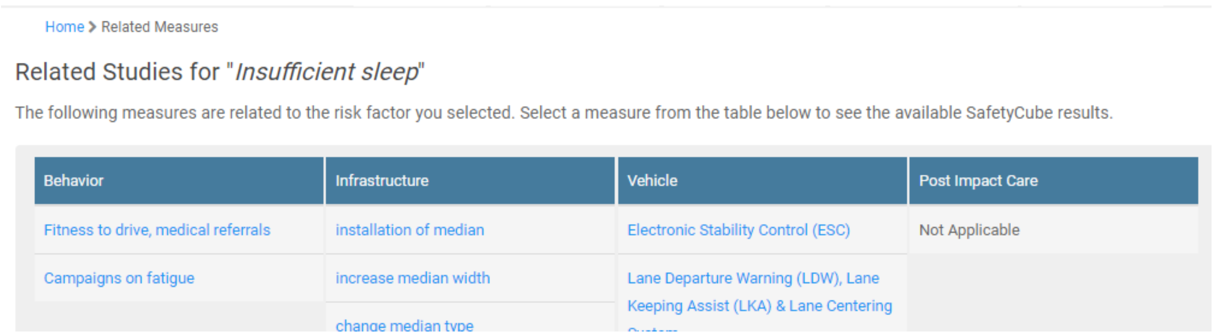


Figure 14: Links between risk factors and measures result page

5.2 ECONOMIC EFFICIENCY EVALUATION (E3) CALCULATOR

The E3 calculator can be accessed from the 'Calculator' option from the menu bar at the top of the DSS pages. The user has a choice between using the calculator to perform their own cost benefit analysis and viewing one of the SafetyCube examples. Select 'My Measure' to calculate a new cost benefit analysis (Figure 16), give the analysis a name in the 'My Measure' text box and fill in the required figures. To use the E3 Calculator knowledge of cost-benefit analyses and using the tool is required. Please see documentation available on the DSS (in the calculator page or quick guide) and detailed guidance for filling in the calculator is available in Martensen & Lassarre (2017).

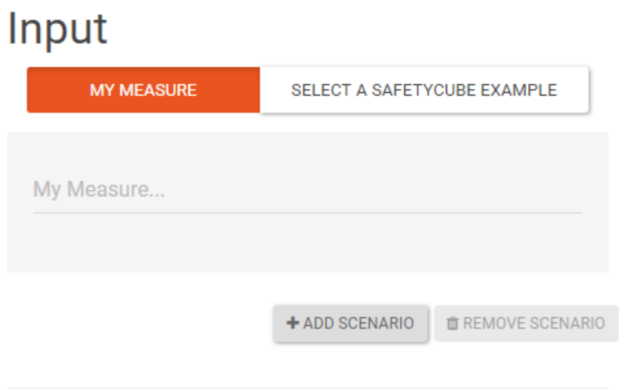


Figure 15: E3 Calculator input for users own cost benefit calculation

To view a SafetyCube example, click on the 'Select a SafetyCube Example' tab and choose an example to view from the drop-down list (Figure 17). The 'Submit' button (blue, at bottom of page) then needs to be clicked to display the Cost-Benefit analysis results. The title of the example and the focus 'measure' name is displayed above the results but no results figures will be given until the submit button is selected (Figure 18). The user can also edit an existing example, e.g. to use other implementation costs. To do this, click on the '+ add scenario' button, amend the figures in the Input column and press 'submit'. The alternative results will be displayed in the 'scenario 2' column alongside the original results (Figure 18).

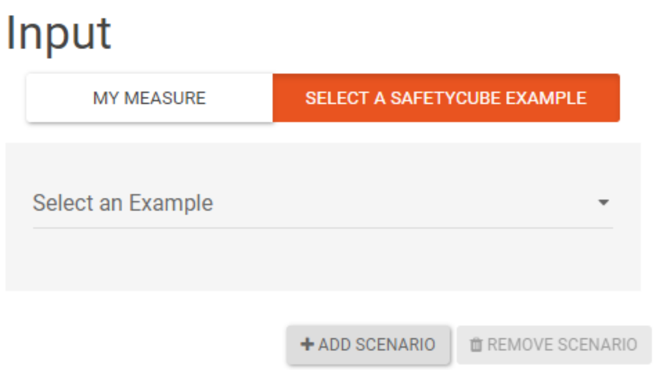
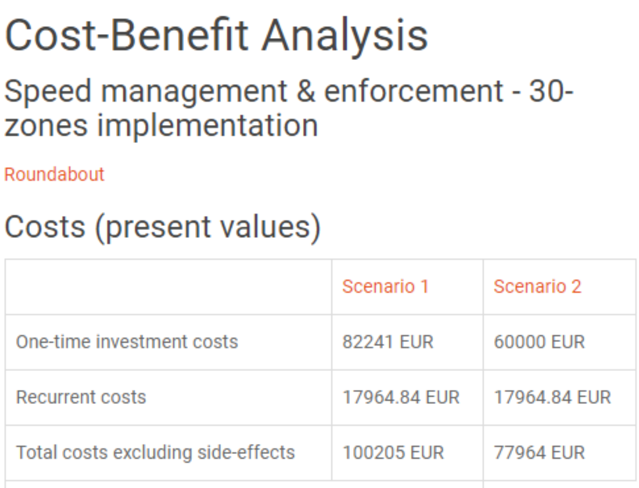


Figure 16: E3 Calculator input for viewing existing SafetyCube example



Cost-Benefit Analysis

Speed management & enforcement - 30-zones implementation

Roundabout

Costs (present values)

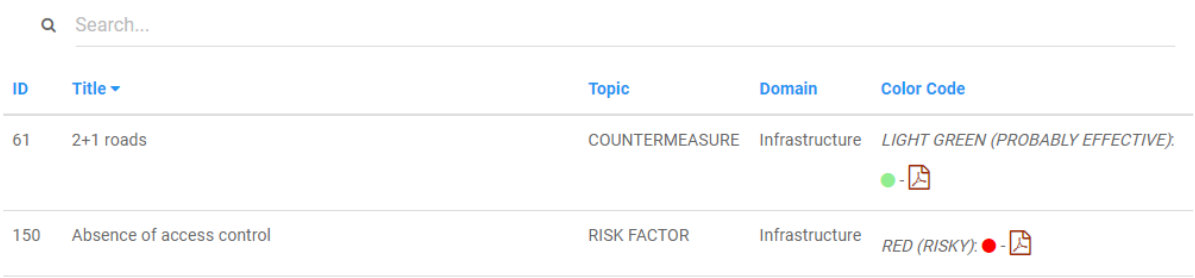
	Scenario 1	Scenario 2
One-time investment costs	82241 EUR	60000 EUR
Recurrent costs	17964.84 EUR	17964.84 EUR
Total costs excluding side-effects	100205 EUR	77964 EUR

Figure 17: Partial results for the SafetyCube example Speed management, roundabout implementation (scenario 1).

5.3 KNOWLEDGE

The Knowledge area of the DSS is divided into three sections: Road Safety Synopses, Serious Injuries and Accident Scenarios.

The Road Safety Synopses contain the list of all synopses contained in the DSS. This is displayed in table form with the synopsis title, topic (risk factor/countermeasure), domain (Behaviour, Infrastructure, Vehicle, Post Impact Care) and Colour code (Figure 19). The PDF of an individual synopsis can be downloaded from here by clicking on the icon following the colour code. The table can be re-ordered by clicking on a table heading and there is a search option which will display the synopses that include the search term in their title.



Search...

ID	Title	Topic	Domain	Color Code
61	2+1 roads	COUNTERMEASURE	Infrastructure	*LIGHT GREEN (PROBABLY EFFECTIVE):* -
150	Absence of access control	RISK FACTOR	Infrastructure	*RED (RISKY):* -

Figure 18: Synopses table in Knowledge area of DSS

The Serious Injuries section contains information about the serious injuries work of SafetyCube as described in Chapter 4 and the Accident Scenarios section contains the accident scenarios factsheets as described in Section 3.3 .

5.4 FURTHER READING

SafetyCube reports are available from the SafetyCube project website: https://www.safetycube-project.eu/

Full technical report on the DSS:

Yannis G., Papadimitriou E. (Eds.) (2018), The European Road Safety Decision Support System - A clearinghouse of road safety risks and measures, Deliverable 8.3 of the H2020 project SafetyCube.

6 Conclusions and the future

The SafetyCube project has fulfilled its main aim of creating a European road safety Decision Support System that is populated with high quality scientific content. Its content is broad and the available evidence for risk factors relating to the road user, infrastructure and vehicle had been evaluated. The scientific knowledge about the effectiveness of measures relating to these elements as well as post impact care has been assessed and links have been established between risk factors, measures and accident scenarios. A methodology for conducting economic efficiency evaluation calculations (E3 calculator) has been developed and applied to selected measures. In addition, knowledge about serious injuries has been expanded, particularly in relation to their estimation, impact, cost and associated risk factors.

The DSS is not intended to be a static tool. The intention is that further funding is sort to develop, expand and update the DSS. The DSS was developed for a very broad range of users and aimed to cover as many topic areas as possible. However inevitably due to this wide-ranging approach and the time constraints of a project with a finite timeline, not all topics could be covered and not all relevant studies could be included. Although not described in full here, stakeholders have been involved in the development of the DSS from initial input into what topics should resources to be focused on to testing and evaluation of the initial and final versions of the DSS. Not all feedback from stakeholders could be incorporated during the SafetyCube project but these could be developed in future versions of the DSS.

Additional content/functionality of the DSS could include:

- Expansion of topics and subtopics address
- Updating synopses with research published following literature searchers
- Including more studies:
  - those from outside Europe/western countries
  - Studies written in languages other than English
  - Those from grey literature – particularly important when dealing with new vehicle technologies
- Evaluating the effectiveness of measures on serious road injuries
- Validation of links between risks and measures
- Evaluating the effects of combined measures
- Translation of DSS content into additional languages

Although the SafetyCube project has ended, the individuals involved will continue to promote its work and the DSS. To assist with this a short promotion video was created: https://www.youtube.com/watch?v=Y-mVUde3knU.The SafetyCube consortium believes that the DSS will be a key tool, assisting in evidenced based policy making both now and in the future.

6.1 FURTHER READING

SafetyCube reports are available from the SafetyCube project website: https://www.safetycube-project.eu/

Future plans for the DSS:

Thomas, P., Filtness, A. (Eds.) (2018), The future Decision Support System, Deliverable 8.5 of the H2020 project SafetyCube

References

SafetyCube reports are available from the SafetyCube project website: https://www.safetycube-project.eu/

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

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Elvik R. (2004). To what extent can theory account for the findings of road safety evaluation studies? Accident Analysis and Prevention 36 (2004) 841–849.

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European Commission (EC) (2010) Towards a European road safety area: policy orientations on road safety 2011-2020. COM (2010) 389 final. Brussels, European Commission.

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Filtness A., Thomas P., Talbot R., Quigley C., Papadimitriou E., Yannis G., Theofilatos A., Aigner-Breuss E., Kaiser S., Machata K., Weijermars W., Van Schagen I., Hermitte T (2016), The application of systems approach for road safety policy making, Deliverable 8.1 of the H2020 project SafetyCube.

Haagsma, J. A., Polinder, S., Lyons, R. A., Lund, J., Ditsuwan, V., Prinsloo, M., ... van Beeck, E. F. (2012). Improved and standardized method for assessing years lived with disability after injury. Bull World Health Organ, 90(7), 513–521. https://doi.org/10.2471/blt.11.095109

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Martensen, H., and Lassarre, S., Eds (2017), Methodological framework for the evaluation of road safety risk factors and countermeasures, Deliverable 3.3 of the H2020 project SafetyCube.

Martensen, H., Daniels, S; Van den Berghe W., Wijnen, W., Weijermars, W., Carnis, L., Saadé, J., Elvik, R. (2018), Guidelines for priority setting between measures with practical examples, Deliverable Number 3.5 of the H2020 project SafetyCube.

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Pérez, K., Weijermars, W., Amoros, E., Bauer, R., Bos, N., Dupont, E., Filtness, A., Houwing, S., Johannsen, H., Leskovsek, B. Machata, K., Martin, JL., Nuyttens, N., Olabarria, M., Pascal, L., Van den Berghe, W., (2016), Practical guidelines for the registration and monitoring of serious traffic injuries, D 7.1 of the H2020 project SafetyCube.

Rasmussen, J., 1997. Risk management in a dynamic society: a modelling problem. Safety Science 27 (2/3), 183–213

Reason, J. (2000). Human error: models and management. BMJ : British Medical Journal, 320(7237), 768-770.

Reed, S., Weijermars, W, et al. (2017), Identification of key risk factors related to serious road injuries and their health impacts, Deliverable 7.4 of the H2020 project SafetyCube.

Schoeters, A., Wijnen ,W., Carnis, L., Weijermars, W., Elvik, R., Johannsen, H., Vanden Berghe, W., Filtness, A. and Daniels, S. (2017), Costs related to serious injuries, D 7.3 of the H2020 project SafetyCube.

Thomas, P., Filtness, A. (Eds) (2018), The future Decision Support System, Deliverable 8.5 of the H2020 project SafetyCube.

Usami, D.S., Papadimitriou, E., Ziakopoulos, A., Quigley, C., Katrakazas, C., Durso C. (Eds) (2017), Inventory of assessed infrastructure risk factors and measures, Deliverable 5.4 of the H2020 project SafetyCube.

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Weijermars, W., Meunier, J.-C., Bos, N., Perez, C., Hours, M., Johannsen, H., Barnes, J., et al. (2016), Physical and psychological consequences of serious road traffic injuries, Deliverable 7.2 of the H2020 project SafetyCube.

Wijnen, W., Weijermars, W., Vanden Berghe, W., Schoeters, A., Bauer, R., Carnis, L., Elvik, R., Theofilatos, A., Filtness, A., Reed, S., Perez, C., and Martensen, H. (2017), Crash cost estimates for European countries, Deliverable 3.2 of the H2020 project SafetyCube.

Yannis G., Papadimitriou E. (Eds) (2018), The European Road Safety Decision Support System - A clearinghouse of road safety risks and measures, Deliverable 8.3 of the H2020 project SafetyCube.

Appendix A SafetyCube project reports

SafetyCube reports are available from the SafetyCube project website: https://www.safetycube-project.eu/

Table 1: Full list and description of SafetyCube project reports by work area

Report	Summary
Project Management	
Thomas, P, Filtness, A., Talbot, R., Magrin, A (2016) Collaboration with other H2020 projects, Deliverable **1.1** of the H2020 project SafetyCube.	The SafetyCube project team has conducted liaison activities with the four other MG 3.4 projects during the first year of the project duration. This brief management report describes the first stages of engagement between the SafetyCube team and the work packages of the other projects. It does not report on any further engagement between the projects that does not involve SafetyCube.
Thomas, P., Filtness, A., Talbot, R., Magrin, A. (2016) Project Report - months 1 - 18, Deliverable **1.2** of the H2020 project SafetyCube.	This document constitutes a mid-term review where all WP Leaders compare actual project progress against the initial plan.
Filtness, A., Thomas, P, Weijermars, W., Talbot, R., Magrin, A (2016) Second exploitation workshop - collaboration with other H2020 projects, Deliverable **1.3** of the H2020 project SafetyCube.	This is a brief management report that describes the further engagement (initial stages in Del.1.1) between the SafetyCube team and the other projects.
Thomas, P, Talbot. R. (Eds) (2018), Final project report, Deliverable **1.4** of the H2020 project SafetyCube.	This report describes work and outcomes of SafetyCube.
SafetyCube (2018) Project conference organisation, Deliverable **1.5** of the H2020 project SafetyCube.	This is a brief management document that provides evidence of the SafetyCube project conference organisation, containing information from the conference website, emails to invite attendance, the final conference program and photos from the conference.
Dissemination and Stakeholder Consultation	
Hagström, L., Thomson, R., Skogsmo, I., Houtenbos, M., Durso, C., Thomas, P., Elvik, R., Wismans, J. (2015), Definition of user needs, Deliverable **2.1** of the H2020 project SafetyCube.	The report defines user needs for the planned Decision Support System (DSS) and "hot topics" to be used as demonstrators in the SafetyCube project.
Tros, M., Houtenbos, M. (2015),	The purpose of this report is to provide a consistent

Dissemination Material Template, Deliverable Number **2.2** of the H2020 project SafetyCube.	graphic profile for SafetyCube in terms of a logo, colour palette, font, and electronic document templates for reports and presentations.
Thomson, R., Hagström, L., Skogsmo, I., Talbot, R., Thomas, P., Houtenbos, M., Yannis, G., Laiou, A., Durso, C., Elvik, R., Etienne, V., Hermitte, T., Kaiser, S., Leskovsek, B., Niewöhner, W., Perez, C., Usami, D., Verhoeven, V., Vázquez-de-Prada, J., Weijermars, W., (2015) Project dissemination plan, Deliverable **2.3** of the H2020 project SafetyCube.	This report includes the dissemination plan that is set up to ensure that stakeholders and partners get efficiently involved in the project. This covers all tasks, including a networking strategy and a time plan of the various dissemination activities. It also refers to the stakeholder input.
Yannis G., Theofilatos A., Folla K., Marinos C., Thomson R., Hagström Li, (2015), Interactive Stakeholders' Platform, Deliverable **2.4** of the H2020 project SafetyCube.	This report presents the interactive platform created in the website of the SafetyCube Horizons 2020 research project that incorporates road safety stakeholders' contribution at the various stages of the project, including online survey facilities for data collection, allowing thematic discussions, etc.
Thomson, R., Magrin, A., Filtness, A., Kaiser, S., Aigner-Breuss, E., Weijermars, W., Martensen, H., Elvik, R., Thomas, P., Yannis, G., Niewöhner, W., Papadimitriou, E., (2016), Review of stakeholder feedback from Midterm Workshop, Deliverable **2.5** of the H2020 project SafetyCube.	This report documents and analyses the input from stakeholders presented at the Mid-term Workshop that held in September 2016, month 17 of a 36-month project. It describes the workshop structure, and then gives a review of discussion topics.
Thomson, R. et al. (2018) Updated Project Dissemination Plan, Deliverable **2.6** of the H2020 project SafetyCube. [In press, reference subject to change]	This report is an update to D2.3 Project dissemination plan.
Development and validation of methodological framework	
Hagström, L., Thomson, R., Hermitte, T., Weijermars, W., Bos, N., Talbot, R., Thomas, P., Dupont, E., Martensen, H., Bauer, R., Hours, M., Høye, E., Jänsch, M., Murkovic, A., Niewöhner, W., Papadimitriou, E., Pérez, C., Phan, V., Usami, D., Vázquez-de-Prada, J., (2015), Description of data-sources used in SafetyCube, Deliverable **3.1** of the H2020 project SafetyCube.	This report identifies and describes the available data sources for the analysis in the project (Work Packages 3 to 7) that covers road user behavior, vehicle, infrastructure, and injuries. In other words, this document provides a searchable inventory of available databases.
Wijnen, W., Weijermars, W., Vanden Berghe, W., Schoeters, A., Bauer, R., Carnis, L., Elvik, R., Theofilatos, A., Filtness, A., Reed, S., Perez, C., and Martensen, H. (2017), Crash cost estimates for European countries, Deliverable **3.2** of the H2020 project SafetyCube.	This report provides crash cost estimates for European countries. Furthermore, it includes a discussion regarding which cost components should be included according to international guidelines on estimating costs of road crashes and how costs for different cost components should be collected.
Martensen, H., and Lassarre, S., Eds (2017), Methodological framework for the evaluation of road safety risk factors and	This report gives the theoretical framework for the Decisions Support System. It addresses the entire methodology that has been applied to generating

countermeasures, Deliverable **3.3** of the H2020 project SafetyCube.	the content of the DSS. The contents consist of the following elements: 1. Repository of studies 2. Synopses that summarize the studies on a particular topic 3. Economic efficiency evaluation of counter measures.
Martensen, H. et al. (2016), Preliminary guidelines for priority setting between measures, Deliverable Number **3.4** of the H2020 project SafetyCube**.**	This report describes the economic assessment of different countermeasures. Cost-effectiveness analysis and cost-utility analysis are compared to cost-benefit analysis.
Martensen, H., Daniels, S; Van den Berghe W., Wijnen, W., Weijermars, W., Carnis, L., Saadé, J., Elvik, R. (2018), Guidelines for priority setting between measures with practical examples, Deliverable Number **3.5** of the H2020 project SafetyCube.	This report gives an outline of the process of prioritising road safety measures and can be used by policy makers to understand what they can do to choose between different countermeasures. It gives an overview, rather than technical details.
Road user behaviour analysis	
Talbot, R., Aigner-Breuss, E., Kaiser, S., Alfonsi, R., Braun, E., Eichhorn, A., Etienne, V., Filtness, A., Gabaude, C., Goldenbeld, C., Hay, M., Jänsch, M., Leblud, J., Leskovšek, B., Paire- Ficout, L., Papadimitriou, E., Pilgerstorfer, M., Rußwurm, K., Sandin, J., Soteropoulos, A., Strand, N., Theofilatos, A., Van Schagen, I., Yannis, G., Ziakopoulos, A. (2016), Identification of Road User Related Risk Factors, Deliverable **4.1** of the H2020 project SafetyCube.	This report presents the process of identifying, selecting, analysing and assessing road safety risk factors related to humans and their behaviour, as well as, its outcomes.
Theofilatos, A., Aigner-Breuss, E., Kaiser, S., Alfonsi, R., Braun, E., Eichhorn, A. et al. (2017). Identification and Safety Effects of Road User Related Measures. Deliverable **4.2** of the H2020 project SafetyCube.	This report aims at identifying key road safety measures focusing on road users – in contrast to measures targeting road infrastructure or vehicles. A further aim is to evaluate these measures in terms of their safety effects based on scientific evidence.
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.	The report includes the assessment of the economic efficiency of road safety measures that are identified as effective. The focus is on measures targeting road users – in contrast to measures targeting road infrastructure or vehicles.
Aigner-Breuss, E., Kaiser, S., Usami, D.S., Reed, S. & Weijermars, W. (2017). Inventory of road user related risk factors and safety measures, Deliverable **4.4** of the H2020 project SafetyCube.	This report is to represent the synthesis of the procedure and results of the effect assessment of road user related risk factors and countermeasures. Furthermore, it reflects the results in broader context linked to the other thematic SafetyCube pillars: road infrastructure, vehicles and serious injuries.
Infrastructure safety analysis	

Filtness A. & Papadimitriou E. (Eds) (2016), Identification of Infrastructure Related Risk Factors, Deliverable **5.1** of the H2020 project SafetyCube.	This report focuses on identifying and evaluating infrastructure related risk factors and related road safety problems by presenting a taxonomy of road infrastructure related risks, identifying "hot topics" of concern for relevant stakeholders and evaluating the relative importance for crash outcomes (risk, frequency, severity) for each identified risk factor.
Machata K., Papadimitriou E., Soteropoulos A., Stadlbauer S. (Eds) (2017), Identification of safety effects of infrastructure related measures, Deliverable **5.2** of the H2020 project SafetyCube.	This report focuses on identifying and evaluating infrastructure related measures by presenting a taxonomy of road infrastructure related measures, identifying "hot topics" of concern for relevant stakeholders, evaluating the relative importance for crash outcomes (risk, frequency, severity) for each identified measure.
Daniels S., Papadimitriou E. (Eds) (2017). Economic evaluation of infrastructure related measures, Deliverable **5.3** of the H2020 project SafetyCube.	This report focuses on identifying and evaluating infrastructure related measures by overviewing of methodology, showcasing data collection and presenting cost-benefit and sensitivity results.
Usami, D.S., Papadimitriou, E., Ziakopoulos, A., Quigley, C., Katrakazas, C., Durso C. (Eds) (2017), Inventory of assessed infrastructure risk factors and measures, Deliverable **5.4** of the H2020 project SafetyCube.	This report describes the underlined methodology, the road infrastructure measures and related risk factors addressed in the "Inventory of road infrastructure safety measures", the type of information the DSS user will find in it related to research studies and their "synopses" (summary of results).
Vehicle safety analysis	
Hermitte T. et al. (2016), Identification of Vehicle Related Risk Factors, Deliverable **6.1** of the H2020 project SafetyCube.	This report presents the process of identifying, selecting, analysing and assessing road safety risk factors related to vehicles, as well as, their outcomes.
Hermitte T. et al. (2016), Identification of Vehicle Related safety measures, Deliverable **6.2** of the H2020 project SafetyCube.	This report presents the process of identifying, selecting, analysing and assessing road safety measures related to vehicles, as well as, its outcomes.
Martin O. et al (2017). Economic evaluation of vehicle related measures. Deliverable **6.3** of the H2020 project SafetyCube	This report focuses on identifying and evaluating vehicle related measures by overviewing of methodology, showcasing data collection and presenting cost-benefit and sensitivity results.
Leopold, F. (2018) Inventory of assessed vehicle risk factors and measures. Deliverable **6.4** of the H2020 project SafetyCube. [In press, reference subject to change]	The report describes the underlined methodology, the vehicle related measures and risk factors addressed in the "Inventory of vehicle related safety measures", the type of information the DSS user will find in it related to research studies and their "synopses" (summary of results).
Chajmowicz, H. et. al (2018) Recommendations for industry and policy action to improve European road safety. Deliverable **6.5** of the H2020 project SafetyCube	This report proposes specific recommendations/actions addressing (industry and policy) stakeholders for facilitating the implementation of vehicle measures.

[In press, reference subject to change]	
Serious road injuries, analysis and strategy	
Pérez, K., Weijermars, W., Amoros, E., Bauer, R., Bos, N., Dupont, E., Filtness, A., Houwing, S., Johannsen, H., Leskovsek, B. Machata, K., Martin, JL., Nuyttens, N., Olabarria, M., Pascal, L., Van den Berghe, W., (2016), Practical guidelines for the registration and monitoring of serious traffic injuries, D **7.1** of the H2020 project SafetyCube.	This report includes practices in Europe reporting serious injuries and provides guidelines and recommendations applied to each of the three main ways of estimate the number of road traffic serious injuries.
Weijermars, W., Meunier, J.-C., Bos, N., Perez, C., Hours, M., Johannsen, H., Barnes, J., et al. (2016), Physical and psychological consequences of serious road traffic injuries, Deliverable **7.2** of the H2020 project SafetyCube.	This report discusses the health impacts of non-fatal (serious) road traffic injuries in terms of Physical/functional, psychological and socio-economic consequences for casualties and Burden of injury (expressed in Years Lived with Disability).
Schoeters, A., Wijnen ,W., Carnis, L., Weijermars, W., Elvik, R., Johannsen, H., Vanden Berghe, W., Filtness, A. and Daniels, S. (2017), Costs related to serious injuries, D **7.3** of the H2020 project SafetyCube.	This report discusses the costs that are related to serious road injuries. Next to the cost estimates in different European countries, it also covers a more detailed analysis of three types of cost components: medical costs, production loss and human costs.
Reed, S., Weijermars, W, et al. (2017), Identification of key risk factors related to serious road injuries and their health impacts, Deliverable **7.4** of the H2020 project SafetyCube.	This report provides information into the identification of contributing factors and injury mechanisms that are of special relevance for seriously injured road traffic casualties.
European road safety policy Decision Support System	
Filtness A., Thomas P., Talbot R., Quigley C., Papadimitriou E., Yannis G., Theofilatos A., Aigner-Breuss E., Kaiser S., Machata K., Weijermars W., Van Schagen I., Hermitte T (2016), The application of systems approach for road safety policy making, Deliverable **8.1** of the H2020 project SafetyCube.	This report aims to coordinate the analysis of risks and measures using a systems framework to ensure that the approaches taken are equivalent throughout the SafetyCube project, using the specific methodologies developed within it.
Van den Berghe, W., Martensen, H., Diependaele, K., Talbot, R., Papadimitriou, E, Yannis, G. (2017), Compilation of analyses of risks and measures, Deliverable **8.2** of the H2020 project SafetyCube.	This report examines the results relating to risks and measures for road users, vehicles, infrastructure and injuries and describes how these have been made accessible for non-statisticians. It gives an overview of the outputs produced, what they are based on and how these outputs are integrated into the DSS, as well as some detail about the operation of the DSS.
Yannis G., Papadimitriou E. (Eds) (2018), The European Road Safety Decision Support System - A clearinghouse of road safety risks and measures, Deliverable **8.3** of the H2020 project SafetyCube.	This report describes how the results of the analyses that carried out throughout the project, were integrated and made available through a Decision Support System (DSS) of road safety risks and measures.

Machata, K (2018) Training material and course presentation, Deliverable **8.4** of the H2020 project SafetyCube	This report contains the training material and the course presented to road safety stakeholders at the organised project workshops.
Thomas, P., Filtness, A. (Eds) (2018), The future Decision Support System, Deliverable **8.5** of the H2020 project SafetyCube.	In this report a business plan has been developed to define future aspirations for the decision support system (DSS) in order that it becomes a service for safety assessment and evaluations.

Appendix B. Safety Cube Taxonomies

The following tables are the risk factor and measures taxonomies for the road user, infrastructure, vehicle and, for measures only, post impact care and the taxonomy created for accident scenarios.

Table 1: Road User Risk Factors Taxonomy

Topic	Subtopic	Specific risk factor
Speed choice	Speeding	Built-up areas
		Rural roads
		Motorways
	Inappropriate speed	Too fast weather-related
		Too fast traffic related
		Too slow
Influenced driving - alcohol	Drunk driving or drunk riding (cyclists/mopeds)	0-0,5‰
		0,51-0,8‰
		0,81-1,6‰
		> 1,6‰
Influenced driving - drugs	Drugged driving/riding, legal (medicine)	Benzodiazepines
		Z-drugs
		Medicinal opiate
		Others (antidepressants etc.)
	Drugged driving/riding, illegal	THC
		Cocaine
		Amphetamines
		Illegal opiate
		Synthetic drugs
	Combined usage	Combined usage
Risk taking	Risky overtaking	Risky overtaking: wrong side
		Without adequate visibility
		Without warning others
		Into oncoming traffic
	Headway distance	Misjudgement
		Tailgating
Fatigue	Not enough sleep	Not enough sleep
		Sleeping disorders
	Driven a long time	Driven a long time
Distraction and inattention	Distraction within vehicle or within the riding or walking	Conversation with person, passenger/codriver
		Music, entertainment systems

Topic	Subtopic	Specific risk factor
	situation	Cell phone use - talking - handheld mode
		Cell phone use - talking - hands-free mode
		Cell phone use - texting
		Operating devices (IVIS, navigation systems etc.)
		Animals, insects, others
		Consumption of goods (eating, drinking, smoking)
	Distraction outside vehicle (if car user)	Watching persons, situations
		Static objects (advertisement, traffic management information etc.)
		Sun, other vehicles' lights
	Distraction through state of mind and cognitive overload	Distraction through state of mind (pondering etc.) and cognitive overload
	Inattention	Inattention, daydreaming
Functional Impairment	Reduced vision (Adaptation, visual field, visual acuity, Contrast perception)	Night time driving
		Safety margins
		Pedestrian detection
		Road sign recognition
		Driving out of a tunnel
		Manoeuvring
		Permanent impairment (physical condition)
		Missing out auditory information of other road users
	Reduced hearing	Decreased driving performance under presence of distractors
		Missing out auditive information of other road users
		Permanent impairment (physical condition)
	Cognitive impairment	Dementia
		Alzheimer disease
		Mild cognitive impairment
		Parkinson's disease
		Depressive symptoms
		Other psychiatric disorders
Insufficient skills	Skills (motor etc.), operating errors	Vehicle manoeuvring related (control of speed and position, shifting...)
		Traffic situation related (communication, speed adjustment, observation...)
		Trip related (planning the trip)
		Control over how life goals and personal tendencies affect driving behaviour
Insufficient knowledge	Knowledge	Knowledge about effects of vehicle properties
		Traffic situation related (knowledge of traffic regulations)
		Trip related (knowledge of location, effects of time pressure in car...)
		Knowledge about life goals and personal tendencies affect

Topic	Subtopic	Specific risk factor
		driving behaviour
Emotions & Stress	Intrinsic stress	Overburdened
	Extrinsic stress (time pressure)	Time pressure
	Positive emotions	Euphoria
	Negative emotions	Aggression / anger
		Fear / anxiety
Misjudgement & Observation Errors	Misjudgement of oneself	Underestimate of own speed
		Misjudgement of braking distance / acceleration
		Misjudgement of behaviour of own car or two-wheeler (dynamic, stability...)
		Misinterpretation of driver assistance information
	Misjudgement of others / situation	Speed
		Distance
		Development of situation
		Misunderstanding between road users
	Observation errors	Missed
		Late
		False
Traffic Rule Violations	Red light running	Red light running
	Disregard of right of way	Not yielding for pedestrians at ped. Crossing
		Running stop sign / yielding sign
	Disregard of obligatory usage of car devices	Not using vehicle light when dark
		Not indicating direction
	Wrong way driving	One-way roads
		Wrong side of road
	Using road lane dedicated to other road user or for other function	Bus lanes
		Truck lanes
		Emergency lanes
		Cycle lanes
Personal Factors	Sensation Seeking	Sensation Seeking
	Type A personality (impatience, time urgency, and hostility)	Type A personality (impatience, time urgency, and hostility)
	ADHD/ADD etc.	ADHD/ADD etc.
	Locus of control	Locus of control
	Introversion/Extraversion	Introversion/Extraversion
Age	Children (4-12 years)	Children (4-12 years)
	Adolescents (12-18 years)	Adolescents (12-18 years)
	Young people (18 -24 years)	Young people (18 -24 years)
	Elderly (65+)	Elderly (65+)
Diseases and disorders	Diabetes	Type A

Topic	Subtopic	Specific risk factor
		Type B
	Epilepsy	Epilepsy
	Influenza	Influenza
	Psychiatric disorders	Anxiety Disorder
		Mood disorder
		Psychotic disorder
		Personality disorder
		Impulse control disorders
	Sudden illness	Heart attack, stroke
		Fainting

Table 2: Road User Measures Taxonomy

Topic	Subtopic	Specific countermeasure
Law and enforcement	Speeding	General police enforcement, speeding
	Drunk driving/riding	Random breath testing
		DUI checkpoints/selective breath testing
		Lowering BAC limits
		BAC limits for specific groups (novice or professional drivers)
	Drugged driving/riding (illegal)	Drugged driving/riding enforcement
	Aggressive and unsafe driving/riding	Aggressive driving enforcement
	Fatigue, professional drivers	Hours of service regulation
	Distraction	Laws restricting the mobile phone use (hand held)
		Laws restricting the mobile phone use (hands free)
		Enforcement of driving while using the mobile phone
	Seat belt	Seat belt law and safety effects
		Seat belt enforcement
	Child restraint	Child restraint law and safety effects
	Protective clothing (excluding helmet)	Protective clothing
	Helmet, cyclists	Helmet wearing law
		Law on helmet standards
		Safety effect of helmet
	Helmet, PTW	Helmet wearing law
		Law on helmet standards
		Safety effect of helmet
	Red light running	Safety cameras/red light cameras
		General police enforcement
	No specific risk factor targeted	Fines and penalties
		Demerit point system
		General police enforcement and patrolling, no specific violation
Education and voluntary trainings/programs	Children/pre-school, primary school	Pedestrian
		Cycling
		Road safety, general
	Adolescents/secondary school	Pedestrian
		Cycling
		Road safety, general
	Young/novice	Driving

Topic	Subtopic	Specific countermeasure
		PTW riding
		Road safety, general
	Elderly	Pedestrian
		Cycling
		Driving
		PTW riding
		Road safety, general
	General population	Usage and fitting of child restraint
		Pedestrian
		Cycling
		PTW riding
		Driving
		Hazard Perception
		Adverse conditions (weather, light)
		Unsafe, risky behaviour
		Rewarding programs
		Road safety, general
	Professional drivers	Truck
		Bus, coach
		Car, van
		Road safety, general
Driver training and licensing	Formal pre-license training	Duration
		Content
		Test
	Graduated driver licensing and probation	General effect of graduated driving licenses
		Speed restriction
		Night-time driving restriction
		Passenger restriction
		Other driving restriction
	Health requirements for initial registration	Private vehicles (car, motorcycle)
		Commercial vehicles (truck, bus, taxi)
	Required age for initial registration	Required age for initial registration
	Accompanied driving, riding	Accompanied driving, riding
Fitness to drive assessment (FDA) and rehabilitation	Offenders	FDA
		Rehabilitation
		Alcohol interlock

Topic	Subtopic	Specific countermeasure
	Young offenders, drivers	FDA
		Rehabilitation
	Medical referrals	Dementia
		Medical referral, other
	Elderly drivers	FDA (Screening)
	Professional drivers	FDA (Screening)
Awareness raising and campaigns	Speeding and inappropriate speed	Speeding and inappropriate speed
	Distraction	Distraction
	Driving under the influence (alcohol and drugs)	Driving under the influence (alcohol and drugs)
	Fatigue	Fatigue
	Seat belt	Seat belt
	Child restraint	Child restraint
	Helmet, protective clothing and visibility	Helmet, protective clothing and visibility
	Aggressive and unsafe behaviour	Aggressive and unsafe behaviour
	Campaigns in general	Campaigns in general

Table 3: Infrastructure Risk Factors Taxonomy

Topic	Subtopic	Specific risk factor
Exposure	Traffic flow	Traffic volume
		congestion
		secondary crashes
		varying traffic composition
		distribution of traffic flow over arms at junctions
		absence of access control
Road type	Road type	Road type
Road surface	Road surface deficiencies (risk of ran-off road)	inadequate friction
		uneven surface
		ice, snow
		oil, leaves, etc.
Road environment	Poor visibility and lighting	poor visibility - darkness
		poor visibility - fog
	Adverse weather	rain
		frost and snow
		wind
Work zones	Work zones	work zone length
		work zone duration
		insufficient signage
Alignment deficiencies - Road segments	Horizontal/vertical alignment deficiencies	low curve radius
		absence of transition curves
		frequent curves
		densely spaced junctions
		poor sight distance - horizontal curves
		high grade
		vertical curve radius
		presence of tunnel
		poor sight distance - vertical curves
Cross-section deficiencies - Road segments	Superelevation / cross-slopes	Superelevation at curve
		cross-slope

Topic	Subtopic	Specific risk factor
	Lanes deficiencies	number of lanes
		narrow lanes
	Median / barrier deficiencies	undivided road
		narrow median
	Shoulder and roadside deficiencies	absence of paved shoulders
		narrow shoulder
		risks associated with safety barriers
		absence of clear-zone
		roadside obstacles
		sight obstructions (landscape, obstacles and vegetation)
		absence of sidewalks
		narrow sidewalks
Traffic control - Road segments	Poor road readability	absence of traffic signs
		misleading or unreadable traffic signs
		absence of road markings
		absence of rumble strips
Alignment-junctions	Interchange deficiencies	ramp capacity
		ramp length
		acceleration / deceleration lane length
		absence of channelisation
		poor sight distance
	At-grade junctions deficiencies	high number of conflict points
		type of junction
		skewness / junction angle
		poor sight distance
		gradient
Traffic control - junctions	Rail-road crossings (risk of collision with train)	uncontrolled rail-road crossing
	Poor junction readability	uncontrolled junction
		misleading or unreadable traffic sign
		absence of road markings

Topic	Subtopic	Specific risk factor
		absence of marked crosswalks

Table 4: Infrastructure Measures Taxonomy

Topic	Subtopic	Specific countermeasure
Exposure	Traffic flow	flow diversion
		2+1 roads
		reversible lanes
		one-way traffic
		ramp metering
		access control
	Traffic composition	HGV traffic restrictions
		creation of HGV lanes
Infrastructure safety management	Formal tools to address road network deficiencies	road safety audits implementation
		road safety inspections implementation
		high risk sites identification
		land use regulations improvement
	Speed management & enforcement	reduction of speed limit
		dynamic & weather-variant speed limits
		individual dynamic speed warning
		speed cameras
		section control
		speed humps
		woonerfs implementation
		narrowing implementation
		30-zones implementation
		traffic calming schemes
		school zones speed reduction measures
Road type	Road type	upgrade / downgrade road class
		upgrade road to motorway
		creation of by-pass road
Road surface	Road surface treatments	improve friction (type of surface)
		road re-surfacing to improve evenness
		ice prevention / winter maintenance
Lighting	Visibility / Lighting treatments	installation of road lighting

Topic	Subtopic	Specific countermeasure
		improvement of existing lighting
Work zones	Work zones	work zone signage installation
		work zone signage improvement
		work zone length treatment
		work zone duration decrease
Alignment - Road segments	Horizontal & vertical alignment treatments	creation of weaving area
		increase horizontal curve radius (curve re-alignment)
		implement transition curves (curve re-alignment)
		reduce number of curves (re-alignment)
		reduce tangent length
		sight distance treatments (horizontal alignment)
		reduce gradient (re-alignment)
		increase vertical curve radius (curve re-alignment)
		sight distance treatments (vertical alignment)
Cross-section - Road segments	Superelevation / cross-slopes treatment	superelevation improvement
		cross-slope improvement
	Lanes / ramps treatments	increase number of lanes
		create speed change lane
		increase lane width
	Median / barrier treatments	installation of median
		increase median width
		change median type
		implementation of rumble strips at centre line
	Shoulder & roadside treatments	shoulder implementation (shoulder type)
		increase shoulder width
		change shoulder type
		safety barriers installation
		change type of safety barriers
		create clear-zone / remove obstacles
		increase width of clear-zone

Topic	Subtopic	Specific countermeasure
		removal of sight obstructions
	Delineation and road markings at road segments	installation of chevron signs at curves
		road markings implementation
		implementation of edge line rumble strips
		transverse rumble strips
	Sidewalks treatments	sidewalk installation
		increase of sidewalk width
	Cycle lanes	cycle lanes treatments
		cycle path treatments
		increase of cycle lane width
Traffic control - Road segments	Traffic signs treatments at road segments	traffic sign installation
		traffic sign maintenance
	Driver information and alert	variable message signs: incident / accident warning
		variable message signs: congestion / queue warning
		V2I schemes
Alignment-junctions	Interchanges treatments	convert at-grade junction to interchange
		increasing ramp width
		increasing ramp curve radius (ramp re-alignment)
		increasing acceleration / deceleration lane length
		increasing lane width
	At-grade junctions treatments	channelisation
		sight distance treatments
		convert junction to roundabout
		convert 4-leg junction to staggered junctions
		improve skewness / junction angle
Traffic control - junctions	Rail-road crossings	rail-road crossing traffic sign
		automatic barriers installation
	Traffic signs treatments at junctions	STOP / YIELD signs installation
		STOP / YIELD signs replacement
	Road markings at junctions	road markings implementation

Topic	Subtopic	Specific countermeasure
		implementation of marked crosswalk
	Traffic signals treatments	traffic signals installation
		improve traffic signals timing
		implementation of pedestrian signal phase

Table 5: Vehicle Risk Factors Taxonomy

Topic	Subtopic	Specific risk factor
Crashworthiness	Compatibility, Age & Underrun	LGV
		Passenger Cars
		Trucks / Bus
	Low Star rating (EuroNCAP)	Passenger Cars
		Pedestrian
Injury mechanism	Risk for unbelted occupants	Trucks / Bus
	Risk of injury in case of fire	Trucks / Bus
	Risk of injury in Rollover	Passenger Cars
		Trucks / Bus
	Risk to be injured in frontal impact (driver, front passenger ,rear passenger)	Passenger Cars
	Risk to be injured in rear impact	Passenger Cars
	Side impact : risk to be injured following nearside/farside impact	Passenger Cars
	Submarining & abdominal injury risk	Passenger Cars
Protective equipment design	Safety Equipment	PTW / ATV
Relevant factors in crash data	Accident characteristics & injury level	Bicycles
		LGV
		Passenger Cars
		Pedestrian
		PTW / ATV
		Trucks / Bus
Technical defects / Maintenance	Technical defects	Passenger Cars
		PTW / ATV
		Trucks / Bus
Vehicle design	vehicle shape & Configuration	Pedestrian
		Trucks / Bus
Visibility / Conspicuity	Visibility, Conspicuity & Blind Spot issue	Bicycles
		LGV
		Pedestrian
		PTW / ATV
		Trucks / Bus

Table 6: Vehicle Measures Taxonomy

Topic	Subtopic	Specific countermeasure
Crashworthiness	Frontal impact	Directive 96/79/CEE et ECE.R94
		EuroNCAP (Full width & ODB)
		Frontal airbag
		PTW Airbag
		Seat belt (effectiveness) SBR and Load limiter included
		anti-submarining (airbags, seat bossage, knee airbag, seatbelt pretensioner,)
	Side impact	Directive 96/27/CEE et ECE.R95
		Regulation UN R135 (Pole side-impact protection)
		EuroNCAP (MBD & Pole)
		Side airbag (Head only Head + Thorax, Thorax + Abd + Pelvis, Farside airbag, curtain, ...)
	Rear impact	Regulation UN R32 (Behaviour of the structure in rear-end collision)
		Anti-Whiplash (Seat, active headrest, …)
		EuroNCAP (whiplash)
	Rollover	Airbag protection (Roof, curtains, …)
		Rollover protection system
	Pedestrian	Pedestrian protection (Active bonnet, pedestrian airbag, EuroNCAP, …)
		Pedestrian regulation
	Child	Child Restraint System (usage, fitting, misuse, ISOFIX, EuroNCAP, …)
	PTW	Helmet + Protective equipment (use & performance)
	Cyclist	Helmet + reflective equipment + lighting (usage + performance)
	HGV	Underrun protection (Front / Side + Lateral Side Guards / Rear)
Active safety / ADAS	Longitudinal	Emergency Braking Assistance system
		Autonomous Emergency Braking AEB (City, interurban)
		Autonomous Emergency Braking AEB (Pedestrians & cyclists)
		Emergency Stop Signal (ESS)
		Braking system PTW (ABS, Combined braking system, …)ABS (PTW)
		Collision Warning
		Intelligent Speed adaptation + Speed Limiter + Speed regulator
		Adaptive Cruise Control (ACC & ACC Stop & start)
	Lateral control	Electronic Stability Control (ESC)

Topic	Subtopic	Specific countermeasure
		Lane Departure Warning (LDW) + Lane Keeping Assist (LKA) + Lane Centring System
	Driver assistance	Drowsiness and Distraction Recognition
		Alcohol Interlock (ALC)
	Visibility enhanced	Enhanced Headlights (automated, adaptive, advanced system, ...)
		Night Vision
		Vehicle backup camera - Reversing Detection or Camera systems (REV)
		Blind Spot Detection
		Blind Spot mirror - Direct vision and VRU detection (VIS) for HGV
	Technical defects	ISO 26262 (road vehicles - functional safety)
		Tyre Pressure Monitoring and Warning
		Vehicle inspection
		Regulation ECE R13 (braking systems)
	Connected	Vehicle to Vehicle communication
Tertiary Safety	Post-Crash	eCall
		Rescue Data Sheet & Rescue code
		ECE R100 (Battery electric vehicle safety)
		Event Data Recorder

Table 7: Post Impact Care Measures Taxonomy

Topic	Subtopic
Ambulances/helicopters	response time
	specialized ambulances
	helicopter rescue
Extraction from vehicle	extraction from passenger car
	extraction from LGV
	extraction from truck
	extraction from bus
Pre-hospital medical care	care on scene vs move to hospital
	ATLS/PHTLS
	mobile medical teams, people in the team (specialist nurses, physicians,) and level of education
Triage and allocation to trauma facilities	triage
	trauma care organisation/regionalisation of trauma care/network of hospitals to choose appropriate hospital
	protocols for multiple casualty crashes
First aid training drivers	First aid training drivers

Table 8: Accident Scenarios Taxonomy

Accident scenario	sub-scenario / pre-crash configuration
Pedestrian Accident	pedestrian crossing road out of crossing path
	pedestrian crossing road on crossing path at straight stretch
	pedestrian crossing road in front of junction
	pedestrian crossing road behind junction
	pedestrian moving along the road
	vehicle reversing
	pedestrian sitting or lying on the ground
	pedestrian – changing mode (e.g. driver getting off the car)
	other pedestrian configuration
Bicyclist Accident	Bicycle alone
	Crossing configuration, Cyclist coming from farside (C1)
	Crossing configurations, Cyclist coming from nearside (C2)
	Same direction, Vehicle turning farside (T1)
	Opposite direction, Vehicle turning farside -T2)
	Opposite direction, Vehicle turning nearside (T3)
	Cyclist coming (nearside) farside,
	Vehicle turning (nearside) farside (T4)"
	Same direction, Vehicle turning nearside (T5)
	Same direction, cyclist ahead (L1)
	Same direction, cyclist ahead and changing lane (L2)
	Opposite direction, Cyclist turning nearside (FAR SIDE) (On)
	Dooring accident
	Other (Re)
Single vehicle accident	The vehicle leaving the road nearside - with rollover
	The vehicle leaving the road nearside - with object collision (tree, pole, wall, ...)
	The vehicle leaving the road nearside - without rollover / object collision
	The vehicle leaving the road farside - with rollover
	The vehicle leaving the road farside - with object collision (tree, pole, wall, ...)
	The vehicle leaving the road farside - without rollover / object collision
	The vehicle leaving the road - other configurations
	Collision with parked vehicle
	Collision with lost load
	Collision with animals on the road
	Falling bus occupant without collision
	Falling PTW without collision with another participant
	Other configurations (e.g. fallen tree)

Accident scenario	sub-scenario / pre-crash configuration
	Collision other obstacle, other impact
Head-on collision / Oncoming traffic	Head-on collision - overtaking
	Head-on collision - unintended lane change stable
	Head-on collision - unintended lane change instable
	Side collision with other participant oncoming - loss of control
	Other type of collision - unintended lane change instable
	Other oncoming traffic accident configuration
Rear-end collision / Same direction traffic	Standing vehicle (Rear-end collision while the vehicle ahead is standing)
	Breaking vehicle (Rear-end collision while the vehicle ahead is braking)
	Driving vehicle (Rear-end collision while the vehicle ahead is driving)
	Lane changing vehicle (Rear-end collision while at least 1 vehicle is changing lane)
	Side-swipe collision with other participant in same direction
	Other configurations (all configurations not included in the previous ones, e.g. overtaking, moving between lanes ...)
Junction accident (no turning)	No turning : participant required to yield crossing from nearside road
	No turning : participant required to yield crossing from farside road
	No turning : other
Junction accident (turning)	Turning : farside turn - other participant in direction (following or overtaking)
	Turning : farside turn - other participant in opposite direction
	Turning : farside turn - other participant from other road
	Turning : farside turn - both participant farside turning
	Turning : farside turn - other
	Turning : nearside turn - other road user in direction
	Turning : nearside turn - other road in opposite direction
	Turning : nearside turn - other road user from other road
	Turning : nearside turn - other
	Turning : other
Railway crossing	with barriers
	without barriers
	barriers unknown

Appendix C. Linking Risk Factors and Measures

The following is a reproduction of section 4.3 of :
Yannis G., Papadimitriou E. (Eds) (2018), The European Road Safety Decision Support System - A clearinghouse of road safety risks and measures, Deliverable 8.3 of the H2020 project SafetyCube.

LINKING RISK FACTORS AND ROAD SAFETY MEASURES

In the SafetyCube DSS, all risks considered in the SafetyCube taxonomies are intended to be linked to measures that have the potential of reducing this risk, and vice versa. There is obvious added value in this feature, as it will assist DSS users in:
(a) knowing which risks can be remedied by which types of measures
(b) knowing which types of risks will be reduced by a particular measure.
These links are meant to reflect situations where a user of the system would be looking for effective measures. This means a measure (e.g. winter maintenance) could be linked to a risk-factor (e.g. snow) but in the end turn out not to be effective. The idea behind this is to give users access to an evaluation of the measure whenever they might consider the measure a solution to their problem.

Review of current frameworks

A common framework for analyzing the accident process combining road user, infrastructure, vehicle and crash characteristics is **the multilevel hierarchical accident model**, according to which road users are 'nested' into vehicles / roads, and vehicles / roads are 'nested' into accidents (e.g. Vanlaar, 2005; Huang & Abdel-Aty, 2010; Dupont et al. 2013). This disaggregation of the accident process allows to take into account the crash characteristics that have common (and sometimes unobserved) attributes: road users in the same vehicle are more likely to sustain similar injuries, as they will be jointly affected by the vehicle speed, mass and protection; vehicles involved in the same accident will be jointly affected by the road traffic and environmental conditions at the crash site (e.g. weather, traffic, visibility, road design deficiencies etc.). This framework provides a meaningful linking of infrastructure, user and road characteristics, and has been mostly helpful in statistical modelling purposes, but is very microscopic and lacks the necessary extension to road safety measures.

Another common framework for analyzing road safety processes is **the Haddon Matrix** (Haddon, 1980; 1999), which provides a useful cross-classification of different crash components (road, user and vehicle) with the crash event configuration and evolution (i.e. pre-crash, crash, post-crash). The matrix was explicitly developed to shift the focus from the approach of simply "correcting human errors", jointly evaluate all the factors that contribute to road injury and provide a methodology to assess the effectiveness of a full range of potential measures (OECD/ITF, 2016). It thereby assists in evaluating the relative importance of different factors and design interventions, by targeting specific combinations of component and crash phase. It is helpful for a broad assessment but may be considered limited in the level of detail required for SafetyCube.

According to Hughes et al. (2016), **systems theory** and practices should be thoroughly applied to develop measures that improve the road system as a whole, rather than in isolation. The road system can be considered to be a socio-technical system, with road users, vehicles and road as the components that interact with each other in order to "produce" transport of people and goods (Larsson et al., 2010). A similar macroscopic approach is taken in the **SUNflower 'pyramid'** (Wegman et al., 2008), in which a six-level hierarchy is proposed, starting from structure and culture at the bottom level, to road safety programmes and measures, affecting first the operational level of road safety (e.g. road user behaviour) and then final outcomes.

However, SafetyCube is strongly based on a **Safe System approach**, which aims for *the ultimate prevention of death and serious injury through systematic intervention (pre-crash, during crash and post-crash as well as involving all key system elements) and more results-focused institutional delivery (safety performance framework, long-term goal interim targets, key safety performance objectives, shared accountability for results etc.)*. It should be underlined that systems approach and Safe System approach are not inconsistent – the former being accommodated in the latter in relation to intervention - but they are not the same. The systems approach is rather neutral in ambition and focuses merely on systematic intervention rather than results, intervention and institutional delivery aspects of road safety management covered by Safe System.

Elvik (2004) proposed **a theoretical framework for linking risks and measures in road safety**, starting from the concept suggested by Evans (1985, 1991). In this concept, a measure normally influences road safety by two causal chains: the engineering effect, and human behavioural feedback to engineering changes ("the behavioural effect"). The paper identifies nine distinct types of risk factors in the engineering effect and six types of behavioural adaptation effects. The idea behind this framework is that a risk factor arises as a result of either (i) physical hazards beyond road user control (e.g. a steep hill along the road) or (ii) inadequate behavioural adaptation among road users; a road safety measure will only be effective if it addresses risk factors arising this way. This framework has two unique contributions: first, the direct linking between risk factors and measures at a finer level of detail; and second, the separate consideration of risk factors as those that are beyond user control, and the behavioural ones.

The SafetyCube model for linking risks and measures

The proposed SafetyCube model for linking risk factors and measures is based on the conceptual framework of Elvik (2004) for the causal chain through which road safety measures influence road safety. More specifically, road safety measures may affect risk factors through two mechanisms: one related to 'generic' factors (i.e. which are beyond the user control) and one related to 'circumstantial' factors (i.e. crash-specific conditions), both eventually affecting road safety outcomes.

In the present approach, we extend this model by taking into account elements of the Safe System approach and the Haddon matrix, which in details means: (i) considering separately the system components i.e. road user, infrastructure and vehicle, (ii) considering the crash chain i.e. pre-crash, crash and post-crash separately and (iii) separately considering the road safety outcomes in terms of crash type and severity.

The **risk factors categories** can be described as follows:

- **Generic (pre-crash) risk factors**: refer to risk factors 'pre-existing' the crash and linked to system design and safety-related purpose. These have impact on the 'baseline risk' in association with combinations of user / vehicle / road infrastructure:
  - Infrastructure: the design of the road (alignment, safety barriers, road markings and traffic signs etc.), even when complying to safety standards, is associated 'by default' to a certain level of risk. For given categories of accidents, motorways are safer than rural roads,

roundabouts are safer than crossroads, etc. Design deficiencies such as a concealed sharp curve, inadequate safety railings, uncontrolled rail-road crossings etc. would also fall under this category.
    - Vehicle: different types of vehicles are 'by default' associated to different levels of risk, e.g. passenger cars are more stable than motorcycles, vehicles equipped with advanced passive safety technologies have higher safety potential than others etc.
    - Road user: regardless of driving behaviour, older road users have higher risk of accident involvement and injury severity (vulnerability); functional disabilities or impairment (e.g. visual or cognitive) will increase risk most probably regardless of the road and traffic conditions, personality characteristics and attitudes such as aggressiveness or risk-taking are inherent to the individual road user etc.
- **Circumstantial (crash-specific) risk factors**: refer to risk factors that may be present circumstantially, creating specific high-risk conditions (e.g. congestion, frost and snow, driving at night or under the influence, vehicle failure), over the 'baseline' risk level created 'by design'.

In many cases, risk factors pertaining to the two general categories above may 'act' separately or be inter-related. For example, a road design deficiency may cause crashes even when no human error or lapse takes place; an alcohol-impaired driver may cause a crash on a perfectly designed road and while driving a five-star vehicle. On the other hand, a young driver (generic risk factor) may be more prone to speeding behaviour (circumstantial risk factor), the risk of a sharp curve will increase with inadequate friction (e.g. due to poor road surface maintenance or rainfall) etc.

Sets of risk factors can be associated with different crash outcomes. These can be categorized as well:
- **Crash types**: different (combinations of) risk factors may affect different crash types; for instance, alcohol and speeding may be more strongly associated with single-vehicle ran-off road crashes, whereas junction design or road design (e.g. lack of median separation) may be more strongly associated with crashes involving two vehicles.
- **Crash consequences**: different (combinations of) risk factors may affect different crash outcomes, overall or within crash types. For example, older age and physical vulnerability may affect the occurrence of pedestrian crash (older pedestrians have higher crash risk) but will also affect injury severity in all types of crashes.

The idea underlying this proposed decomposition of risk factors and outcomes is that each crash is caused by a combination of circumstantial risk(s), which are possible consequences of pre-existing generic risks. The combination of risk factors then may result in specific crash types. Therefore, each risk factor contributing to a specific crash type and its possible outcomes must be assessed and addressed by one or more specific measure.

As a consequence, all **measures can be classified** as primarily addressing a different component of the accident chain:
- **Measures addressing generic risk factors**: these are measures targeted at the entire population or at the road network, tackling safety standards or safety cultures that induce generic risks: road safety management, education, training and licensing, vehicle regulations etc. belong to this category.
- **Measures addressing circumstantial risk factors**: these are more relevant to circumstantial risk factors, for example speed management measures, visibility measures (either infrastructure or vehicle related), enforcement and campaigns on specific topics, vehicle systems to detect fatigue, alcohol etc.
- **Measures addressing crash types**: there are several measures that aim at preventing specific crash types, regardless of the risk factor(s) causing the crash. A good example of these are ADAS

and in-vehicle systems for longitudinal and lateral cruise control. Lane Departure Warning systems warn in cases of running off-lane, regardless of whether this is caused by distraction, fatigue, alcohol, speed, inappropriate curve design or any other factor.

- **Measures addressing crash outcomes (injury severity)**: again, regardless of the risk factor that causes the crash, there are measures directly aiming at mitigating the consequences of the crash. These include passive safety systems, protective systems (seat belts, helmets and clothing) both in terms of legislation and enforcement, dealing with road visibility and obstacles.

An overview of the proposed model to 'link' road safety measures to risk factors is presented in Figure 1.

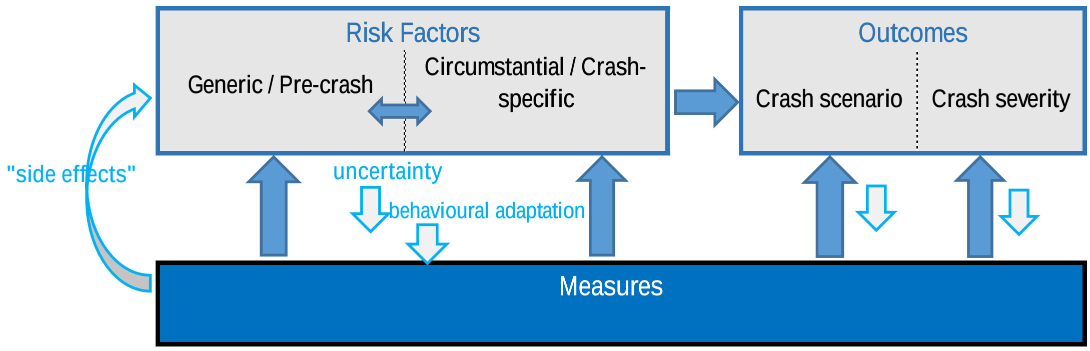

Figure 1. SafetyCube theoretical model for linking road safety risks and measures

There are two main point to note about the proposed framework:

First, it should be kept in mind that the expected **eventual effectiveness of measures** may be compromised:

- Due to **behavioural adaptation** of road users, e.g. infrastructure improvements may result in increased speeds.
- Measures may have other **"side-effects"** (such as the well-known accident migration downstream the intervention site, or the induction of new risks for instance safety barriers inducing risks for motorcyclists etc.)
- There is always **uncertainty** in the effectiveness of measures, which will always vary in different conditions or settings.

It is therefore underlined that the proposed model reflects the **theoretical potential of measures to address risks**. Only the existing evidence in the literature can give the final answer about the (current) strength of each link between a risk and a measure. The DSS contents (individual studies, synopses and meta-analyses) may thus "validate" or "conditionalize" the links, assist to understand the conditions of measures effectiveness and flag the sources of uncertainty.

Second, in the proposed framework Safety Cube addresses the **results of individual risks and measures rather than integrated programmes** needed to apply a Safe System approach. In Safe System, the linkages between intervention in a holistic approach are important, however this was not fully achieved in the present model. Moreover, although addressing different crash outcomes, the model does have death and serious injury prevention as its main focus, and this also limits the full implementation of a Safe System approach.

Implementation of the links

The steps taken in order to implement the links in the DSS can be summarized as follows:

- The SafetyCube risk factors from the taxonomies were classified according to the above model as generic, circumstantial, or directly affecting the crash outcomes.
- Next, it was tested how the SafetyCube taxonomies conform to the proposed model of chains of risk factors and outcomes. In each case, the implementation started from the circumstantial risk factors and proceeded to linking:
    - related generic risk factors,
    - other related circumstantial risk factors and
    - related crash types.
- Figure 2 demonstrates indicative examples with infrastructure, vehicle and behaviour circumstantial risk factors placed in the center.
- Accordingly, the SafetyCube measures from the taxonomies were classified as addressing different risks / outcomes in the accident chain.
- Finally, the above models and classifications were exploited to attempt the actual linking of risks and measures.

The links between risks and measures were finally implemented at the lowest level of the SafetyCube taxonomy. The relationship between risks and measures is a "one-to-many" relationship, as each risk factor can be addressed by different measures, and each measure may mitigate different risk factors.

All these elements are integrated in the DSS and taken into account when checking for measures that should be considered as remedies for a risk factor in question. Moreover, by linking risk factors to measures from different domains, an important aspect of the **Safe System approach** is emphasized for the user. As an example, when looking for measures linked to a road user related risk like "speeding", the user will be guided to measures that address road users (campaigns, demerit point systems) or infrastructure (speed humps, section control) or the vehicle (ISA, adaptive cruise control).

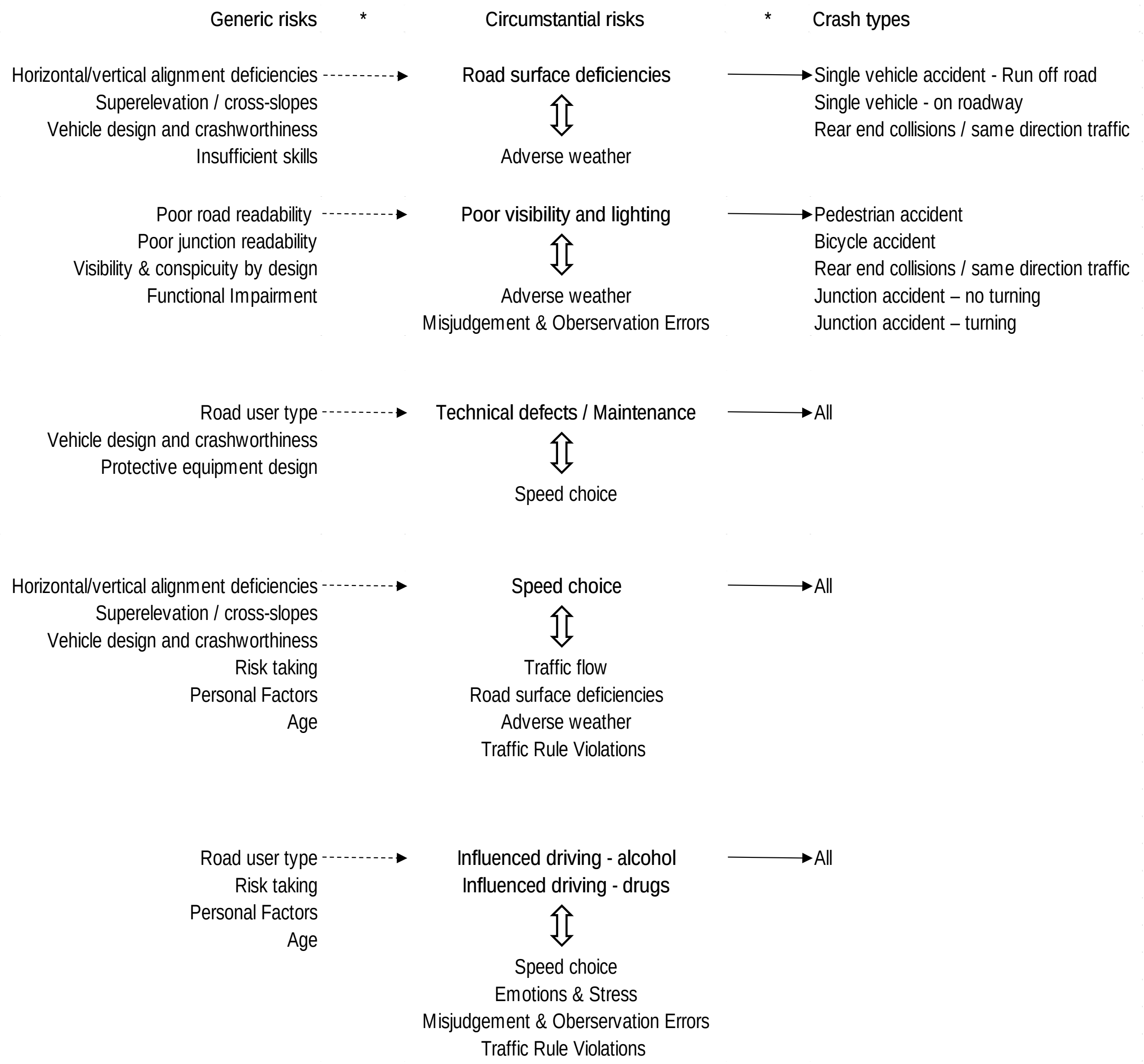

Figure 2. Examples of chains of risk factors and outcomes in SafetyCube taxonomies

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