Proceedings of 7th Transport Research Arena TRA 2018, April 16-19, 2018, Vienna, Austria

SafetyCube - the European Road Safety Decision Support System

George Yannis[a*], Eleonora Papadimitriou[a], Athanasios Theofilatos[a], Pete Thomas[b], Ashleigh Filtness[b], Heike Martensen[c], Wouter Van den Berghe[c], Kevin Diependaele[c], Rune Elvik[d], Klaus Machata[e], Susanne Kaiser[e], Eva Aigner-Breuss[e], Wendy Weijermars[f], Thierry Hermitte[g], Rob Thomson[h]

[a] *National Technical University of Athens, Department of Transportation Planning and Engineering, Iroon Polytechneiou 9, GR-15773, Athens, Greece*

b Loughborough University, Transport Safety Research Group, Loughborough Design School, Epinal Way, Loughborough, LE11 3TU, UK

c VIAS Institute, 1405 Haachtsesteenweg, B-1130 Brussels, Belgium

[d] *Institute of Transport Economics, Gaustadalleen 21, NO-0349 Oslo*

[e] *Kuratorium für Verkehrssicherheit (KfV), Schleiergasse 18, 1100 Vienna, Austria*

[f] *Stichting Wetenschappelijk Onderzoek Verkeersveiligheid (SWOV), Bezuidenhoutseweg 62, 2509 AC, The Hague, the Netherlands*

[g] *LAB, PSA Peugeot Citroën, 132 rue des Suisses 92000 Nanterre, France*

[h] *Divison of Vehicle Safety, Chalmers University, SE-412 96 Göteborg, Sweden*

Abstract

SafetyCube is a European co-funded research project which addresses generating new knowledge about accident risk factors and the effectiveness of measures relevant to Europe and integrating it into a European Road Safety Decision Support System (DSS). The DSS is the only system worldwide that includes, in addition to measures, quantitative information on risk factors as well. It is also the only system worldwide which exhaustively covers behaviour, infrastructure, vehicle and post-crash care topics. The DSS was designed and developed in close consultation with numerous road safety stakeholders who provided feedback on user needs and desired functionalities. It is populated with more than 1200 studies (more than 7000 effects) on risk factors and safety measures, electronically coded and stored in a sophisticated back-end database. The studies were selected and analysed by means of a dedicated common methodology. Meta-analyses or other pertinent techniques were applied to produce comprehensive synopses for all topics. The DSS also provides cost-benefit evaluations and all the related analytic background. A user friendly interface provides a powerful and flexible search engine which allows the user to access the individual studies and a series of synopses evaluating each considered topic. The system includes five entry points to meet the needs of different DSS users: keyword search, risk factors search, measures search, road user groups search, and accident scenarios search. The development of the DSS presents a great opportunity to support decision making at local, regional, national and international level. The DSS is a powerful tool intended to become a major source of information for industry, policy-makers and the wider road safety community.

Keywords: road safety; decision support system; road safety measures.

[*] *Corresponding author. Tel.: +30-210-7721326; fax: +30-210-7721454.*
E-mail address: geyannis@central.ntua.gr

1. Background and objectives

Evidence based road safety policies are becoming more desirable and there is increasing availability of national data which can be used to inform policy. However, in order for road safety policies to be effective there is a need for state of the art knowledge and understanding of accident risk factors and potential measures to address them. Existing road safety Decision Support Systems worldwide have a number of limitations. For instance, the CMF Clearinghouse (FHWA) has a focus only on CMFs on infrastructure. Similarly, the Road Safety Engineering Kit (AustRoads) and the PRACT Repository (CEDR) have a focus on infrastructure measures only.

SafetyCube (Safety CaUsation, Benefits and Efficiency) is a European funded research project under the Horizons 2020 programme which addresses these gaps by generating new knowledge about accident risk factors and the effectiveness of measures relevant to Europe and integrating it into a European Road Safety Decision Support System (DSS).

The SafetyCube DSS aims to enable policy-makers and stakeholders to identify, select and implement the most appropriate strategies, measures and cost-effective approaches to reduce casualties of all road user types and all severities. Road safety stakeholders at the local, regional and national level, as well as the EU level and beyond have been consulted at all stages of the project. The SafetyCube DSS combines road user, infrastructure, vehicle and post impact care aspects framed within a Safe Systems approach. Another major gap of knowledge that is addressed by this DSS is the linking between risk factors and the respective countermeasures, as most available systems and repositories so far are compilations of interventions and their impacts on crashes.

This paper aims to present the SafetyCube DSS development, in terms of both the methodology used to collect and analyse information, as well as the design and functionalities of the system (back-end database, user interface).

2. Methodology

The main features of the methodology behind the SafetyCube DSS population with high quality information can be summarized as follows, and detailed in the sections below:

i. Taxonomies of risk factors and measures
ii. Literature review and rigorous study selection criteria
iii. Template for coding studies, to be introduced in the DSS back-end database
iv. Synopses summarising results of risk factors / measures, by means of meta-analyses or other comprehensive synthesis, to estimate the effects of risk factors / measures.
v. Links between risk factors and measures within a systems approach.
vi. Quality Assurance
vii. Economic Efficiency Evaluation of measures

2.1. Taxonomies of risk factors and measures

The risk factors and the measures included in the DSS were identified based on a systematic analysis of the road safety literature. The risks and measures were assigned to one of four main areas: a) Road users, b) Infrastructure, c) Vehicles, d) Post impact care (only measures). The draft taxonomy was systematically evaluated during four workshops, where stakeholders were asked to prioritise and indicate missing topics. Three workshops were directed to a general audience of road safety policy makers and practitioners, one was focused on infrastructure. For each of the risk and measures areas, a three-level taxonomy was developed consisting of the main topic at the first level, several subtopics on a second level, and, if appropriate, specific topics at a third level.

2.2. Literature review and study selection criteria

To identify relevant studies for the inclusion into the DSS, a systematic scoping review was conducted for each item in the taxonomy. The aim of this approach is to represent the body of literature in a scientific way. While the criteria applied differed between research fields, there was a schematic approach followed for each review, consisting of initial search, screening, identifying additional papers, and prioritizing papers for coding. All SafetyCube partners have been querying all commonly available scientific literature databases such as Scopus, TRID, Google Scholar, Science Direct, Taylor & Francis Online, and Springer Link. The potentially relevant

studies were then screened to assess their eligibility for further analysis. Generally, only studies with quantitative results were coded for the database. This was done first on the basis of the abstract, then on the basis of the full paper. If few relevant papers had been retrieved, the reference lists of the selected papers were examined to identify any additional relevant papers. Table 1 below, provides a summary overview of the taxonomy utilized in SafetyCube.

Table 1. Overview of SaferyCube taxonomy - higher level risk factors and measures

	Risk Factor	Measure
Road Users	Speed Choice	Law and Enforcement
	Influenced Driving – alcohol	Education and Voluntary Training/programs
	Influenced Driving – drugs	Driver Training and Licensing
	Risk Taking	Fitness to Drive Assessment and
	Fatigue	Rehabilitation
	Distraction and Inattention	Awareness Raising and Campaigns
	Functional Impairment	
	Insufficient Knowledge	
	Emotion and Stress	
	Misjudgement and Observation Errors	
	Traffic Rule Violations	
	Personal Factors	
	Age	
	Disease and Disorders	
Infrastructure	Exposure	Exposure
	Road Type	Infrastructure Safety Management
	Road Surface	Road Type
	Road Environment	Road Surface
	Workzones	Lighting
	Alignment Deficiencies – Road Segments	Workzones
	Cross-section Deficiencies – Road Segments	Alignment – Road Segments
	Traffic control – Road Segments	Cross-section – Road Segments
	Alignment – Junctions	Traffic Control – Road Segments
	Traffic Control - Junctions	Alignment – Junctions
		Traffic Control - Junctions
Vehicles	Crashworthiness	Crashworthiness
	Injury Mechanism	Active Safety/ADAS
	Protective Equipment Design	Tertiary Safety
	Relevant Factors in Crash Data	
	Technical Defects/Maintenance	
	Vehicle Design	
	Visibility/Conspicuity	
Post impact care	-	Ambulances/Helicopters
		Extraction from Vehicle
		Pre-hospital Medical Care
		Triage and Allocation to Trauma Facilities
		First Aid Training for Drivers

For several of the risk factors and measures, meta-analyses were already available. If this was the case, the most recent meta-analysis was used as the basis, and completed with additional studies published after, and consequently not included in that meta-analysis. Studies included in a meta-analysis were not included individually. If there were too many other papers, they were listed in descending order of importance for the road safety DSS, based on outcome, transferability, recent publication date, language and source. Papers that evaluated measures and risks in terms of observed crashes were considered most relevant, followed by evaluation studies based on observed road safety behaviour (e.g. speeding) and finally studies that had other indicator variables as outcomes (e.g. self-reported behaviour, etc.). SafetyCube is focused on Europe, therefore prioritizing European studies. Other criteria such as publication date (recent studies before older studies etc.) were also applied.

2.3. Study coding through a dedicated template

The collected studies investigated the effect on different outcome variables: crash-counts, simulated crash data, injury severity, on-road driving, driving in a simulator, crash simulations, and so on. They employed a large variety of research designs: before-after studies, cross-sectional designs, case-control, induced exposure, time-series; and statistical methods: simple comparisons of counts or means, different types of regression analyses, empirical Bayes, hazard rate, to name just a few. The enormous differences between studies constitute a big challenge for the creation of a joint database. The structure has to be general enough to allow coding different kinds of safety- or risk effects and flexible enough to capture all important details of different types of studies. For each study, the template therefore includes general information of the sampling frame and study conditions (e.g. road user types, severity of crashes, road types included), but also allows for the inclusion of conditions that are relevant to the specific area only (e.g. the differentiation between different injury types or details of the roadway design). Furthermore, for each estimated effect the following specifications were registered:

- what was compared to what;
- analysis method/model;
- measure of effect (often odds ratio but also many other less commonly used measures of effect);
- statistical results (standard error, confidence interval);
- conclusion (significant effect on road-safety or not).

The selected studies were individually coded in an Excel coding template. The coding template consisted of several sheets, requiring the researcher to provide information, mostly in predefined categories. On the basis of the study features coded, a result Table shapes itself in which the results for all conditions that were coded can be entered. Another important issue is the quality of research results, as the definition of a good quality study is very difficult and again varies strongly with the research area. Rather than rating the studies, it was decided to indicate possible biases of a particular study. To this end, common biases for the major research designs, such as non-representative sample, unknown validity of the of experimental task, regression to the mean and so on were described and included into the coding template.

2.4. Synopses of results and ranking of risks / measures

After having coded all selected studies, the researchers analysed the results. Three ways had been defined to analyse and summarise the results, in a decreasing order of priority:

- Meta-analysis, if there is a sufficiently large number of studies that are comparable in terms of both their scientific design features and the type of results they produced.
- Vote-count analysis, if a meta-analysis is not possible due to large differences between studies.
- Review-type analysis, if the number of studies is small or if the studies are so heterogeneous that a vote-count analysis is not meaningful. In a review-type analysis the results are summarized in a more qualitative way.

For each of the studied risk factors and measures, a colour code was based on the results of the (majority of) the studies' outcomes to indicate the overall conclusion about the effect, as shown in Table 2.

Finally, for each risk factor and each road safety measure, a synopsis has been drafted. The synopsis provides a synthesis of the findings for a specific risk factor or road safety measure, including both quantitative information from the coded studies and more qualitative information from previous review studies. Each synopsis consists of three parts:

a) Summary: In maximum two pages, the summary very briefly reports some background of the topic concerned, and the main results and conclusions based on the analysis.,
b) Scientific overview: In approximately four to five pages, the scientific overview describes the essence of the way the reported effects have been estimated, including a full analysis of the methods and results and its transferability conditions in order to give the user all the necessary information to understand the results and assess their validity and
c) Supporting document: The supporting document gives a more elaborate description of the literature search strategy, as well as the details of the study designs and methods, the analysis method(s) and the analysis results. Here, also a full list of coded studies and their main features is provided.

Table 2. Colour code for ranking risk factors and measures

	Risk factor		**Countermeasure**
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.
Orange	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.		
Green	Results consistently show that exposure to the presumed risk factor does not increase risk.	**Red**	Results consistently show that the countermeasure does NOT reduce road safety risk and may even increase it.

2.5. Links between risks and measures

All risks in the SafetyCube taxonomies are intended to be linked to measures that have the potential of reducing this risk. This means a measure (e.g. skid training) 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 to be a solution to their problem. The links between risks and measures are based on a dedicated model categorising risks as to (Elvik, 2004):

- Generic risks, concerning the general state of the transport system (e.g. design of roads or vehicles, knowledge of the road users, etc.)
- Circumstantial risks, concerning the transient state of the system at the moment the crash occurred (e.g. defects, environmental conditions, road-user impairment, etc.),
- Consequences of a crash.

Finally, all risk factors were categorised according to their relation to particular crash types. The interaction of risk factors and the chain of events of the crash is taken into account within this framework, acknowledging that several risk factors may be involved in a particular crash type, and therefore a number of solutions may exist respectively. Moreover, by linking risk factors to measures from different domains, the systems approach is achieved. As an example, when looking for measures linked to a behavioural risk like “speeding”, the user will be guided to measures that address behaviour (campaigns, demerit point systems) or infrastructure (speed humps, section control) or the vehicle (ISA, adaptive cruise control) when appropriate.

2.6. Economic Efficiency Evaluation of measures

The measures for which the analysis of safety effects has resulted in a significant estimated reduction of crash occurrence (e.g. green or light green colour code) were further analysed by means of economic efficiency evaluation. A tool for Economic Efficiency Evaluation (E3-calculator) of road safety measures was implemented in the DSS. This tool allows to combine the information about the effectiveness of a measure (i.e. the percentage of crashes or casualties prevented) with the costs of these measures. Different outputs are produced on the basis of different scenarios, defined on the basis of sensitivity analysis (e.g. confidence intervals of the best estimate of the safety effect, scenarios of under- or over-estimated measures costs, and their combinations).

In a cost benefit analysis, outcomes of different severity can be considered jointly by including a monetary valuation of these outcomes (Martensen et al., 2016; Wijnen et al., 2009; Hakkert and Wesemann, 2004; Elvik, 2001). To build the E3-calculator, the estimated costs for crashes and casualties of different severity have been collected from all European countries (Wijnen et al., 2017). For more information, the reader is encouraged to follow Martensen et al. (2017).

2.7. Quality Assurance procedures

The scientific quality of contents of the SafetyCube DSS has been a top priority during the development phases. Strict quality assurance procedures were put in place for the validation of the numerous outputs (coded studies,

synopses, cost-benefit analyses), comprising several steps:

- Comprehensive guidelines, supported by workshops, webinars, Q&A sessions, and a help desk, assisted the SafetyCube researchers with their work.
- The selection and coding of studies, as well as the analyses and synopses of the findings were peer reviewed within the project.
- A small pool of independent experts checked both the outputs of individual coded studies and the overall contents of the synopses, applying a set of predefined quality criteria. One expert specifically looked at consistency within and between synopses.
- All synopses went through a language check by a native English speaker.

3. Development of the DSS

3.1 Structure and characteristics of the DSS

The DSS is available at the following URL: http://www.roadsafety-dss.eu. Its pilot operation started in early 2017 and is constantly updating until April 2018 (end of the SafetyCube project) and beyond. The system consists of the backend database (including more than 1200 studies, including more than 7,500 specific effects estimates), the front end website (user interface) and the way they integrate (queries). All SafetyCube outputs are undergoing a thorough debugging process before they can be introduced in the database. (Filtness et al., 2016).

The DSS Search Engine (i.e. the queries developed to retrieve information from the database), was developed on the basis of the following principles:

- Linked search: the user may search a road safety problem alone or through the measures, search a measure alone or through the road safety problems, search for risks and measures related to specific road user groups or crash types, and so on.
- Fine level of detail: the user may refine the search and filter the results with many parameters among those found in the database (e.g. road types, road user groups, countries etc.)
- Flexibility: the user my continuously adjust the search according to the results
- Transparency: the process is fully documented and the user may access background information at any stage (links, etc.)

The SafetyCube DSS is structured in three operational levels plus an initial level for the Home Page (Level 0: Home Page, Level 1: Search Pages, Level 2: Results Pages, Level 3: Individual study pages) reachable through five entry points (keywords, risk factors, measures, road user groups, accident scenarios) as shown in Figure 1.

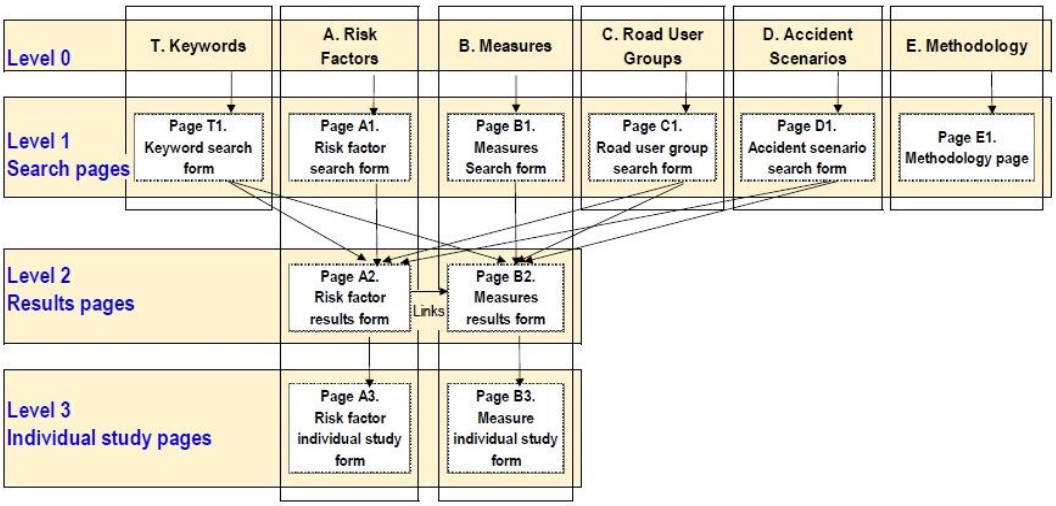

Fig. 1 Structure of the DSS

3.2. Search Page - System entry points

Level 1 consists of the specific search that the user wishes to carry out on the basis of five entry points (see Figure

2). The philosophy of this search is as follows:

- **Keyword search:** the system will let the user type in a keyword in free text and – as you type – will show all potential matches in the database. Once a keyword is entered (or selected from the dynamic pop-up list), the system will respond with the related subsets of risk and measure taxonomies for further selection.
- **Risk factors:** the user may search for a crash risk factor through the SafetyCube taxonomy
- **Measures:** the user may search for a road safety measure through the SafetyCube taxonomy
- **Road user groups:** if one wishes to inquire about risks or measures specifically related to a road user group, one may want to enter via the road user groups entry point. As for keyword search, the system will respond with the adequate subsets of risk and measure taxonomies – in relation to that road user group – for further selection.
- **Accident categories:** if one wishes to inquire about risks or measures specifically related to a specific accident scenario

It is important to highlight that all entry points at Level 1 eventually lead to a selection of risk factors or measures of interest at Level 2 (see also Figure 1). The more general level of the taxonomy is displayed and they can then choose for a general family of risks / measures (see Figure 2).

Fig. 2 The DSS entry points - Search page of the risk factors entry point

3.3. The DSS results page

Upon selecting an entry on one of the above lists (risk factors or measures), the main results page will appear. The results consist of (see Figure 3):

- Short introductory texts and the colour code(s), describing the risks or the effectiveness of measures

- Links to the available SafetyCube synopses on the issue (pdf link button next to the colour code)
- A Table listing the available meta-analyses and other coded studies in the SafetyCube database together with their main characteristics such as design, country, and year of publication. Selecting a study from the Table will lead the user to the individual study page.
- Depending on the selected domain, adaptive search filters are available on the left side of the results page. Filters include: specific risk factor, road user group, road type, country.
- A button which links to related measures (if the results page is in the risks domain) or to related risk factors (if the results page is in the measures domain).

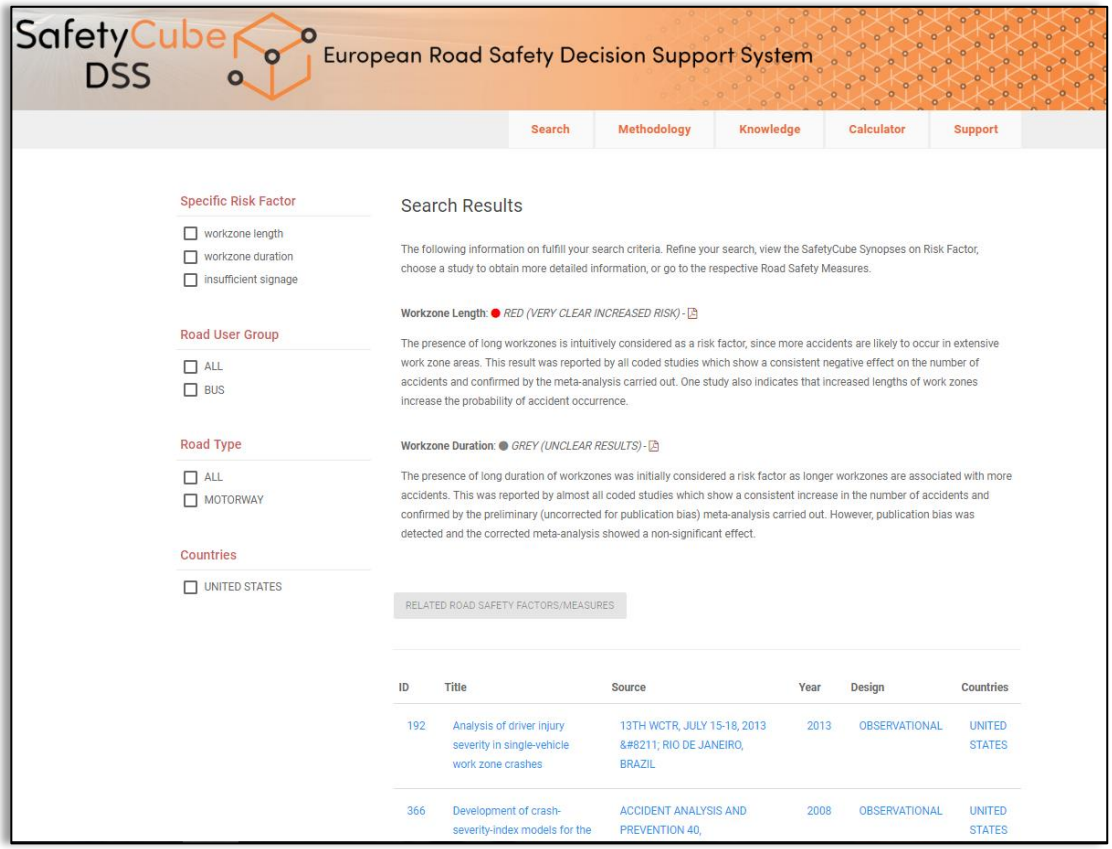

Fig.3 The Results Page of risk factor "work zones"

The "related risk factors / measures" button is activated only once a "Specific Risk Factor" or a "Specific Measure" is selected from the adaptive search filters on the Results Page on the left. Selecting one related risk factor / measure from the list, a table listing the available synopses and studies in the SafetyCube database for the related risk factor / measure appear. Adaptive search filters are also available on the left side. Then, selecting an entry of the table will take you to the individual study page.

3.4. The individual study page

The individual study results (see Figure 4) provided in Level 3, include the study abstract, the related URL, and a table of all risk / measure safety effects available in the study containing:

- test and reference condition (e.g. helmet vs. not helmet)
- type of outcome (e.g. injury severity)
- type of estimate (e.g. CMF, odds ratio)
- statistical significance.

The page also includes a summary of the main study features and findings, as well as an explicit outline of potential methodological issues or biases identified by the SafetyCube partner who analysed and coded the study.

Fig.4 The Results Page of risk factor "work zones"

3.5. The Calculator

If a study analysing a countermeasure results in an input suitable for an economic efficiency evaluation, a link will lead to the E3-calculator prefilled according to the study results. The user can change the input (e.g. select another country, or enter measure costs according to their own estimation) to evaluate how this changes the results in comparison to the prefilled SafetyCube analysis. The E3-calculator can also be used stand-alone (i.e. without input from SafetyCube), allowing users to perform their own cost-benefit analyses.

3.6. Other pages

The DSS includes the following additional pages:

- **Knowledge**: this page lists all risks and measures synopses developed in SafetyCube, including the links to their pdf. files, and further allows the user to sort them on the basis of risk factor or measure tackled, area (road user behaviour, infrastructure, vehicle or post-impact care), and colour code.
- **Methodology**: this page includes background information on the SafetyCube project, including the methodology, a disclaimer document with things to know when using the DSS, a glossary, as well as details on the Quality Assurance procedures.

- **Support**: this page presents contact information for user support, allows to download the Quick Guide that serves as the DSS manual, and to access a dedicated user feedback survey through which feedback can be sent to the SafetyCube partners.

4. Conclusions

The SafetyCube DSS main objective was to provide the European and Global road safety community with a user friendly, web-based, interactive Decision Support Tool in order 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 internal pilot operation started in early 2017. The beta-testing of the DSS was performed in mid-2017 and is constantly updating until April 2018 (end of the SafetyCube project) and beyond. The DSS includes more than 1200 studies in the areas of road safety risks or measures, with more than 3,500 risk estimates and 4,000 measure effects estimates, summarised in more than 130 synopses (including approximately 45 meta-analyses). It also includes several cost-benefit analyses of road safety measures.

Overall, it is the only road safety DSS with the following features:

- comprehensive and linked information both on crash risks and measures so that users are directed from problems to solutions on a user-friendly graphical interface
- locates both risks and measures in robust taxonomies, mapping the whole road safety domain, across the fields of human behaviour, infrastructure, vehicles and post-impact care.
- allows users with various backgrounds to benefit from the vast knowledge contained in the system by casting scientific evidence on every risk and every measure (or groups thereof) into comprehensive synopses, reachable through different entry points.

Moreover, the SafetyCube DSS is the first integrated road safety support system developed in Europe. It aims to be a core reference system for road safety in Europe, constantly improved and enhanced.

Therefore, the development of the DSS presents a great potential to further support evidence-based decision making at all levels, aiming to fill in the current gap of integrated risks and measures effectiveness evaluation across Europe and worldwide.

Acknowledgements

This paper is based on work carried out within the SafetyCube project of the H2020 programme of the European Commission (Grant number 633485). The information and views set out in this paper are those of the authors and may not reflect the official opinion of the European Commission.

References

Elvik, R., 2001. Cost-benefit analysis of road safety measures: applicability and controversies. Accident Analysis and Prevention, Vol. 33, pp. pp. 9–17.

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

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.

Hakkert, S., Wesemann, P. eds (2004). The use of efficiency assessment tools. Solutions to barriers. ROSEBUD Report Nr. 5.

Martensen, H., Diependaele, K., Van den Berghe, W., Papadimitriou, E., Yannis, G., Van Schagen, I., Weijermars, W., Wijnen, W., Filtness, A. Thomas, P., Machata, K., Aigner Breuss, E., Kaiser, S., Hermitte, T., Thomson, R., 2017. SafetyCube: Building a Decision Support System on Risks and Measures. Road Safety & Simulation International Conference, The Hague, 17–19 Oct 2017.

Martensen, H, Van den Bergh, W, Wijnen, W., Weijermars, W., Carnis, L, Elvik, R., 2016, Preliminary guidelines for priority setting between measures, Deliverable Number 3.4 of the H2020 project SafetyCube.

Wijnen, W., Wesemann, P. de Blaeij, 2009. Valuation of road safety effects in cost-benefit analysis. Evaluation and Program Planning, Vol. 32, pp. 326–331.

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.