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Safety effects of infrastructure road safety measures

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Abstract

The objective of this study is the comparative assessment and ranking of a large number of infrastructure measures in order to aid road safety stakeholders reach informed decisions concerning the implementation of measures with an evidence-based approach. This analysis was carried out within the SafetyCube project, which aims to identify and quantify the effects of risk factors and measures related to behaviour, infrastructure or vehicle, and integrate the results in an innovative road safety Decision Support System (DSS). More than 260 high quality studies were examined for the aforementioned measure factors, including more than 30 recent and updated meta-analyses which provide results from a number of original works. This allowed the ranking of infrastructure related measures into three groups: clearly reducing risk (14 measures), probably reducing risk (21 measures), and unclear (13 measures). Obtained results provide state-of-the-art, comprehensive information for the examined measures that can be exploited both microscopically, for instance for site improvements, and macroscopically, for instance for strategic decisions.

Keywords: road safety; measure effects; infrastructure; meta-analysis

1. Introduction

The European Union (EU) has made substantial progress in improving road safety and reducing traffic fatalities. In the decade up to 2010, the number of fatalities was reduced by 45% and the total number of injured casualties was reduced by 30% (EuroStat, 2012). To further reduce the road toll it is necessary to understand the risks involved and select appropriate measures. Safety CaUsation, Benefits and Efficiency (SafetyCube) is a European Commission supported Horizon 2020 project with the objective of developing an innovative road safety Decision Support System (DSS) that will enable policy-makers and stakeholders to select and implement the most appropriate strategies, measures and cost-effective approaches to reduce casualties of all road user types and across all severities (since several measures have the benefit of mitigating all levels of injuries and fatalities).

One of the most critical factors affecting road safety outcomes is road infrastructure and environment (e.g. road type, geometrical design, traffic control, lighting and weather conditions, etc.) (Elvik et al., 2009). The European Commission and the European Road Safety Observatory (ERSO) release annual reports based on macroscopic data from CARE/CADaS, which include crash trends and developments related to road infrastructure (ERSO,

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2016a; 2016b; 2016c; 2016d). The available macroscopic data indicates that there are persistent road safety problems related to the road infrastructure and environment in the European countries, and particular issues regarding rural roads (including motorways), urban areas and junction areas. This raises the need for further insight into the identification of specific critical infrastructure treatments and their impact on road safety outcome indicators which is not possible through the analysis of the available macroscopic data alone.

The SafetyCube project aims to identify, analyze in-depth and rank the specific road network management, design, traffic control and environmental treatments that affect road safety outcomes. In this framework, the objective of this paper is to provide a comparative assessment and critical review of a variety of infrastructure related measures with the explicit purpose of ranking them based on how beneficial they are towards road safety outcomes (i.e. crash risk, frequency and severity). This evaluation was conducted by examining studies from the existing literature, selected and analyzed on the basis of a dedicated common methodology.

2. Methodology

Within the SafetyCube project, 'measure' refers to any intervention that contributes to the prevention of road accidents or the mitigation of their consequences. Measures can have a direct influence on the risk of an accident occurring, on the consequences of the accident (severity), or more indirectly by influencing a Safety Performance Indicator (SPI). All elements of the road system can potentially be improved by measures. For the analysis of infrastructure related measures, a dedicated methodology was developed as follows (Martensen et al. 2017):

- A taxonomy of measures was created, in order to systematically classify areas and topics to be analysed
- A dedicated methodology was developed for searching the literature and identifying the most relevant, high quality and recent studies; moreover, tools were developed in order to analyse studies and systematically code them and assess their findings.
- A stakeholders' consultation was carried out in order to identify "hot topics" in the field of infrastructure safety.

2.1. A taxonomy of infrastructure measures

The aim of creating a taxonomy is to identify the relevant topics covering all aspects of infrastructure and road environment measures, and structure them in a meaningful way (e.g. general topics, specific topics), to serve as the backbone of the analyses. A comprehensive list of measures specific to road infrastructure was created on the basis of several key publications (ERSO, 2016; Elvik et al. 2009; CEDR, 2008; ROSEBUD, 2006; SUPREME, 2007a and 2007b, OECD/ITF, 2012; PRACT, 2016; iRAP, 2016).

The entire taxonomy of measures utilized in the SafetyCube project is not presented here for reasons of space and the reader is referred to Machata et al. (2017). General categories of infrastructure elements were firstly considered and then 94 specific measures were assigned to the respective elements and measure categories. The 11 infrastructure elements that are examined and included are: Exposure, Infrastructure safety management, Road type, Road surface, Lighting, Workzones, Alignment - Road segments, Cross-section - Road segments, Traffic control - Road segments, Alignment – Junctions, and Traffic control – Junctions.

2.2. Identification of "hot topics" / Stakeholder contribution

The SafetyCube project had already identified a core group of stakeholders from government, industry, research, and consumer organizations covering the three road safety pillars: vehicle, infrastructure, road user. Several workshops and consultations took place from the beginning of the project. A more dedicated workshop was carried out with the participation of 12 road infrastructure stakeholders on February 22nd, 2016, in Brussels (SafetyCube, 2017). The participants represented key road infrastructure stakeholders, including EC-INEA, EC-DG-MOVE, EURORAP, ASECAP, ETSC, POLIS network, FIA, BRRC and Belgian regional authorities. The objectives of the workshop were the analysis of infrastructure stakeholders' needs for the DSS, as well as selecting "hot topics" from the infrastructure related topics from the taxonomy.

On the basis of the workshop results, it was indicated that the Decision Support System (DSS) should be suitable for use by a wide range of end users. It should not be limited to EU policy makers, but also be applicable for local authorities. It is intended that the system will help policy makers make an "informed decision". Moreover, it has to be an impartial system, which will not advocate for specific measures – the intention is "to guide, rather than to dictate". Using this structured approach to policy making should eventually enhance public acceptance of measures by providing a solid evidence base for decisions. It was also suggested that the DSS should include robust data, allowing for critical analysis and transparency, there should be access to the studies used and to all results as well. The main expected outcomes of the project in the area of road infrastructure are the following:

- Recommended good quality studies covering the topics at each taxonomy level
- Contextual information on studies (local, environmental, etc.), limitations of studies, implementation difficulties
- Conducting a meta-analysis where possible
- A range of solutions can be suitable for addressing any particular road safety problem

A complete list of "hot topics" identified through previous consultations was examined in the dedicated infrastructure workshop, to be given priority in the analyses. More specifically, the hot-topics were rated for relative importance by stakeholders. Both the general areas and the specific topics within each area were rated. The four main areas were prioritized in the following order of importance: A) Urban road safety measures, B) Self-explaining and forgiving roads (equally rated), C) Road safety management, D) ITS applications. The top rated specific risks and measures for each area are shown in Table 1. Consequently, the SafetyCube analyses will take this into account and put special emphasis on the highest priority topics.

Table 1. Prioritisation of "hot topics" by road infrastructure stakeholders.

A. Urban road safety (detailed ranking was not possible)	B. Self-explaining and forgiving roads	C. Road safety management	D. ITS applications
1.Pedestrians / cyclists	1.Removing obstacles	1.Quality of measures implementation	1.ISA
2.Upgrade of Crossings	2.Introduce shoulder	2.Appropriate speed limits	2.Dynamic speed warning
3.New crossings	3.Alignment (horizontal/vertical)	3.Enforcement	3.ADAS and active safety with V2I
4.Junctions/roundabouts treatments for VRU	4.Sight distance	4.Availability of cost-effectiveness data	4.Implementation of VMS
5.Visibility	5.Traffic signs	5.Workzones	
	6.Raised crossings/intersections		

2.3. Dedicated Methodology for the assessment of measures

The aim of the development of a common SafetyCube methodology was to collect information for each measures in a uniform way to allow for the ranking of measures in a standardised manner. This included developing a literature search strategy, a 'Coding template' to record key data and metadata from individual studies, and Guidelines for summarising the findings per measure.

Collating information from a variety of studies each of which may use different underlying theories, designs and methods presented a big challenge. Therefore the approach and 'coding template' developed was designed to be flexible enough to capture important information but also facilitate the comparison between studies. These documents and the associated instructions and guidelines can be found in Martensen et al. (2017).

2.3.1. Literature search and Study Selection

For each of the identified measure topics a standardized literature search was conducted in order to identify relevant studies to include in the Decision Support System (DSS) and to form a basis for a concluding summary (synopsis) and further analyses. A standardized procedure was developed and applied for each examined measure; however, in some cases insufficient literature was identified and some measures could not be evaluated. The literature searches were carried out between February and June 2017. The process was documented in a standard format to make the gradual reduction of relevant studies transparent. The main databases used to search for infrastructure measures were the following: Scopus, TRID, Google Scholar, Science Direct. Taylor & Francis Online, Springer Link.

The aim was to find studies that provided an estimate of the crash risk (or crash number) reduction due to the presence of the measure. Therefore, studies considering crash data were designated the most important, with a large emphasis on before-and-after crash studies. However, while the actual occurrence of crashes can be seen as the ultimate outcome measure for road safety, SPIs have in recent years been taken into consideration to quantify the road safety level (Gitelman et al., 2014). For some measures, studies considering SPIs are included in addition to those focusing directly on crashes.

Since the study design and the outcome variables are just basic criteria, for some measures the literature search had the potential to yield an excessive number of related studies and therefore additional selection criteria were adopted. Furthermore, on major and well-studied infrastructure measures, meta-analyses were available. While the aim was to include as many studies as possible for as many measures as possible, it was simply not feasible, given the scope and resources of the project, to examine all available studies for all measures and their variants. The general criteria for prioritizing studies to be selected for further analysis and eventual inclusion in the DSS were based on the following guidelines:

- Key meta-analyses (singular studies already included in the key meta-analysis were not coded again)
- Most recent studies (preferably after 1990)
- High quality of studies
- Country origin: Europe before North America/Australasia before other countries/regions
- Importance: number of citations
- Language: English
- Peer reviewed journals (conferences or ‘grey literature’ were only considered in absence of journal studies)

According to the level of detail of the topic and the history of research in the field, the exact approach to prioritization and number of studies that were eligible for 'coding' varied. A challenge within the task of identifying studies to be included in the repository was to distinguish between risk factors and countermeasures. For example, studies dealing with the absence of a safety barrier may be designed to record e.g. crashes before and after the installation of a safety barrier. Although dealing with a risk factor, these studies describe effects resulting from the treatment of a risk factor/application of a remedial measure. Such studies were coded and considered within the subsequent measures analysis of SafetyCube activities.

2.3.2. Study Coding and Quality Control

Within the aim of creating a data-base of crash risk estimates related to road infrastructure design and layout, a template was developed to capture relevant information from each study in a manner that this information could be uniformly reported and shared across topics within the overall SafetyCube project. The coding template was designed to accommodate the variety and complexity of different study designs. For each study the following information was coded and will ultimately be presented in the DSS:

- Road system element (Road User, Infrastructure, Vehicle) and level of taxonomy so that users of the DSS will be able to find information on topics they are interested in.
- Basic information of the study (title, author, year, source, origin, abstract)
- Road user group examined
- Study design
- Measures of exposure to the treatments
- Measures of outcome (e.g. number of injury crashes)
- Type of effects (within SafetyCube this refers to the numerical and statistical details of a given study in a manner to quantify a particular association between exposure and a road safety outcome)
- Effects (including corresponding measures e.g. confidence intervals)
- Limitations
- Summary of the information relevant to SafetyCube (may differ from the original study abstract).

A quality control procedure was established in which all measures were allocated to the primary and secondary coding partner. The studies which proved complicated were discussed between the primary and secondary coding partner so as to reach consensus. Complications in studies could emerge from a number of issues: (i) studies that examined applications of several measures in overlap (so the separate safety effects of each measure were unclear), (ii) studies that reported effects marginally pertinent for road safety (such as behavioral variables) or even (iii) ambiguity in result interpretations due to the manner in which they are reported).

A critical mass of study coding was the identification and integration of key meta-analyses. This was predominantly conducted for a number of meta-analyses contained in the Handbook of Road Safety Measures

(Elvik, 2009) and updated to include more recent papers (Høye, 2016) through the work carried out within the framework of the SafetyCube project. The updated meta-analyses offer comprehensive insights in their respective road safety treatment topics.

2.3.3. Synopses and ranking of measures

The syntheses of studies for each topic were made available in the form of a 'synopsis' indicating the main findings for a particular measure derived from meta-analyses or another type of comprehensive synthesis of the results (e.g. vote-count analysis), according to the guidelines and templates available in Martensen et al. (2017).

Synopses were created on different levels of the measure taxonomy, dependent on the availability of studies for a certain topic. The synopses contain additional context information for each measure from literature that could not be coded (e.g. literature reviews or qualitative studies). Moreover, there were cases where there was not enough information to write a full synopsis (for details see Machata et al., 2017).

The synopses aim to facilitate different end users: decision-makers looking for global estimates vs. scientific users interested in result and methodological details. Therefore, they contain sections for different end user groups that can be read independently. The structure of each measure synopsis is as follows:

- Summary: Abstract, Overview of effects, Analysis methods
- Scientific overview: Short synthesis of the literature, Overview of the available studies, Description of the analysis methods, Analysis of the effects.
- Supporting documents: Details of literature search, Comparison of available studies in detail as per the criteria established in section 2.3.1, (optional), other pertinent information

The final step was the ranking of measures and for that purpose a colour code scale was created. The colour code indicates how important this measure is in terms of the amount of evidence demonstrating its impact on road safety regarding mitigating crash risk, frequency or severity.

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

3. Results

In total, more than 260 studies on infrastructure related measures have been coded. Ultimately 48 synopses on road infrastructure measures have been developed for inclusion in the DSS, namely by merging some of the 94 specific topics for which there were not enough studies. This work has been completed by 9 different SafetyCube partner organizations. Table 2 presents the infrastructure measures classified by colour code.

Table 2. Infrastructure related measure ranking by colour code

Green (clearly reducing risk)	**Light green (probably reducing risk)**	**Grey (Unclear)**
✓ HGV traffic restrictions	✓ Road safety audits & inspections	? 2+1 roads
✓ Speed limit reduction measures to increase road safety	✓ High risk sites treatment	? Implementation of woonerfs
✓ Dynamic speed display signs	✓ Dynamic speed limits	? Installation of median
✓ Installation of section control & speed cameras	✓ Implementation of narrowings	? Increase number of lanes
✓ Installation of speed humps	✓ School zones	? Increase lane width
✓ Implementation of 30-zones	✓ Installation of traffic calming schemes	? Change shoulder type
✓ Installation of lighting & Improvement of existing lighting	✓ Road surface treatments	
	✓ Creation of by-pass roads	
	✓ Increase median width	

✓ Workzones: Signage installation and improvement	✓ Change median type	? Installation of cycle lane and cycle path
✓ Implementation of rumble strips at centreline	✓ Shoulder implementation (shoulder type)	? V2I schemes
✓ Installation of chevron signs	✓ Increase shoulder width	? Convert junction to roundabout (cyclists)
✓ Traffic sign installation; Traffic sign maintenance	✓ Safety barriers installation; Change type of safety barriers	? Improve skewness or junction angle
✓ Convert at-grade junction to interchange	✓ Create clear-zone / remove obstacles & Increase width of clear-zone	? Convert 4-leg junction to staggered junctions
✓ Sight distance treatments	✓ Road markings implementation	? STOP / YIELD signs installation / replacement
✓ Automatic barriers installation	✓ Implementation of edgeline rumble strips	? Implementation of marked crosswalk
	✓ Variable message signs	? Traffic signal reconfiguration
	✓ Convert junction to roundabout	
	✓ Channelisation	
	✓ Installation of rail-road crossing traffic sign	
	✓ Traffic signal installation	

In total 14 measures were given the colour Green, indicating that there is consistent evidence that these measures provide decreased road safety risk, frequency and/or severity of crashes when this measure is applied. The specific measures in the Green category are distributed across a range of infrastructure elements, demonstrating that the greatest effectiveness is spread across several aspects of the taxonomy. This is a particularly important finding for the following measures, as these were also identified as hot topics: Dynamic speed display signs, Speed limit reduction measures, Workzones, Traffic signs treatments, Installation of speed humps, Implementation of 30-zones, Sight distance treatments.

It is interesting to note that some measures that were allocated a Green colour code were not identified by stakeholders as being hot topic measures. This suggests that there is a degree of discordance between stakeholder perception or opinion of which infrastructure factors are most beneficial in mitigating risk and scientific evidence. This may be due to the fact that different stakeholders may have different specific areas of interest, and therefore not all measures are of equal importance to all stakeholders. Alternatively, stakeholders may be aware of specific risks in their respective regions but feel they are already controlled for with specific measures, or not possible to control for, thus favoring certain kinds of measures over others. While there is no mandate for a perfect match between stakeholder perception and objective effectiveness, the discrepancy is noteworthy nonetheless.

A further 21 measures were marked as light green (probably effective) with a mostly positive effect on road safety, however, problems of non-robust findings, or small inconsistencies between studies or few studies mean that the evidence for the measures was not considered sufficient to be coded Green.

Grey (unclear) was assigned to 13 measures, where no clear conclusion could be drawn about their impact on road safety. This represents existing gaps in road safety scientific literature, or a widespread lack of consideration for the implementation of the measures. It would be beneficial for future research to consider addressing each of these factors. This is a particular problem because some of the Grey colour coded measures are hot topics. This demonstrates that the scientific literature is not currently meeting all the needs of road safety stakeholders for evidence-base.

A detailed assessment of infrastructure related road safety problems is presented in Table 3. Results are classified by colour code and indication on the type of road safety outcomes affected, as well as whether or not this is a hot topic. The infrastructure element "Infrastructure safety management" (including formal tools to assess road network deficiencies and speed management) has the highest number of specific measures with a Green colour code.

Table 3. Overview of results of synopses on infrastructure related measures and associated impact on crashes

Infrastructure Element	Specific Measure	Colour code	Crash risk	Crash frequency	Crash severity	Hot topic (Yes/No)
Exposure	2+1 roads	Grey	-	-	↓	N
	HGV traffic restrictions	Green	↓	↓	-	N
	Road safety audits & inspections	Light green	↓	↓	-	N
	High risk sites treatment	Light green	↓	↓	-	N
	Speed limit reduction measures to increase road safety	Green	↓	↓	-	N
	Dynamic speed limits	Light green	↓	↓	-	Y
	Dynamic speed display signs	Green	-	↓	-	Y
Infrastructure safety management	Installation of section control & speed cameras	Green	↓	↓	-	N
	Installation of speed humps	Green	↓	↓	-	N
	Implementation of woonerfs	Grey	-	-	-	N
	Implementation of narrowings	Light green	↓	-	-	N
	School zones	Light green	↓	-	-	N
	Implementation of 30-zones	Green	↓	↓	-	N
	Traffic calming schemes	Light green	↓	↓	-	N
	Creation of by-pass road	Light green	-	↓	-	N
Road surface	Road surface treatments	Light green	-	↓	-	N
Lighting	Installation of lighting & Improvement of existing lighting	Green	-	↓	↓	Y
Workzones	Workzones: Signage installation and improvement	Green	↓	-	-	Y
Cross-section - Road segments	Increase number of lanes	Grey	-	-	-	N
	Increase lane width*	Grey	-	-	-	N
	Installation of median	Grey	-	-	↓	N
	Increase median width	Light green	↓	↓	-	N
	Change median type	Light green	↓	↓	-	N
	Implementation of rumble strips at centreline	Green	↓	↓	-	N
	Shoulder implementation (shoulder type)	Light green	↓	↓	-	Y
	Increase shoulder width	Light green	↓	-	-	Y
	Change shoulder type	Grey	-	-	-	N
	Safety barriers installation; Change type of safety barriers	Light green	-	↓	↓	Y
	Create clear-zone / remove obstacles & Increase width of clear-zone	Light green	↓	↓	-	Y
	Road markings implementation†	Light green	↓	-	-	N
	Installation of chevron signs	Green	↓	↓	-	N
	Implementation of edgeline rumble strips	Light green	↓	↓	-	N
	Installation of cycle lane and cycle path	Grey	-	-	-	N
	Traffic sign installation; Traffic sign maintenance	Green	↓	-	-	Y
Traffic control - Road segments	Variable message signs	Light green	↓	↓	↓	Y
	V2I schemes	Grey	↓	-	-	N
	Convert at-grade junction to interchange	Green	↓	↓	-	N
Alignment-	Channelisation	Light green	↓	↓	-	N

* This synopsis contains two similar topics: Cross-section – Lanes / ramps treatments / Increase lane width & Interchanges treatments / Increasing lane width

† This synopsis contains two similar topics: Cross-section – Road segments / Road markings implementation & Traffic-control – junctions / Road markings implementation

Infrastructure Element	Specific Measure	Colour code	Crash risk	Crash frequency	Crash severity	Hot topic (Yes/No)
junctions	Sight distance treatments	**Green**	↓	↓	-	Y
	Convert junction to roundabout - overall	**Light green**	-	↓	↓	N
	Convert junction to roundabout - cyclists	**Grey**	-	-	-	N
	Convert 4-leg junction to staggered junction	**Grey**	-	-	-	N
	Improve skewness or junction angle	**Grey**	-	-	-	Y
	Installation of rail-road crossing traffic sign	**Light green**	↓	↓	-	N
	Automatic barriers installation	**Green**	↓	↓	-	N
Traffic control - junctions	STOP / YIELD signs installation / replacement	**Grey**	-	-	-	N
	Implementation of marked crosswalk	**Grey**	-	-	↓	N
	Traffic signal installation	**Light green**	↓	↓	↓	N
	Traffic signal reconfiguration	**Grey**	-	-	-	N

The limitations of this work should be noted. The process of allocating colour codes was related to both the magnitude of the safety impact observed for a measure – and the corresponding presence of evidence. It is possible for a measure with a light green colour code to actually have a greater impact on road safety than a measure coded green, if there was limited evidence of its impact recorded in the literature. Furthermore, due to resource constraints, a certain amount of prioritising during study coding was necessary for measures with many identified studies. The criteria for prioritising within each synopsis is detailed in each supporting document. Across all measures, priority was given to existing relevant meta-analyses, as well as studies which considered crashes over changes in driving behaviour or effects of safety performance indicators such as speeds. This approach focused on studies with the highest methodological quality, however, it is possible that not considering all methodological approaches were given equal weights. Finally, within the considered literature, crash risk and crash frequency are much more commonly studied than crash severity. For some measures this makes it difficult (or impossible) to consider the implications for injury mitigation.

4. Conclusions and next steps

The present paper describes the identification and evaluation of infrastructure related measures within the SafetyCube project. It outlines the related results, which aimed to identify and evaluate infrastructure related measures and related road safety treatments by (i) presenting a taxonomy of infrastructure related measures, (ii) identifying “hot topics” of concern for relevant stakeholders and (iii) evaluating the relative importance for road safety outcomes (crash risk, crash frequency and severity etc.) within the scientific literature for each identified measure.

In total, the aforementioned process allowed the ranking of infrastructure related measures into three groups: green - clearly reducing risk (14 measures), light green - probably reducing risk (21 measures), and grey - unclear (14 measures).

The next steps of this endeavor concern the cost-and-benefit economic evaluation of treatments. A critical selection of the most effective and 'hot topic' measures has been undertaken, for the purpose of obtaining figures on the economic efficiency for each of them. A methodology comparable to study coding (as explained in the previous) has been developed and is applied to the topics to obtain cost-benefit ratios for several scenarios which will aid stakeholders with the prioritization and planning of road safety measures.

All these results are or will be incorporated in the DSS under development; pilot operation of the system has started and full operation and accessibility to all users is set to be on March 2018 (end of the SafetyCube project). The DSS will integrate related results from the road user behaviour and the vehicle areas, and will support evidence-based policy making. When deciding how to allocate limited resources for improving road safety, the DSS will increase awareness of the relative evidence for risk of each factor and of the effectiveness and efficiency of each measure. It will therefore assist in decision making, both on a microscopic level (for instance site treatment) and on a macroscopic level (strategic and national level).

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References

CEDR (2008). Best Practice on Cost Effective Road Safety Infrastructure Investments, Conference of European Directors of Roads (CEDR), Paris.

Elvik, R., Hoye, A.; Vaa, T., Sorensen, M. (2009). The handbook of road safety measures. 2nd Edition. Emerald, Bingley, UK

European Road Safety Observatory, ERSO (2016a). Traffic Safety Basic Facts 2016-Urban areas.

European Road Safety Observatory, ERSO (2016b). Traffic Safety Basic Facts 2016-Motorways.

European Road Safety Observatory, ERSO (2016c). Traffic Safety Basic Facts 2016-Junctions.

European Road Safety Observatory, ERSO (2016d). Traffic Safety Basic Facts 2016-Roads Outside Urban areas.

Filtness A. & Papadimitriou E. (Eds) (2016), Identification of Infrastructure Related Risk Factors, Deliverable 5.1 of the H2020 project SafetyCube.

Gitelman, V., Vis, M. ,Weijermars, W. & Hakkert, S. (2014). Development of Road Safety Performance Indicators for the European Countries. Advances in Social Sciences Research Journal, 1(4), 138-158.

Høye, A. (2016). The Handbook of Road Safety Measures, Norwegian (online) version. http://tsh.toi.no/

iRAP (2016). Road Safety Toolkit (http://toolkit.irap.org/).

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.

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

OECD/ITF (2012). Sharing Road Safety: Developing an International Framework for Crash Modification Functions. Paris.

PRACT (2016). Predicting Road Accidents - a Transferable methodology across Europe (http://www.pract-repository.eu/).

ROSEBUD (2006). Examples of assessed road safety measures – a short handbook. ROSEBUD Consortium, Research Project. European Commission, Brussels.

Safety CaUsation, Benefits and Efficiency - Project Website [Online], 2017. Available: http://www.safetycube-project.eu/.

SUPREME (2007a). Handbook for measures at the Country level. SUPREME Consortium, research project. European Commission, Brussels.

SUPREME (2007b). Handbook for measures at the European level. SUPREME Consortium, research project. European Commission, Brussels.