Overview of the SafetyCube project: Towards a European Road Safety Decision Support System

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Abstract

Evidence based road safety policies are becoming more desirable and crucial for road safety improvements. The core of the SafetyCube project is a comprehensive analysis of accident risks and the effectiveness assessment and cost-benefit analysis of safety measures, focusing on road users, infrastructure, vehicles and post-impact care, framed within a Safe System approach, with road safety stakeholders at the national level, EU and beyond having involvement at all stages. The present work outlines the methods and outputs of developing the SafetyCube innovative road safety Decision Support System (DSS) which contains a wealth of road safety information.

Keywords

Road safety; evidence-based policy; risk assessment; measure effectiveness; cost-benefit analysis; decision support system

1. INTRODUCTION

The European Union (EU) has made substantial progress in improving road safety and reducing traffic fatalities. In the decade leading to 2010 the number of fatalities decreased by 45% and the total injured casualties by 30%. Nevertheless, in 2010, 31,000 fatalities still occurred on EU roads (WHO, 2015). Further casualty reduction now presents a considerable challenge to policy-makers, demanding development of measures that will reduce the number and societal costs of traffic crashes in a cost-effective and publicly acceptable manner. Moreover, in the present austere times where road safety budgets may be substantially reduced, the challenge of implementing the most cost-effective measures becomes more pronounced.

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. 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).

1.1 Aim of the 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. Therefore, the present paper aims to present the whole SafetyCube project and the SafetyCube DSS development in particular, in terms of both the methodology used to collect and analyse information, as well as the design and functionalities of the system.

1.2 Practical applications of the DSS

The SafetyCube DSS has a wide range of practical applications. Firstly, it is readily usable by a broad range of users, from academics to policy makers to road safety industry practitioners. It provides different levels of detail, from comprehensible summaries to technical and scientific effects for all examined road safety aspects. The DSS contains quantitative results for road safety risks and measure effects, and Cost-Benefit Analyses for selected measures, all based on a common methodology. This enables the detailed ranking of risk and measure impacts on road safety.

2. IDENTIFICATION OF USER NEEDS

2.1 Overview of Existing Systems

Existing road safety Decision Support Systems worldwide have a number of strengths but also considerable limitations when considering use on a European level.

1. The CMF Clearing House (www.cmfclearinghouse.org) is funded by the U.S. Federal Highway Administration. A CMF is an estimate of the change in crashes expected after implementation of a countermeasure. As of March 2018, it featured 6,251 CMFs across 19

categories of infrastructure measures (exclusively) with a quality assessment system. This system does not include any measures from the domains of human behaviour, vehicle technology or post impact care, and does not provide any assessment of road safety risks.

2. PRACT ("Predicting Road ACcidents – a Transferable methodology across Europe") (http://www.pract-repository.eu/) was developed by the University of Florence, the National Technical University of Athens, the Technical University of Berlin and the Imperial College London and financed by the Conference of European Directors of Roads (CEDR). The Repository contains the most recent Accident Prediction Models (APMs) and Crash Modification Factors (CMFs) – as of March 2018, 889 CMFs and 273 APMs and focuses in the sphere of infrastructural road features. It is designed for road infrastructural professionals with prior knowledge of theory and application of CMFs or APMs.
3. The Road Safety Engineering Toolkit (www.engtoolkit.com.au) was designed as a reference tool for road engineering practitioners in state and local governments. It is provided by Austroads and includes 67 types of infrastructural interventions, grouped in various combinations. The Engineering Toolkit is limited to infrastructure treatments. It is mostly focused on textual, easily accessible descriptions of safety deficiencies and countermeasures.
4. The iRAP Toolkit (http://toolkit.irap.org/) is the result of collaboration between the International Road Assessment Programme (iRAP) and other partners. It hosts information on 58 types of interventions, 42 on infrastructure, 5 on vehicle safety, and 11 on behaviour ("Safer People"). The Road Safety Toolkit is focused on common language advice on treatments across various fields of road safety work – excluding post impact care, and is not intended to directly support Cost-Benefit Analysis (CBA) and does not provide any assessment of road safety risks.
5. The UK Road Safety Observatory (http://www.roadsafetyobservatory.com/) has been developed by the UK Government, and has many features of a knowledge repository. The dose not directly support CBA and does not provide any structural assessment of road safety risks. There is no assessment of the quality of the underlying studies given.

2.2 Review of User Needs and Stakeholder Input – Identification of Hot Topics

The identification and assessment of user needs for a road safety DSS was conducted on the basis of a broad stakeholders' consultation. Dedicated stakeholder workshops yielded comments and input on the SafetyCube methodology, the structure of the DSS and identification of road safety "hot topics" for human behaviour, infrastructure and vehicles. One of the key challenges of SafetyCube, was detailed safety data analysis in support of road safety "hot topics", especially in areas that had not yet been properly evaluated. Therefore, the issue received prime attention in the first stakeholder workshops (Kick-off & Stakeholder Workshop – Brussels 2015, Stakeholder Workshop – Ljubljana 2015, Infrastructure Stakeholder Workshop – Brussels 2016, Mid-term workshop – Brussels 2016).

Several hot topics were given by stakeholders in these workshops, with several key priorities per section. For behaviour: drugged driving/riding, risk taking, insufficient skills/knowledge, functional impairments, diseases and disorders, sensation seeking and ADHD, distraction through conversation with passengers, music/entertainment systems and outside of vehicle, observation errors. Infrastructure input concerned four major areas: Urban road safety, Self-explaining and forgiving roads, Road safety management and ITS applications. Vehicle safety concerns were mainly over vehicle safety countermeasures effectiveness, new vehicle technology effects (autonomous vehicles, connected vehicles, ADAS), among others.

3. DESIGN OF THE DSS

3.1 DSS Design Principles

On the basis of the previous, the DSS Design principles, the general structure and the main functionalities were defined. The back-end database, the front-end system and the search engine that links the two were designed, resulting in a framework system ready to be populated with the wealth of information that was accumulated within SafetyCube.

3.2 Structure of the DSS

The DSS was developed after taking the prospective users' needs into account, as described in the previous section. The SafetyCube DSS was designed with a structure of three operational levels plus an initial 'dummy' level for the Home Page: Level 0: Home Page, Level 1: Search Pages, Level 2: Results Pages, Level 3: Individual Study Pages.

The Search Pages include a dynamic part and a static part. The dynamic part concerns a Search tab allows the user to query the DSS backend database and retrieve results for risk factors or measures, and the Calculator, a one-page web application which allows the user to retrieve one of the SafetyCube examples of CBAs or conduct their own. The static part includes additional one-level pages with supporting documentation, text and links including the Knowledge tab which compiles the SafetyCube key documents as a knowledge library, the Methodology tab with background information and the Support tab, with contact information and user guides.

4. POPULATING THE DSS

The main features of the methodology behind the SafetyCube project and the SafetyCube DSS population with high quality information can be summarized as follows, and detailed in the sections below: (a) Taxonomies of risk factors and measures, (b) Literature review and rigorous study selection criteria, (c) Template for coding studies, to be introduced in the DSS back-end database, (d) Synopses summarising results of risk factors/measures, by means of meta-analyses or other comprehensive synthesis, to estimate the effects of risk factors/measures, (e) Links between risk factors and measures within a systems approach, (f) Quality Assurance and (g) Economic Efficiency Evaluation of measures. A more detailed description of the methodological approach can be found in Martensen et al. (2018).

In order 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.

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 selected studies were individually coded in a purpose-made Excel coding template. The coding template consisted of several sheets, requiring the researcher to provide information, mostly in predefined categories. Rather than rating the studies, it was decided to indicate possible biases of a particular study.

After having coded selected studies, the researchers analysed the results. Three ways had been defined to analyse and summarise the results, in a decreasing order of priority:
(a) Meta-analysis, (b) Vote-count analysis, and (c) Review-type analysis. 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. Hence, an assessment and ranking of risks and measures took place.

Lastly, for each risk factor and each road safety measure, a synopsis has been compiled. 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, (b) Scientific overview, (c) Supporting document.

Another innovative aspect of the SafetyCube project is the fact that all risks in the SafetyCube taxonomies are intended to be linked to measures that have the potential of reducing this risk. This means that a measure could be linked to a risk-factor 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. Additionally, 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.

The measures for which the analysis of safety effects has resulted in a significant estimated reduction of crash occurrence were further analysed by means of economic efficiency evaluation. A tool for Economic Efficiency Evaluation (E^3 calculator) of road safety measures was implemented. 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. In a cost benefit analysis, outcomes of different severity can be considered jointly by including a monetary valuation of these outcomes. In order to develop the E^3 calculator, the estimated costs for crashes and casualties of different severity have been collected from all European countries.

Furthermore, serious injuries and their mechanics are also considered in the DSS, and their findings are discussed in more detail elsewhere (Pérez et al., 2018; Weijermars et al., 2018).

The scientific quality of contents of the SafetyCube DSS has been a main priority during the development phases. Strict quality assurance procedures were in place for the validation of the numerous outputs (coded studies, synopses, cost-benefit analyses), comprising several steps such as development of comprehensive guidelines, internal peer review of selection and coding of studies/analyses/synopses of the findings within the project, independent experts evaluation of the outputs of individual coded studies and the overall contents of the synopses and lastly a language check by a native English speaker.

5. DEVELOPMENT OF THE DSS

5.1 DSS Search Pages

The SafetyCube DSS Search is open since April 2017 and available at www.roadsafety-dss.eu. It is structured around two main pillars, i.e. risk factors and measures, and in three operational levels, as mentioned in section 3.2. These are reachable through five entry points (keywords, risk factors, measures, road user groups, accident categories).
More specifically, Level 1 consists of the specific search methods which the user may want to use, based on the five entry points. The philosophy of this search is as follows:

- Keyword search: search on the basis of keywords retrieved through the SafetyCube list of master keywords, numbering more than 500 terms (each one of them linked to one or more of the thousands of keywords from the coded studies).
- Risk factors: search for a crash risk factor through the SafetyCube taxonomy
- Measures: search for a road safety measure through the SafetyCube taxonomy
- Road user groups: search for the risks and measures concerning particular road user group.
- Accident categories: search for risks or measures related to a specific accident category.

The Structure of the DSS is visually showcased in Figure 1 and described in the following: In the DSS Results Pages, the user has numerous options: to refine the search through a set of filters (e.g. country, road user type, road type, more specific topic), to download the synopses available, to browse the related risks/measures, or to select one of the individual studies available for the topic.

Figure 1: Representation of the Structure of the SafetyCube DSS

In the DSS Individual Study Pages, the abstract and source of each study are provided, together with information on the design and sampling used, the estimates provided, their confidence intervals and the statistical significance. Links to the full text are also provided, depending on the access rights of each user.

The DSS E^3 Calculator consists of a web-based application of the E^3 tool, allowing the user either to perform their own Cost-Benefit Analysis, or select one of the SafetyCube examples of Cost-Benefit Analysis of selected effective road safety measures. In each case, the possibility to run a sensitivity analysis and compare the results on the same screen is provided. Finally, the DSS features additional Knowledge, Methodology and Support Pages as outlined in section 3.2.

6. CONCLUSIONS

6.1 The DSS in figures

Being now in its completed stage, the DSS includes the content described on Table 1:

Taxonomy, risk factors and measures:	**Links within a Safe System approach:**	**Contents and outputs:**
4 areas: road user, infrastructure, vehicle, post impact care	762 links between risk factors and measures. Risk Factors (118) are linked to one or more Road Safety Measure(s) (167) - A few risk factors or measures (e.g. post-impact care) were not “linkable”.	1300 studies (including more than 90 meta-analyses) including more than 7500 effects of risk factors or measures
88 risks and measures (38 risk factors, 50 measures) e.g. distraction, roadside, crashworthiness	3350 database keywords, reduced to 531 Master keywords	215 synopses on risk factors and measures effects & 8 Accident scenario synopses
313 specific risk factors and measures (120 risk factors, 193 measures) e.g. mobile phone use, no clear-zone	A total of 380 links between risks, measures and Accident Scenarios; 8 scenarios are linked with 109 specific risks and 271 specific measures	38 CBAs: Behaviour (12 examples), Infrastructure (19 examples), Vehicle systems (4 examples), Post-impact care (1 example)

Table 1: Description of the content available in the SafetyCube DSS

6.2 Added Value of the DSS and Transferability of its Content

The SafetyCube DSS is the first integrated road safety support system developed in Europe. It aspires 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.

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

- Includes 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
- Both risks and measures are located 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.

The information given in the Decision Support System about risk factors and road safety measures is taken from studies made in many countries during a long period. The question therefore arises if the results of a study made in one country at a certain time can be transferred to a different country at a different time. This issue is referred as the transferability of knowledge. Transferability is discussed in the synopses summarising knowledge about risk factors and road safety measures. In an earlier project, the concept of range of replications was developed. It was intended to indicate both the number of countries in which studies had been made and the length of time during which studies had been made (Elvik 2012). It is seen that the effects remain very stable over time (across replications) and as new countries have been added to those in which the effects of road lighting have been evaluated. This kind of stability supports a belief in transferability. Results have been found to be transferable between countries and over time so far. Additionally, it is possible to test the transferability of results in meta-analysis, which was conducted whenever enough data was available. For further reading and technical details the readers are referred to Yannis & Papadimitriou (2018).

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REFERENCES

1. CMF Clearinghouse (2013). FHWA, US Department of Transportation (www.cmfclearinghouse.org). Accessed 30-08-2018.
2. Elvik, R. (2012). The range of replications technique for assessing the external validity of road safety evaluation studies. Accident Analysis & Prevention, 45, 272-280.
3. iRAP Road Safety Toolkit (http://toolkit.irap.org/). Accessed 30-08-2018.
4. Martensen, H., Diependaele, K., Daniels, S., Van den Berghe, W., Papadimitriou, E., Yannis, G., ... & Talbot, R. (2018). The European road safety decision support system on risks and measures. Accident Analysis & Prevention.
5. Pérez, K., Weijermars, W., Bos, N., Filtness, A. J., Bauer, R., Johannsen, H., ... & Olabarria, M. (2018). Implications of estimating road traffic serious injuries from hospital data. Accident Analysis & Prevention.
6. PRACT (2016). Predicting Road Accidents - a Transferable methodology across Europe (http://www.pract-repository.eu/). Accessed 30-08-2018.
7. Road Safety Engineering Kit, Austroads, (www.engtoolkit.com.au), Accessed 30-08-2018.
8. 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.
9. UK Road Safety Observatory. (http://www.roadsafetyobservatory.com/). Accessed 30-08-2018.
10. Weijermars, W., Bos, N., Filtness, A., Brown, L., Bauer, R., Dupont, E., ... & Thomas, P. (2018). Burden of injury of serious road injuries in six EU countries. Accident Analysis & Prevention, 111, 184-192.
11. World Health Organization – WHO. (2015). Global status report on road safety 2015.