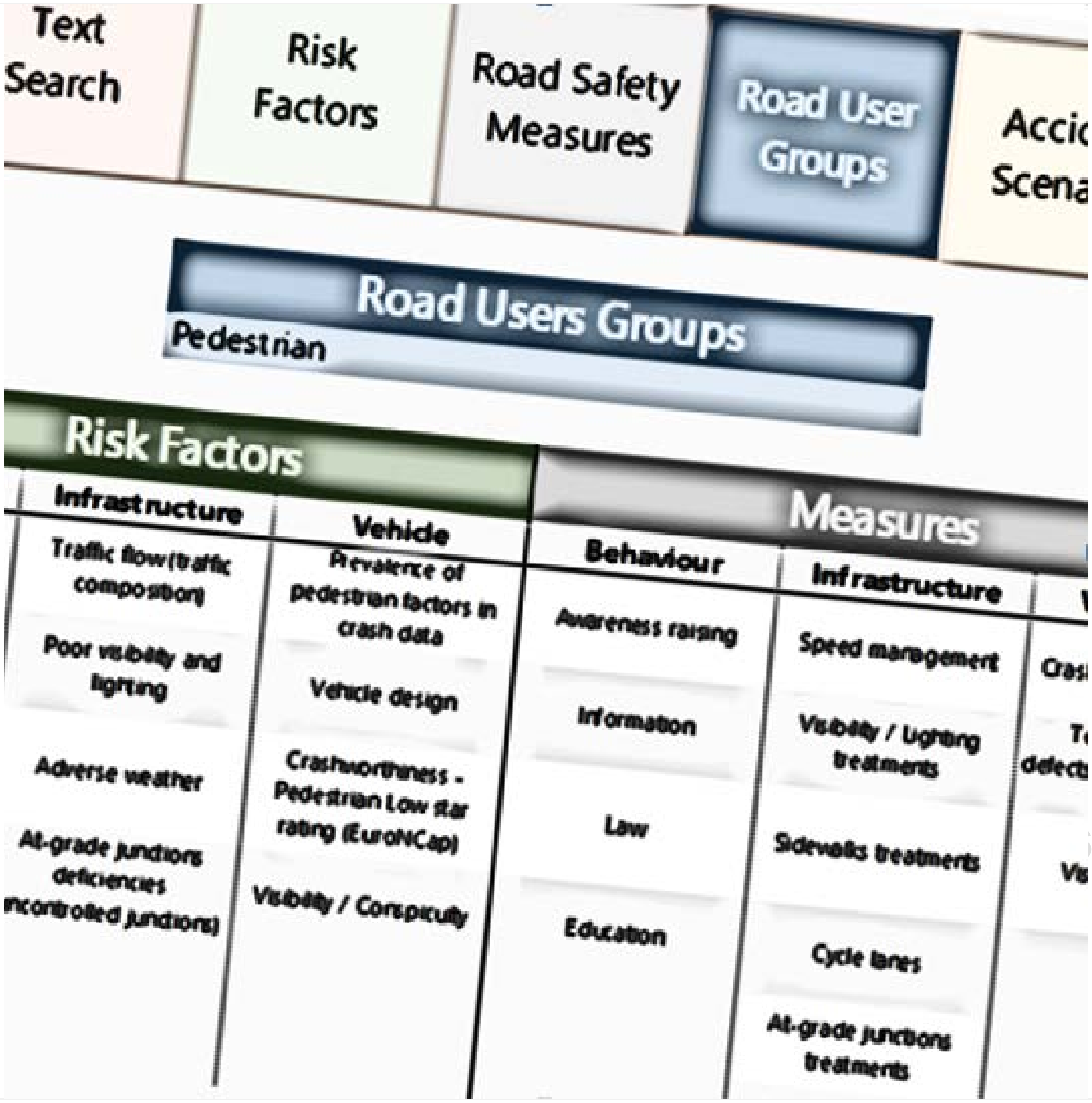

The application of systems approach for road safety policy making

Deliverable 8.1

SafetyCube

The application of systems approach for road safety policy making

Work Package 8, Deliverable 8.1

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Executive summary

The present Deliverable (D8.1) describes the **co-ordination of the analysis of risks and measures using a systems framework** within the SafetyCube project. It outlines the results of Task 8.1 of Work Package (WP) 8 of SafetyCube. This has involved (i) defining the systems approach to be used within SafetyCube, (ii) developing a taxonomy of risks and measures, (iii) identifying a common set of accident scenarios and (iv) initiating work on the Decision Support System (DSS) development. WP8 of the SafetyCube project has a number of specific aims, including developing the European DSS for supporting evidence-based policy making. It also aims to co-ordinate analysis undertaken in other WPs ensuring integrated research outputs, compilation of the project outputs into a suitable form to be incorporated within the DSS and the European Road Safety Observatory, and finally to develop tools to enable the continued support of evidence based road safety policies beyond SafetyCube.

Evidence-based policy making enables policy makers to make justified decisions in the complex reality of road safety interventions. It refers to the use of objective, scientifically-based evidence in all stages of the policy making process. Two important pillars for evidence-based road safety policy making are road safety data and statistics and scientific knowledge (Wegman et al, 2015). This type of policy making can be beneficial (e.g. helps to identify road safety problems and select most appropriate interventions) but also has it's challenges (e.g. a lot of information at varying levels of detail is required to inform decisions). The DSS that is being developed within SafetyCube aims to support decision makers as well as other stakeholders in their evidence-based policy making.

In addition to evidence-based policy making, SafetyCube and in particular the DSS is grounded in the systems approach. The systems approach aims to steer away from the more traditionally 'human error' blame focussed approach to road safety, and instead takes into account all 'components' in a system (i.e. road users, vehicles, roads) which contribute to a risk of an accident occurring. In SafetyCube, the systems approach is being integrated in the DSS in two main ways. First, the risk factors which relate to the road user, the road or the vehicle will be linked to measures in any or all of these areas if appropriate. Second, to clarify the added value of complementary measures rather than measures in isolation, where appropriate, a description of a measure will pay special attention to and link to supporting measures.

The SafetyCube DSS is underpinned by four taxonomies; Road User Behaviour (WP4), Infrastructure (WP5), Vehicles (WP6) and Post Impact Care (WP7). The taxonomy is a main structural part of the DSS system, it can be used as a search option in the DSS, it creates a uniform structure over all work packages and it can be used as a basis for linking risk factors with their corresponding measures. The structure consists of three levels, which are topic, subtopic and specific topic. Thirteen main topics were identified for Road User Behaviour (WP4), 10 main topics for Infrastructure (WP5) and six main topics for Vehicle (WP6). Four topics (based on the DaCoTA webtext on Post Impact Care, 2012), were included in WP7 (Post Impact Care). As expected, there was found to be some overlap between risk factors in one taxonomy and risk factors in another (e.g. is poor vehicle maintenance a Vehicle or Road User-related risk factor?), and some overlaps where a topic could be a risk factor or a countermeasure. Discussions between WPs ensured decisions could be made about how to overcome these ambiguities.

Accident scenarios are used within SafetyCube. These are considered to be a classification system for crashes whereby crash types may be grouped according to similar characteristics under a particular scenario heading, creating specific clusters. In total, nine high level accident scenarios will form an entry point to the DSS. Each high level has multiple sub-levels which provide more detailed information about the conflict situation (before the crash). A total of 63 sub-level scenarios are considered.

The task of linking risks and measures is currently underway within the SafetyCube project. The accident scenarios will provide a useful and systematic way by which to link risks and measures. They will be used, in order to generate a meaningful set of links, between risks related to specific situations, and measures to address them.

The primary objective of the DSS is to provide the European and Global road safety community a user friendly, web-based, interactive Decision Support Tool which will enable policy-makers and stakeholders to select and implement the most appropriate strategies, measures and cost-effective approaches to reduce casualties and crash severity for all road users. It consists of information such as risk factors, road safety measures, cost-benefit, casualty reduction effectiveness estimates.

In order to develop the DSS, a review of current existing Decision Support Systems was carried out to provide a first insight into such tools (e.g. Crash Modification Factors Clearinghouse, PRACT Repository, Road Safety Engineering Kit, iRAP). No European DSS were found in the search and of the DSS reviewed, the majority focussed on infrastructure and no risk factors were included. The SafetyCube DSS addresses these gaps. To understand user needs better, three stakeholders workshops were carried out, which allowed participants to comment on the proposed DSS and suggest 'hot topics' (i.e. important risk factors) to address in SafetyCube, and the findings of these workshops found that the DSS should be suitable for use by a wide range of users, should be impartial, include robust data and access to all studies used and generated results. A comprehensive common SafetyCube methodology was designed, which included: a complete taxonomy of human behaviour, infrastructure and vehicle; a detailed and recorded literature review and the development of a template for coding research studies and existing results to be stored in a database linked to the DSS.

The DSS is being created on the basis of a number of design principles (e.g. modern web-based tool, ergonomic interface, simple, easily updated…). As well as a consistent layout the content itself is also of high importance (e.g. quantitative results over qualitative, methodologically sound, clarity). The DSS itself consists of the backend (relational database), the front end (website) and the way they integrate (queries). The heart of the DSS consists of the searchable/dynamic and static aspects, which consists of five entry points and three levels. The design principles of the DSS ensure a smooth integration of the Work Packages in two ways, firstly that the SafetyCube common methodology is applied and secondly that the fully linked search allows the end user to better perceive the interactions between various components in road safety.

There are five entry points into DSS: 'text search', 'risk factors', 'road safety measures', 'road user groups' and 'accident scenarios'. Once a search has been undertaken using one of these five entry points, a results page is shown to the user, which consists of a table listing the available synopses[1] (overview of the topic created by synthesising findings from the coding of existing studies), meta-analysis and other studies in the database. From this, the user can then also access the individual study pages for each study listed in the results. Finally, a Tools page allows the user to access other SafetyCube tools (e.g. cost-benefit calculator, methodology information, glossary).

[1] More details about the synopses can be found in the Milestone M3.1 (Martensen 2016).

So far, more than 500 studies have been analysed in the area of road risks with more than 3,500 risk estimates, summarised in more than 60 synopses (including approximately 10 meta-analyses), and the related measures analyses are in progress. This wealth of information will all be incorporated into the DSS and become its core outputs. The overall design of the DSS is finalised and is currently available, with the next stage being the DSS development, including all risk factors and measures. The DSS Pilot Operation will occur later in the project, followed by the final opening of the DSS, with continual updates from the end of the project onwards. The SafetyCube DSS is intended to have a life well beyond the end of the SafetyCube research project.

1 Introduction

This chapter describes the project and purpose of the deliverable. A short description of the workpackage which produced the deliverable is also provided.

1.1 SAFETYCUBE

Safety CaUsation, Benefits and Efficiency (SafetyCube) is a European Commission supported Horizon 2020 project with the objective of developing an innovative road safety Decision Support System (DSS) that will enable policy-makers and stakeholders to select and implement the most appropriate strategies, measures and cost-effective approaches to reduce casualties of all road user types and all severities.
SafetyCube aims 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 is a comprehensive analysis of accident risks and the effectiveness and cost-benefit of safety measures focusing on road users, infrastructure, vehicles and injuries framed within a systems approach with road safety stakeholders at the national level, EU and beyond having involvement at all stages.

1.1.1 Work Package 8

The main objectives of work package 8 are to:

- Set up the European Decision Support System (DSS) for supporting evidence-based policy making.
- Co-ordinate the analyses undertaken in other work packages ensuring that the research outcomes integrate road user, vehicle and infrastructure factors.
- Compile the project outputs into a suitable form to be incorporated within the DSS and the European Road Safety Observatory.
- Develop the structure, operational procedures and business plan to enable the DSS to continue to support evidence based road safety policies beyond SafetyCube.

A systems approach provides a framework within which the work of other Work Packages is integrated into the DSS. A road collision is rarely the result of a single factor. Risk and problems from road user behaviour, infrastructure and vehicle deficiencies interact with each other resulting in environments within which a crash may occur. Understanding these risks and the most appropriate measures and solutions to mitigate them is central for evidence based policy making. In order to provide policy-makers and industry with comprehensive and well-structured information about measures, it is essential that a systems approach is used to ensure the links between risk factors and all relevant safety measures are made fully visible.

1.2 ADVANCES BEYOND THE STATE OF KNOWLEDGE

The objective of SafetyCube is to prepare a Decision Support System that will enable all EU Member States and other countries to adopt the best possible approach to road safety. This is a highly challenging objective owing to the need to develop a consistent evaluation of accident causation factors and quantified risks together with the currently highly diverse, unstructured and often incomplete information about the effectiveness of measures. Even the best performing countries do not have available an evidence-base of the breadth and depth to which SafetyCube will work so all can expect to have further opportunities to reduce casualties further on the basis of the SafetyCube DSS.

As yet there is no systematic pan-European in-depth study of accident causation and it is very difficult for policy-makers and other road safety stakeholders to assemble a clear evidence base of the causation paths and associated risks. The data that is available, and which will be deployed within the project, has been gathered for a variety of purposes using a range of protocols and selection criteria. It is therefore a significant challenge to bring this data together to form a single coherent analysis of accident causation mechanisms and risks.

In a similar manner there is also no systematic catalogue of measures and their safety effects. There are many individual studies of well-established measures in the literature but the measured effectiveness, limitations and applicability can be highly varied. It is therefore difficult for road safety stakeholders to form conclusions over the most appropriate measures to be deployed. The SafetyCube team includes an impressive group of data analysts, researchers and policy advisors who are highly experienced in transferring the research results into well-founded policy-support information. To do this a series of new procedures will be developed to combine and analyse the safety effect of a wide range of measures, thereby extending the current level of knowledge and simplifying and making accessible what is currently a very large body of knowledge. There is currently no central source for this information covering Europe and it will be highly challenging to develop such an approach. A particular advance will be enabling the prediction of estimates of the effectiveness of new technologies which may only be on the road in small numbers or not yet in use.

A further area where the project will develop the state of the art to a new level of understanding concerns analysis of the costs and benefits of measures. There is currently a lack of systematic information on the cost-effectiveness of measures when implemented in the European context. Cost information is scarce, particularly when concerning vehicle based measures. There is currently no method available that enables comparable calculations of cost-effectiveness for crash avoidance, crash mitigation and injury mitigation technologies. For example there are currently no comparable estimates of the benefits of eCall and co- operative driving technologies yet these represent fundamental road safety decisions to be made by road safety stakeholders of all types.

SafetyCube will address each of these challenges within one compressive online tool. This will further the state of the art in the understanding and access to information for informing evidence-based road safety policy making.

1.3 PURPOSE AND STRUCTURE OF THIS DELIVERABLE

This deliverable reports on the work in Task 8.1. The aim of Task 8.1 is to coordinate the analysis of risks and measures using a systems framework. Within this task it will be ensured that the approaches taken are equivalent between work packages using the specific methodologies developed within SafetyCube. The approaches of each Work Package will therefore be comparable and can be treated in combination to develop the Decision Support System (DSS).

This task has included:

1. Defining the systems approach to be used within SafetyCube.

This included understanding of evidence based policy making.

2. Developing a taxonomy of risks and measures.

This taxonomy has two major components: risks and measures. Firstly it provides a comprehensive overview of the driver behaviour, infrastructure and vehicles risk factors which may be a road safety problem influencing crash risk. Secondly, it provides an overview of driver behaviour, infrastructure, vehicle and post impact care measures which may be solutions to road safety problems.

3. Identifying a common set of accident scenarios.

A set of accident scenarios has been developed to form an entry point to the DSS. End users will be able to use these accident descriptions to navigate to risks and measures of interest.

4. Initiate work on Decision Support System development.

The foundation has been laid for the development of the DSS, which will be completed in Task8.3.

1.3.1 Report structure

This report has five chapters. The first (current) chapter provides background information about the SafetyCube project. Chapter 2 introduces the systems approach at the heart of SafetyCube. An overview of evidence based policy making, explanation of the systems approach and what this means to SafetyCube are provided. Chapter 3 introduces two key components of the DSS, those being the taxonomy and accident scenarios. Chapter 4 provides an overview of the DSS including its design and development. Chapter 5 concludes the report, summarising the current situation and detailing the next steps.

2 The safe system approach in evidence-based road safety policy making

This Chapter introduces the concepts of evidence-based policy making and the Safe Systems Approach, and describes how these concepts are going to be integrated in the SafetyCube Decision Support System.

2.1 EVIDENCE-BASED POLICY MAKING

The policy making process for road safety interventions is complex. An important reason is that various road safety problems as well as other transport related issues are competing for the scarce recourses available. Besides, many different stakeholders are involved in the policy and decision making process, all with their own interests. Evidence-based policy making enables policy makers to make justified decisions in this complex reality.

Evidence-based policy making refers to the use of objective, scientifically-based evidence in the all stages of the policy making process. Figure 1 shows the road safety policy making cycle. 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 have to 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).

Wegman et al. (2015) distinguish two important pillars for evidence-based road safety policy making:

1) road safety data and statistics, and
2) scientific knowledge.

Efficiency assessment tools are the important evidence-based instruments which are used to assess new measures. Efficiency assessment tools have been defined as *"a systematic assessment of the improvement in road safety that can be realised by means of various road safety measures"* and can help governments to select those measures that will likely maximize the social benefits of public investment (OECD/ITF, 2012).

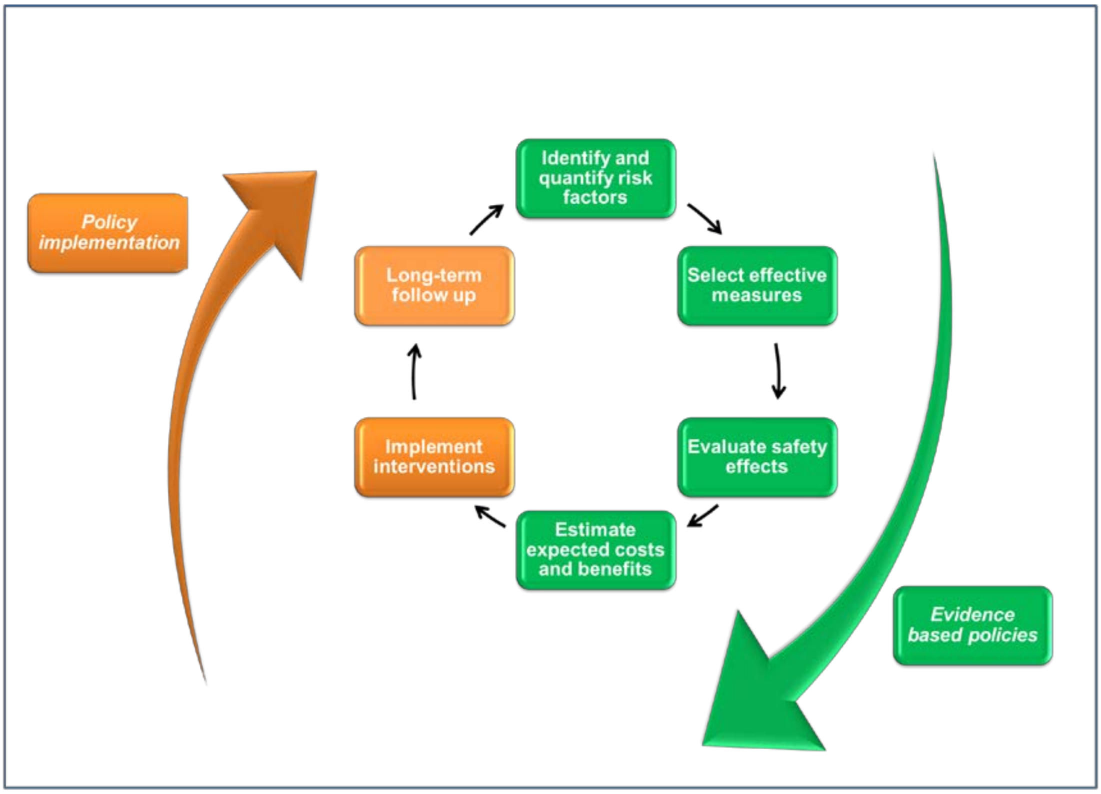


Figure 1 Road safety policy making cycle.

Evidence-based policy making is beneficial for a number of reasons. First and foremost, as already indicated, evidence-based policy making is crucial for identifying relevant road safety problems, and selecting the most appropriate road safety interventions. Additional information on the costs of the different interventions is necessary to determine which measure is most appropriate from a cost-effectiveness point of view. Note that also other criteria, like available funding or political support, might be relevant when selecting the most appropriate measures. In these cases, efficiency assessment tools provide evidence-based input regarding the cost-effectiveness[2], benefit-cost ratio[3] or net present value[4] of different road safety measures. For more information on these assessment tools see Deliverable 3.4 (Martensen et al., 2016).

A second advantage of evidence-based policy making is that it helps to ensure governments allocate an appropriate share of their total budget to road safety. Road safety is not only competing with other budget demands for road transport like congestion, environment, but also with budget demands for health and other policy areas. Cost- Benefit analysis enables policy makers to determine which investments have the highest benefits in relation to their costs.

Finally, evidence-based policy making enables policy makers to justify expenditure on road safety policy interventions and provides them with convincing arguments in the face of sceptical and sometimes hostile lobbies (OECD/ITF, 2012). However, there are also challenges to evidence based policy making, one of which is the high demand placed on the need for information to inform decisions (Frey 2010). This presents policy makers with a difficult situation on how to access and interpret the information needed to inform decisions. Furthermore, there is variation in the level of

[2] Cost effectiveness: number of crashes prevented/ costs of implementation.
[3] Benefit-cost ratio: benefits (expressed in monetary value)/costs.
[4] Net-present value: benefits (expressed in monetary value) – costs.

detail different types of decision makers seek to inform their policy making (Papadimitriou & Yannis, 2014).

The Decision Support System (DSS) that is being developed within SafetyCube aims to support decision makers as well as other stakeholders in their evidence-based policy making. More specifically, the DSS provides information on risk factors and road safety measures and a tool to conduct a cost-benefit analysis of these measures. Thereby, the DSS covers the green phases of the road safety policy making cycle of Figure 1.

2.2 THE SYSTEMS APPROACH TO ROAD SAFETY

In addition to identifying risk factors and effective countermeasures, evidence-based policy also aims to clarify the interrelationship between different risk factors and different types of measures. This brings us to the systems approach to road safety.

Traditionally, road safety policy focused on correcting human errors, and road safety efforts relied heavily on road user education measures (OECD/ITF, 2016). A significant shift away from this not very successful approach was pioneered by Haddon around 1970. He developed an injury-prevention matrix that encouraged joint evaluation of all the factors that contribute to road injury and provided a methodology to assess the effectiveness of a full range of potential countermeasures (OECD/ITF, 2016). This was one of the first attempts to move away from a blame approach of identifying a single cause of an accident to seeking countermeasures for broader accident prevention. It could be considered the forerunner of what is currently known as the systems approach in road safety.

Reason (2000) describes the previous approach as the 'person approach' focusing on "the errors of individuals, blaming them for forgetfulness, inattention, or moral weakness". The systems approach on the other hand, according to Reason, "concentrates on the conditions under which individuals work and tries to build defences to avert errors or mitigate their effects."

The systems approach has been applied to prevent all kind of types of accidents, like industrial accidents and crashes with airplanes. The approach considers these accidents as failures of the social-technical system, resulting from unexpected, uncontrolled relationships between a system's constituent parts (Underwood & Waterson, 2013). According to these authors, understanding accidents and defining the appropriate measures require the study of the system as a whole, rather than considering its parts in isolation.

Also 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).

Based on this systems theory, Hughes et al. (2016) present a framework for road safety strategies (Figure 2). The underlying rationale of the framework, and consistent with the systems approach, is that a comprehensive set of policy tools (box 1) have the potential to be applied to all relevant components of the road system (box 2) in order to improve road safety (box 3).

Figure 2 Framework for road safety strategies consistent with systems theory. Source: Hughes et al (2016)

In recent years, the systems approach for road safety has been further developed by for example Hughes et al (Hughes et al., 2016; Hughes et al., 2015) and Salmon et al. (Salmon & Lenne, 2014, Salmon et al., 2010, Salmon et al., 2012) focussing more on the various organisational levels of the system and how they synergistically work together so that safety is an emergent property arising from interactions between the components of the system (Salmon et al., 2012). This approach commonly follows the theoretically underpinning of Rasmussen (1997) who identifies six levels of the system from governments and regulators at the top to individual actors and environment e.g. drivers and road infrastructure at the bottom, all of which have a role to play in the creation of an optimal and safe system. For a system to operate, safety decisions and actions occurring at each level need to transfer up and down the hierarchy to inform decisions and actions of those from different levels (Salmon et al., 2012). The existence of different organisational levels in the system has been recognized in earlier work as well (e.g. by Larsson et al., 2010), but at that time the systems approach interventions mainly focused on changing behaviour of road users, either directly or via road design or vehicle-related measures. It did not yet focus on the role of, for example, road designers or vehicle manufacturers. Acknowledging different organisational levels in the system, the second generation system approach also considers the entire road design process, the vehicle design process, as well as for example the organisation of police enforcement as part of the system. In that case, improving these processes in order to prevent errors at the organisational level would explicitly become part of road safety policy making.

In the area of road safety, a fairly well-known concept is the Safe System Approach. This is closely related to the systems approach, but is not the same. The Safe System approach is more focused than the systems approach and can be considered to be more like a philosophy or an ideology, whereas the systems approach is based on systems theory. The Safe System approach starts with the ethical imperative that no human being should be killed or seriously injured in a road crash (OECD/ITF, 2016). Subsequently, the Safe System approach applies the systems theory in order to create a Safe System. The Safe System approach 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).

2.3 THE SYSTEMS APPROACH WITHIN SAFETYCUBE

In order to ensure maximum impact on road safety, SafetyCube, and in particular the DSS, applies as far as possible the systems approach. More specifically this means that the DSS will provide evidence-based information that takes account of the interrelationship of both risks and the appropriate measures for infrastructure, road user behaviour, vehicles and injury prevention and will indicate the added value of combinations of measures.

To build this into the DSS is not a straightforward task. SafetyCube starts by collecting information on risk factors and measures related to each of the three main components of the road system: road users, infrastructure and vehicles. This is done within WP's 4, 5 and 6. In addition, WP7 collects information on measures related to post-impact care. According to the systems approach, however, the elements of the road system should not be considered in isolation, but in interaction and in combination with each other. Ensuring that the DSS reflects the systems approach is coordinated within WP8.

At this stage, the systems approach is being integrated in the DSS in two main ways. First, the risk factors which relate to the road user, the road or the vehicle will be linked to measures in any or all of these areas if appropriate. An example: one of the risk factors in WP4 on road users is speeding. In line with systems thinking this driver behaviour is recognised to interact with other system factors (e.g. infrastructure and vehicle factors) which enable the adverse driver behaviour (Salmon & Lenne, 2014). Within the DSS the risk factor speeding will not just be linked to road user-related measures, such as campaigns or enforcement, but also to infrastructure, e.g. the implementation of speed humps or traffic calming schemes, and to the vehicle, e.g. adaptive cruise control (ACC).

Second, to clarify the added value of complementary measures rather than measures in isolation, whenever appropriate, a description of a measure will pay attention to and link to supporting measures. Again an example in the area of speeding, an integrated speed management policy exists of a series of interrelated steps (DaCoTa, 2012b): set a safe speed limit, ensure that road users know the limit, ensure that the road design and the environment sufficiently reflect the speed limit (credibility of the speed limit), enforce when needed, and this all surrounded by information and communication. Chapters 3 and 4 of this Deliverable will describe in more detail the components and the design of the DSS.

According to recent developments, the systems approach should also deal with different (organisational) layers of the road system. Although the main focus within SafetyCube is on risk factors and measures in the areas of road users, road design, and vehicles, some of the risks and measures relate to what can be considered to be organisational aspects, such as road management, road safety audits, and safety culture. However, since SafetyCube explicitly aims to exploit quantitative information on risk factors and effects of measures, and this information is lacking on especially for this type of risks/measures, these organisation aspects will be taken into account only to a limited extent.

3 Key components of the DSS

3.1 INTRODUCTION TO TAXONOMY

The SafetyCube DSS is underpinned by four taxonomies. One for each of driver behaviour (WP4), infrastructure (WP5), vehicles (WP6) and post impact care (WP7).

The requirements for the taxonomy in Safety Cube were:

- Should be a main structure part of the DSS system.
- Can be used as a search option in the DSS.
- Create a uniform structure over all work packages.
- Can be used as a basis for linking risk factors with their corresponding measures.

Additionally, all individual modes of transport (pedestrians, cyclists, powered two-wheelers, car drivers, truck drivers) and all kinds of road users (children, elderly etc.) should be considered in the taxonomy. Within SafetyCube it was agreed to use a three-level structure across the analytic WPs, and that is how the topics will also appear within the web-based DSS.

The hierarchical three level structure consisting of topic – subtopic – specific topic, which was used for each taxonomy, is shown in Figure 3.

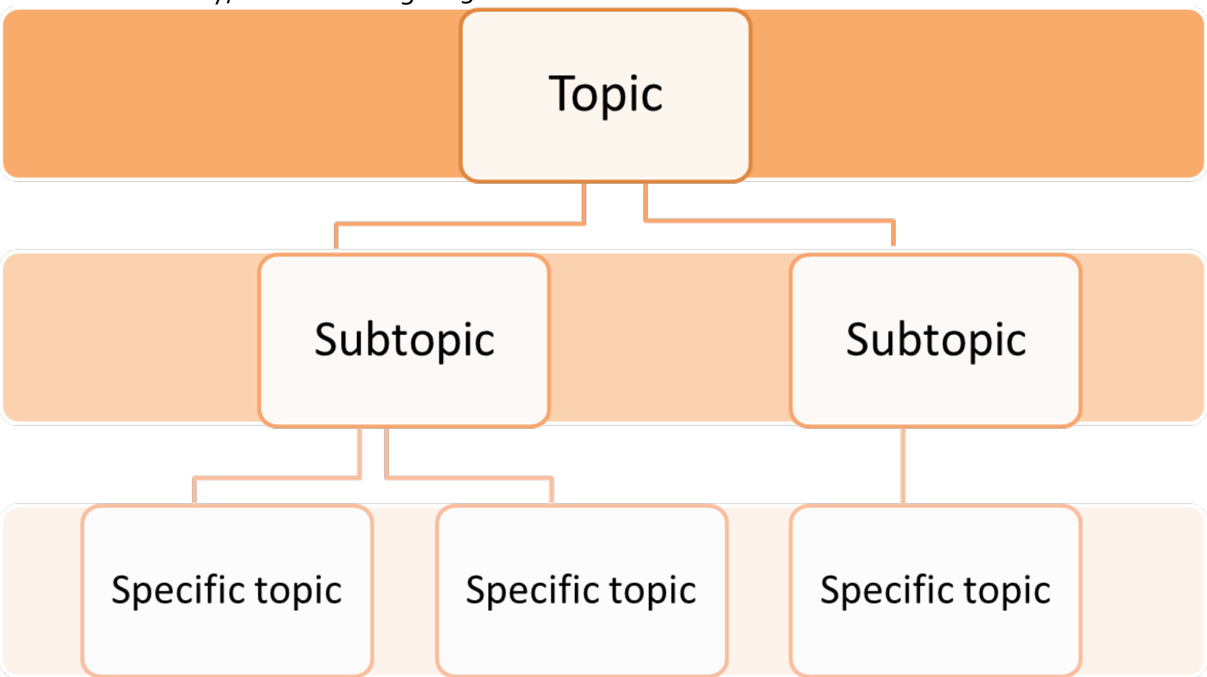


Figure 3: hierarchical three level structure for human related risk factors and measures

3.1.1 Road user behaviour (WP4) taxonomy

The objective of work package 4 (road user behaviour analysis) is to analyse data, and to implement in SafetyCube developed methodologies concerning accident risk factors[5] and road safety measures related to human factors.

Based on the three level structure and the described requirements of SafetyCube the specific taxonomy for risk factors and measures related to the human behaviour was developed. As a first step an exhaustive list of known human related risks in road traffic has been created with broad categories. Additionally existing classifications of road safety risks, like accident causation analysis within former projects such as SafetyNet (Wallén Warner et al., 2008) or TRACE (Naing et al., 2007), were screened to see if these could be used in SafetyCube. None of them exactly suited the needs of SafetyCube since each of these tools were developed with a very specific aim. Therefore, it was decided that a new, made-to-measure taxonomy should be created, although the accident causation classifications formed a useful starting point.

The taxonomy for human related risk factors included 13 main topics:

- Speeding
- Influenced driving
- Risk taking
- Fatigue
- Distraction and inattention
- Functional impairment
- Insufficient skills and knowledge
- Emotion & stress
- Misjudgement & observation errors
- Traffic rule violations
- Personal factors
- Diseases and disorders
- Age

The main topics were refined and differentiated based on literature search and expertise of the involved researchers (Figure 4). Several adaptations of the taxonomy had to be made in an iterative process. As the DSS is designed to be a living rather than a static system, the taxonomies of road safety risks and measures do not claim to be exhaustive.

[5] Within the SafetyCube project 'risk factor' refers to any factor that contributes to the occurrence or the consequence of road accidents. All elements of the road system can hold an accident risk factor.

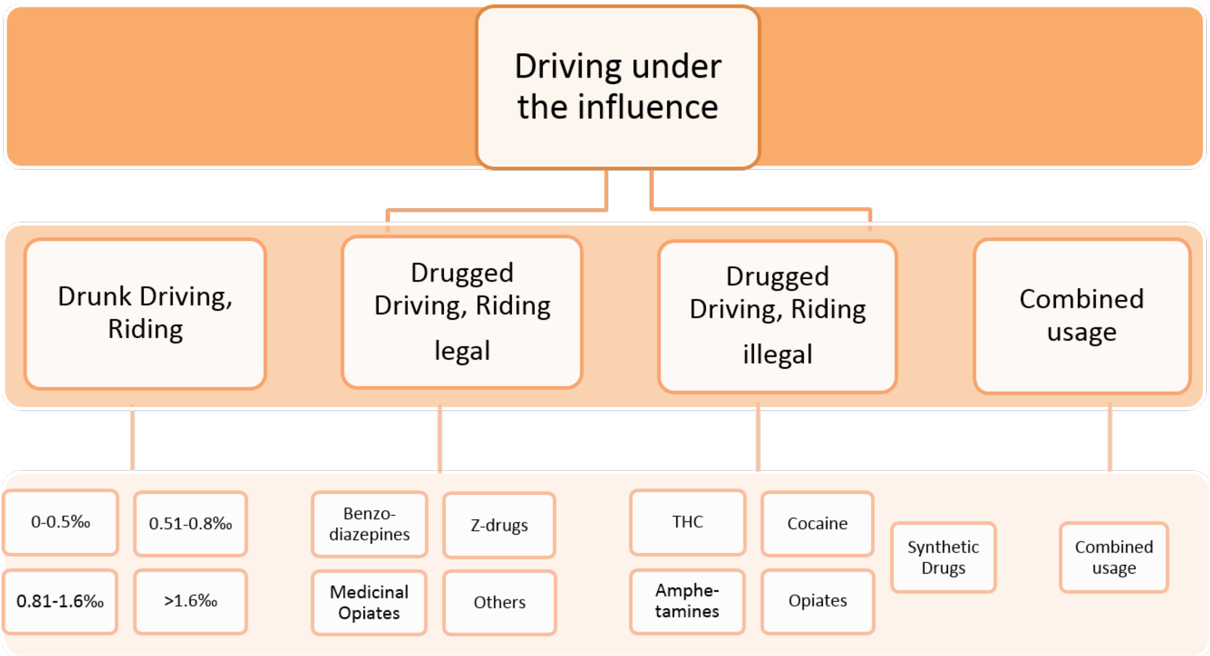


Figure 4: Example for division of a main topic in two sublevels

Road user groups such as pedestrians or cyclists are addressed within the relevant specific topics. In the DSS there is an entry point 'road users', which is linked to the specific risk factors for a road user group.

While road safety research shows clearly that certain age groups are more at risk than others (e.g. young males, children, elderly), it is inappropriate to claim that 'age' is a risk factor per se. Therefore, similar to road user groups, age groups are treated within the relevant topics. E.g. elderly are more affected by functional impairment and therefore studies for this topic focus mainly on this age group. For reasons of practicality, (enable the search for an age group) age was included in the main topics of the taxonomy.

A special focus will be put on VRUs in the course of dealing with measures.

The full road user behaviour taxonomy can be found in Appendix A.

3.1.2 Infrastructure (WP5) taxonomy

The objective of work package 5 (infrastructure analysis) is the in-depth understanding of infrastructure related accident causation factors and the identification and evaluation of the most appropriate related measures.

The taxonomy for risk factors and measures related to the road infrastructure was developed on the basis of the SafetyCube criteria, starting with the creation of a comprehensive list of risk factors specific to the road infrastructure, on the basis of a thorough review of literature. This included **key resources and publications** such as:

- **ERSO** web-text on infrastructure (DaCoTA, 2012a, http://ec.europa.eu/transport/road_safety/specialist/erso/pdf/safety_issues/road_safety_mesures/01-roads_en.pdf),
- **The Handbook of Safety Measures** (Elvik, 2009),
- **CEDR** Report on 'Cost-Effective Infrastructure Investments' (2008),
- **ROSEBUD** Handbook (2006),

- **SUPREME** Handbook (2007a and 2007b),
- **Highway Safety Manual** (http://www.highwaysafetymanual.org/Pages/default.aspx),
- **OECD/ITF** report on 'Sharing Road Safety (2016)',
- **PRACT** research project (EU repository of infrastructure CMFs, http://www.practproject.eu/),
- **iRAP** toolkit and related publications (http://toolkit.irap.org/) ,
- **SWOV** fact-sheets (http://www.swov.nl/UK/Research/factsheets.htm).

The list of risk factors identified was then examined on the basis of the methodological framework developed in WP3 within the overall objectives of SafetyCube, in order to make the **final selection and a meaningful classification** of risk factors that would be analysed, ranked and evaluated in terms of their impact on accident causation. Eventually, **59 specific risk factors within 16 general risk factors, all within 10 infrastructure elements,** have been identified.

General categories of infrastructure elements were firstly considered and then the specific risk factors were assigned to the respective element and general risk factor. The 10 **infrastructure elements** that are included are as follows:

- Exposure.
- Road type.
- Road surface.
- Road environment.
- Work zones.
- Alignment - Road segments.
- Cross-section - Road segments.
- Traffic control - Road segments.
- Alignment - Junctions.
- Traffic control - Junctions.

It is noted that road and junction types were considered to be horizontal elements, and therefore all risk factors and measures are to be considered for all infrastructure types applicable. The **infrastructure types** covered in the SafetyCube taxonomy include:

- Freeway segments.
- Interchanges (including speed change lanes, ramp segments, crossroad ramp terminals).
- Rural road segments.
- Rural junctions (including rail-road crossings).
- Urban road segments.
- Urban junctions.

As regards the measures taxonomy, which is to be finalised later within the project, it currently includes 99 infrastructure related road safety measures. The main difference from the risks taxonomy is that it does not include some elements related to risk factors that cannot be directly addressed with dedicated measures (e.g. weather conditions), and it includes some additional elements (e.g. road infrastructure safety management, ITS etc.).

The main risk topics were refined and differentiated based on literature search and expertise of the involved researchers and several adaptations of the taxonomy were made in an iterative process. Similar iterative process is expected during the measures analysis, optimising the related taxonomy.

The full infrastructure taxonomy can be found in Appendix B.

3.1.3 Vehicle (WP6) taxonomy

The objective of work package 6 (vehicle analysis) is to analyse data, to implement in SafetyCube developed methodologies concerning accident risk factors and road safety measures related to vehicle factors.

As required by the SafetyCube methodology, the taxonomy for the risk factor related to the vehicle is based on a three level structure.

Because every vehicle type has its own characteristics (size, weight, agility …), different uses, and travels on different types of infrastructure (roadway, sidewalk, path …), the first level of this taxonomy is comprised from various type of road users:

- Pedestrian
- Bicycle
- Powered Two Wheeler / All-Terrain Vehicle
- Passenger car
- Light Commercial Vehicle or Light Goods Vehicle
- Truck / Bus

The second level has been based particularly on each of these road user groups while trying to have some common main characteristics. This second level has been developed from the literature review, results on previous European projects (such as SafetyNet (Wallén Warner et al., 2008), TRACE (Naing et al., 2007), DaCoTA (2012), etc.) and our expertise. Attempts have been made to harmonize this second level through the different vehicle categories when it was possible. The third level proposes more specific risk factors for each road user type.

The category 'Pedestrian' was added to the initial list that was composed of vehicle types. The first reason for this was to harmonize with the risk factors studied in the WP4, which included pedestrians, and add the contribution from the point of view of the vehicle. WP4 approached from the point of view of human behaviour, and parts of the specific accident characteristics connected to pedestrians and their interaction with the other road users (vehicles) were not tackled. The second reason was to gather the pedestrian risk factors in the same category that otherwise would have been studied in every category of vehicle.

Looking carefully at the WP4 and WP6 taxonomies some overlaps can be found, such as pedestrian or rider protective equipment. The main difference comes from the point of view used to tackle these risk factors, with WP4 taking into account the human behaviour and the use of the equipment aspects while WP6 deals with interaction between road users and with the protection (in term of injury risk) brought by these equipment.

The taxonomy for vehicle related risk factors included a total of 69 factors distributed from 24 subtopics:

Pedestrian	Prevalence of pedestrian factors in crash data
	Vehicle design
	Visibility / Conspicuity
Bicycles	Prevalence of cyclists factors in crash data
	Visibility / Conspicuity
PTW / ATV	Prevalence of PTW factors in crash data
	Protective equipment design
	Technical defects / Maintenance
	Visibility / Conspicuity

Passenger Cars	Prevalence of vehicle factors in crash data Injury mechanism Crashworthiness Technical defects / Maintenance Visibility / conspicuity Specificities
LGV	Prevalence of vehicle factors in crash data Crashworthiness Technical defects / Maintenance Visibility / conspicuity
Trucks / Bus	Prevalence of vehicle factors in crash data Injury mechanism Crashworthiness Technical defects / Maintenance Visibility / conspicuity

The full vehicle taxonomy can be found in Appendix C.

3.1.4 Post impact care (WP7) taxonomy

Within WP7, information is collected on a number of post-impact care measures. The taxonomy of these measures is to a large extent based on the DaCoTa webtext on Post Impact Care (update 2012, http://safetyknowsys.swov.nl/Safety_issues/Post-impact-care.html). For each of the (sub)topics discussed in the DaCoTA Webtext, it is decided whether specific measures could be implemented that would be expected to be effective, and whether these measures are within the scope of SafetyCube and within the scope of WP7. These decisions are based on expert judgement. **Table 1** shows for each topic whether or not it is included in the taxonomy of WP7 and why not. The full post impact care taxonomy can be found in Appendix D.

Table 1 Topics included in the DaCoTa webtext, included and not included in the taxonomy of WP7.

Topic	Included in WP7	argumentation
Lay bystanders	No	No effective measures expected
Access to emergency medical system	No	Potential effective measure is eCall, but this measure is dealt with in WP6
Emergency rescue system	Yes	
Extraction from vehicle	Yes	
Pre-hospital medical care	Yes	
Triage and allocation to trauma facilities	Yes	
Trauma care	No	Outside scope SafetyCube
Rehabilitation	No	Outside scope SafetyCube

3.2 HARMONISATION OF TAXONOMY

In the course of establishing taxonomy in parallel between the separate work packages for road user behaviour, infrastructure and vehicles, it was not always clear how to separate certain factors from each other. As the three areas - behaviour, infrastructure, and vehicle - are of course interrelated in the traffic system as a whole, for practical purposes of SafetyCube, it was necessary to divide topics between work packages. There has been some overlap with WP6 (vehicle) and WP4 (road user behaviour). E.g. the lack of maintenance of a car or a powered two-wheeler, which clearly is risky for road safety, can be interpreted as belonging to the sphere of vehicles but also relates to human behaviour. On the other hand, there is some overlap between WP6 (vehicle) and WP7 (post-impact care). Ecall can be considered as both a vehicle measure and a post-impact care measure. In cases of ambiguity WP8 facilitated discussions between the other work packages. For example, in discussions with WP4 and WP6 it has been decided to assign all risk factors to WP6 that are physically tied to the vehicle like checking tire pressure or car maintenance in general.

The linking of risks and measures also occurs across areas. This is particularly the case for infrastructure and vehicle measures which are aimed at driver behaviour risks. Within the driver behaviour measures taxonomy (Appendix B) it is apparent that several measures will be addressed by the other work packages. For example, speed management was decided to be assigned to WP5, as several treatments correspond to infrastructure interventions (e.g. reduction of speed limit, weather-variant speed limits, installation of individual dynamic speed warning, installation of speed cameras or section control, implementation of 30-zones, implementation of traffic calming scheme), whereas other types of speed enforcement (e.g. by traffic police, including demerit point systems) will be considered within WP4.

A further difficulty is defining certain behaviours as either risks or as measures. For example, within WP4 not using a bicycle helmet (or any other safety device) is a risk in terms of severity of injury in the case of an accident. Using the helmet in turn is a measure to mitigate injury outcomes. Similarly, within WP5 the risk of having a poorly readable road is interlinked with the measure of implementing an easily read road. Also for WP6 for example, the risk of poor conspicuity of powered two wheelers is commonly studied by investigating measures to improve conspicuity.

In summary, the following decisions were made:

WP4:

- The use of safety devices will be dealt with as measures. This will prioritize and assess measures targeting unsafe human behaviour.
- 'Age' has been addressed within other risk factors, e.g. elderly road users within functional impairment). While road safety research shows clearly that certain age groups are more at risk than others (e.g. young males, children, elderly), it is inappropriate to claim that 'age' is a risk factor per se. A focus will be put on these age groups when it comes to identifying and selecting measures for assessment. The topic of age appears in the WP4-taxonomy as a separate topic for practical reasons.
- Road user groups as pedestrians or cyclists are addressed within the relevant specific topics.

WP5:

- Poor road readability is a recognised risk, but within SafetyCube this will be considered as a measure to improve road readability. This is the manner by which it is most commonly studied.
- Absence of some infrastructure elements could not always be considered as a risk factor (e.g. absence of channelization or traffic control), and the analyses will be focused on within understanding the effect of the measure to include the particular infrastructure element.

WP6:

- Technical defects, poor maintenance and overloading related risks, although associated with both the road user and the vehicle, are treated as vehicle risks in SafetyCube.
- Some factors recognised as risks e.g. conspicuity and protective system design are most commonly studied in terms of measures to improve the risk. In this situation WP6 will evaluate the measures to mitigate this risk rather than the risk per se.

WP7:

- Risks related to injury are covered within WP6 so WP7 only examines measures.
- E-call is a post impact care measure but as it is a vehicle related safety system it will be covered in WP6 as a measure.

3.3 ACCIDENT SCENARIOS

In road safety research the concept of scenario is very often used (1) as a tool of diagnosis (description of the situation, follow-up, etc.), (2) for the analysis (identification of the problems and the associated counter-measures), or (3) for the evaluation of the effectiveness of safety systems.

Scenarios can be seen as a classification of a population (e.g. injury accidents) by grouping items according to the criteria required by the initial research question. This classification allows for simplification of the problem (by dealing with clusters) and to avoid the complexity due to the diversity of the individual components.

A scenario is a cluster, gathering individuals which have similarities from the studied point of view. Together all the scenarios propose an almost exhaustive classification of the studied object. For analysing and quantifying the number of actors in each category, it is important to create a hierarchy with various criteria so as to avoid double counting. Let us take an example: an accident involving two vehicles moving in the same direction, at an intersection. The lead vehicle turns left while the second vehicle makes an overtaking manoeuvre. Let us suppose that our classification based on the accidental situations attributed to every vehicle, and consists of among other scenarios "Overtaking" and "Intersection: striking vehicle”. We can see here that the second vehicle (overtaking) can be classified into both of these two scenarios; however, this is not desirable. The analyst has to define a priority order according to the objective of the research question and finalise one possible option for categorising this situation.

For the road safety diagnosis, scenarios provide a good overview of the studied problem. For the end users scenarios give a simplification and a descriptive point of view of the problem, each scenario having its own characteristics and representing the handling of a specific part of this problem. A unique and typical scenario does not exist because they are always linked to an initial research question and put forward as a classification of the population according to the similarity of the studied characteristics. Every scenario can be also subdivided into sub-scenarios, which can themselves be constituted by sub-scenarios, etc., the level of granularity depending on the initial objective but also on available characteristics of the sample. The smallest component of this refinement is the individual (i.e. specific crash) itself.

For the end users, the main interest of scenarios is to allow the consideration of a group of similar individuals instead of having to consider each individual component in turn. Thus, the sub-levels must be used intelligently: they have to be in sufficient number to correctly describe the problem but not too numerous as to not represent small populations. The first level of scenarios is usually rather generic to be able to distribute the set of the individuals, the sub-scenarios then take into account more and more specific characteristics. Another advantage of this hierarchy is the ability to by-pass the problem of the missing values. Indeed, every individual is classified within a scenario which is most suited to them. In the case of missing information, the individual who cannot be placed in a subclass will belong to the superior class if all the conditions of membership are respected. In the manipulation of the scenarios it is thus preferable to use generic and large scenarios at the first level so as to be able to classify all the individuals, then for every main scenario to define one or two additional levels allowing distribution by finer details of characteristics.

For a given problem, the relevance of the scenarios is dependent on the one hand to the way the scenarios were developed (level of granularity, interpretation and independence classes, etc.) and on the other hand to the quality and the adequacy of the data used to complete the scenarios. There are two main ways to build scenarios, the one using statistical tools (data clustering, K-mean, Kohonen, hierarchical ascending classification, etc.) the other one based on the expert method. The statistical methods require a selection of markers (variables) the most relevant to characterize the problem. This selection can be realised by the use of statistical methods (e.g. logistic regression), either by expertise or by a mixed method.

The difficulty in the use of the statistical method in the creation of scenarios is the interpretation of the determined clusters. Some crossings of variables or even the modalities of variables, can create groupings of individuals which it is difficult to simply understand and complicate research outcomes.

The expert method to build the scenarios is most often used. It is based on a good interpretation of the research question but also on an excellent knowledge of the potential of the available data. The interpretation of each class is easier than in the statistical method because the resemblances are based on known and more concrete characteristics.

Several types of scenarios are used in road safety, most of the time these are associated with a well-established methodology (e.g. pedestrian scenarios (vFFSS, no date; Cuny & Krishnakumar, 2012), Cyclists scenarios (Uittenbogaard et al., 2014), HFF scenarios (Van Elslande & Fouquet, 2007; Van Elslande et al., 2012), etc.).

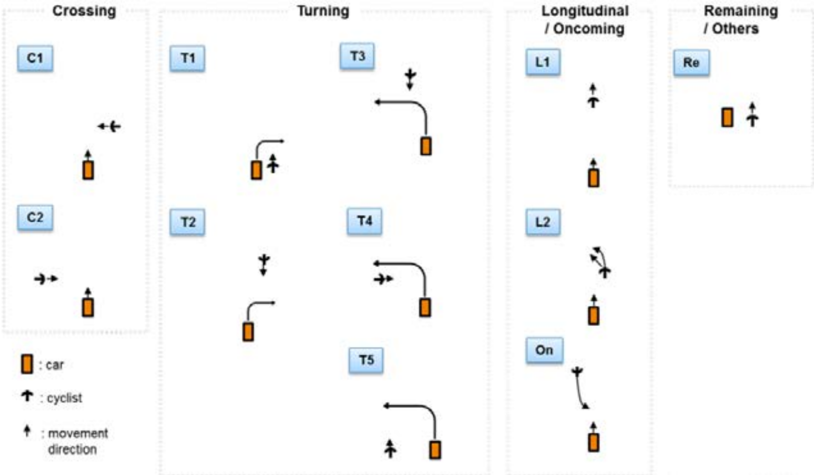


Figure 3: illustration of the scenarios used in the CATS project (Uittenbogaard et al., 2014)

For example, in the HFF method (Van Elslande & Fouquet, 2007; Van Elslande et al., 2012), scenarios are based on the driver's errors during the cognitive process (perception, diagnostic, prognostic, decision, action, overall). The adopted point of view is the driver's failure, outing the driver at the centre of this point of view. This classification facilitates work on the driver's needs (countermeasures). The need for these countermeasures is seen as being directly linked to the observed failure and what is necessary for the deletion of this failure. In the HFF method there are three levels, every under level bringing an additional characterization of the upper level.

From the assessment point of view, scenarios allow the selection of only the relevant injury accidents according to the studied safety system in order to avoid simulation of all possible accidents. For example if a person wanted to study AEB City (Automatic Emergency Braking for low speeds), the relevant scenario is composed of rear-end injury accidents in urban area involving a striking vehicle with a collision speed below 50km/h (speed range where the system is active). Scenarios are also used to quickly quantify the target population i.e. the maximum target that the studied system could avoid. In cases where the target population is very small scenarios allow the simulation step to be avoided. Indeed, the target population gives the maximum number of accidents that could be avoided thanks to the contribution of the safety system without taking into account all the limits of the use or functioning's of the system. If this number is statistically significant, only accidents included in the selected scenarios can be used for the simulation step.

3.3.1 Overview of scenarios

For SafetyCube, scenarios have been introduced in order to give a complementary point of view to the risk factor and measures entry points to the DSS, and more oriented to accident configuration.

The final hierarchy of scenarios is composed of a main level based on accident participant (nine main groups) and a sub-level giving more detailed information about the conflict situation (before the crash). A total of 63 sub-level scenarios are proposed below.

In order to take into account the mix of left hand side and right hand side driving countries, it is advised to avoid using left and right and instead to use the words nearside and farside instead. Nearside refers to the kerb side, where the front seat passenger would sit, and farside to the opposite side (i.e. side of a vehicle where the driver would sit).

For the Bicycle scenarios, we decided to reuse those define by the European project CATS (Cyclist-AEB Testing System development). The accident scenarios used in SafetyCube are presented in Table 2.

Table 2 Accident Scenarios used in SafetyCube

Main groups	Main Level	Sub level	Scenario no.
1	**Pedestrian accident**	pedestrian crossing road out of crossing path	1.1
		pedestrian crossing road on crossing path at straight stretch	1.2
		pedestrian crossing road in front of junction	1.3
		pedestrian crossing road behind junction	1.4
		pedestrian moving along the road	1.5
		vehicle reversing	1.6
		pedestrian sitting or lying on the ground	1.7
		pedestrian – changing mode (e.g. driver getting off the car)	1.8
		other pedestrian configuration	1.9
2	**Bicycle accident**	crossing configuration, Cyclist coming from farside (C1)	2.1
		crossing configurations, Cyclist coming from nearside (C2)	2.2
		same direction, Vehicle turning farside (T1)	2.3
		opposite direction, Vehicle turning farside -T2)	2.4
		opposite direction, Vehicle turning nearside (T3)	2.5

		cyclist coming nearside, Vehicle turning nearside (T4)	2.6
		same direction, Vehicle turning nearside (T5)	2.7
		same direction, cyclist ahead (L1)	2.8
		same direction, cyclist ahead and changing lane (L2)	2.9
		opposite direction, Cyclist turning nearside (On)	2.10
		dooring accident	2.11
		other (Re)	2.12
3	**Single vehicle accident - Run off road**	leaving the road nearside - with rollover	3.1
		leaving the road nearside - with object collision (tree, pole, wall, …)	3.2
		leaving the road nearside - with collision with other road user	3.3
		leaving the road nearside - without rollover / object collision	3.4
		leaving the road farside - with rollover	3.5
		leaving the road farside - with object collision (tree, pole, wall, …)	3.6
		leaving the road farside - with collision with other road user	3.7
		leaving the road farside - without rollover / object collision	3.8
4	**Single vehicle - on roadway**	collision with parked vehicle	4.1
		collision with lost load	4.2
		collision with animals on the road	4.3
		falling bus occupant without collision	4.4
		falling two-wheeler without collision with another participant	4.5
		other (e.g. fallen tree)	4.6
5	**Head-on collisions / on coming traffic**	front to front (overtaking)	5.1
		front to front (unintended lane change stable)	5.2
		front to front (unintended lane change instable)	5.3
		side collision with other participant oncoming (loss of control)	5.4
		other	5.5
6	**Rear end collisions / same direction traffic**	standing vehicle	6.1
		breaking vehicle	6.2
		driving vehicle	6.3
		lane changing vehicle	6.4
		side stripe collision with other participant in same direction	6.5
		other	6.6
7	**Junction accident – no turning**	participant required to yield crossing from nearside road	7.1
		participant required to yield crossing from farside road	7.2
		other	7.3
8	**Junction accident – turning**	farside turn - other participant in direction (following or overtaking)	8.1
		farside turn - other participant in opposite direction	8.2
		farside turn - other participant from other road	8.3
		farside turn - both participant farside turning	8.4

		farside turn - pedestrian/cyclist on sideway	8.5
		farside turn - other	8.6
		nearside turn - other road user in direction	8.7
		nearside turn - other road in opposite direction	8.8
		nearside turn - other road user from other road	8.9
		nearside turn - pedestrian/cyclist on sideway	8.10
		nearside turn - other	8.11
		other	8.12
9	**railway level crossing**	with barriers	9.1
		without barriers	9.2

The Accident scenarios form an entry point to the DSS. These are discussed in section 4.4.1 of this report.

3.4 LINKS BETWEEN RISKS AND MEASURES

As mentioned in section 3.2, the complexity of linking risks and measures, which is one of the primary objectives of SafetyCube, became obvious early in the project, during the creation and harmonisation of the taxonomies of all work packages. Early attempts to link risks and measures were made by means of a matrix of the risks taxonomies versus the measure taxonomies of all WPs, aiming to identify meaningful links. The task proved to be less efficient than expected, as several risks could be linked to several more general measures but not all links would be meaningful in all cases. This was particularly the case for the general risks and measures. For example, there would be numerous measures related to speeding behaviour, from road user-, infrastructure- or vehicle-targeted interventions, but only some of these links would be applicable in specific cases (e.g. traffic calming could be more related to addressing speeding in urban areas, pedestrian safety etc., Intelligent Speed Adaptation would be most meaningful to prevent ran-off-road crashes in rural areas etc.), whereas other links would be generally applicable (e.g. campaigns against speeding, lowering speed limits).

The creation of Accident Scenarios, described in section 3.3, provided a useful option to address the links between risks and measures in a systematic way. It was decided to link risks and measures for each specific accident scenario, in order to have a meaningful set of links, between risks related to specific situations, and measures to address them. The process, (under way at the time of writing), is to use the accident scenarios as a typology of crash types, on which risks and measures may be attached. For example, for scenario 3 - "Single vehicle accident - ran-off-road", several elements from the risks taxonomies may be identified as directly and explicitly linked with that type of crash configuration:

- **From a road user viewpoint:** Speed choice, Influenced driving - alcohol, Influenced driving - drugs, Fatigue, Distraction and inattention (several specific factors), Personal Factors (e.g. sensation seeking).
- **From an infrastructure viewpoint:** Road surface deficiencies, Poor visibility and lighting, Adverse weather, Horizontal/vertical alignment deficiencies, Superelevation / cross-slopes, Poor road readability (with several specific risk factors each).
- **From a vehicle viewpoint:** Technical defects / maintenance, crashworthiness (star rating) etc.

For each one of these risk factors, specific measures can be identified from the measures taxonomy, addressing each risk factor within the context of "ran-off-road single vehicle accidents". In this way, fewer but more meaningful links could be made, leading to a "chain" of causes, consequences and ways to mitigate them in the accident process, and this approach appears to be more useful for the DSS users as it provides targeted and context-specific evidence-based information.

In Table 3 below, a draft presentation of risks and measures linked to accident scenario 1 - "Pedestrian accident" are presented, as developed for testing and demonstration purposes for the DSS.

Table 3. Risks and measures categories linked to accident scenario 1 - "Pedestrian accident"

Risk Factors			Measures		
Behaviour	**Infrastructure**	**Vehicle**	**Behaviour**	**Infrastructure**	**Vehicle**
Distraction and inattention	Traffic flow (traffic composition)	Prevalence of pedestrian factors in crash data	Awareness raising	Speed management	Crashworthiness
Functional Impairment	Poor visibility and lighting	Vehicle design	Information	Visibility / Lighting treatments	Technical defects/maintenance
Traffic Rule Violations (red light)	Adverse weather	Crashworthiness - Pedestrian Low star rating (EuroNCap)	Law	Sidewalks treatments	Visibility
Personal Factors	At-grade junctions deficiencies (uncontrolled junctions)	Visibility / Conspicuity	Education	Cycle lanes	
Age				At-grade junctions treatments	
				Rail-road crossings	
				Traffic signals treatments	

At a first stage, links between risks and measures are established at a higher more general level, i.e. category level risk (e.g. distraction) / accident scenario (pedestrian accident) / measure level (awareness raising). As a next step, the linking will be made at specific level of risk factor (e.g. mobile phone handheld by driver) / accident scenario (e.g. pedestrian crossing the road) / measure (e.g. campaigns against mobile phone use by drivers), resulting in a detailed, comprehensive, and useful to decision makers set of links between risks and measures.

4 The DSS

4.1 DSS OBJECTIVES

SafetyCube aims to generate new knowledge about accident risk factors and the effectiveness of measures relevant to Europe, and to structure this information in a Decision Support System (DSS). Thus, the SafetyCube DSS is the ultimate product of the project. The primary objective of the DSS is to provide the European and Global road safety community 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. This tool will enable policy-makers and stakeholders to select and implement the most appropriate strategies, measures and cost-effective approaches to reduce casualties and crash severity for all road users.

The main contents of the SafetyCube DSS concern:

- road accident risk factors and problems,
- road safety measures,
- best estimate of casualty reduction effectiveness,
- cost-benefit evaluation,
- and all related analytic background.

Finally, a specific focus is given to linking road safety problems (for instance, risk factors) with related countermeasures (see section 3.4) for specific crash configurations (accident scenarios), allowing to address crash causes and risks related to specific situations.

The SafetyCube DSS is intended to have a life well beyond the end of the SafetyCube research project, so that a vast number of users are able to exploit this tool. Potential DSS users include Public Authorities (local, regional, national, European and international), Industry (Infrastructure, Vehicle, Insurance, Technology), Research Institutes, Non-Governmental Organisations, Mass media etc. Furthermore, the tool will be developed in a form that can readily be incorporated within the existing European Road Safety Observatory of the European Commission DG-MOVE.

The next sections of this chapter present the methodology, the structure and the functioning of the DSS, both in terms of back-end database and front-end user interface.

4.2 METHODOLOGY

Figure 6 illustrates the overall DSS development methodology. A review of existing road safety DSS worldwide, together with a review and analysis of user needs, together with the SafetyCube common analysis methodology (taxonomies, analysis methods etc.), led to the definition of design principles of the DSS. All these actions have led not only to the design of the DSS, but also to the development of the DSS. An iterative process of getting feedback from SafetyCube experienced researchers and several road safety stakeholders is involved to improve the design of the DSS.

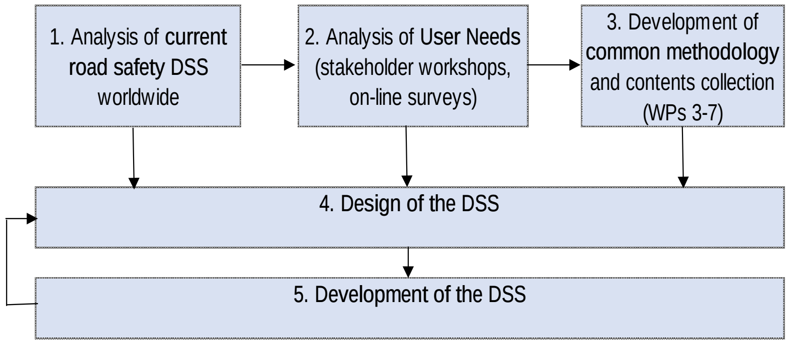


Figure 6: DSS development methodology.

4.2.1 Review of existing DSS

First of all, a detailed and exhaustive review of current existing decision support systems was carried out in order to get a first insight of such tools and also to advance them in the new European DSS through the SafetyCube project. The existing DSS that were reviewed are summarized below.

The Crash Modification Factors Clearinghouse (www.cmfclearinghouse.org) was developed by NHTSA (USA) and was the first DSS that was reviewed as it is one of the most popular worldwide. The website is funded by the U.S. Department of Transportation Federal Highway Administration and maintained by the University of North Carolina Highway Safety Research Centre. It has information of about 5,151 Crash Modification Factors (and functions) and is on-going. However, the CMFs of this site regard infrastructure only.

A newly created repository is the PRACT Repository (www.pract-repository.eu) which was developed by CEDR (Europe). This Repository is of high quality and contains the most recent Accident Prediction Models (APM) and Crash Modification Factors (CMF), highlighting effectiveness of road safety measures worldwide, for use by road safety decision makers and practitioners worldwide. In specific, it includes information of 889 CMFs and 273 APMs on infrastructure only.

Another interesting DSS is the Road Safety Engineering Kit (www.engtoolkit.com.au), developed by Austroads (Australia). This tool contains information of about 67 treatments, but it regards only infrastructure.

Other current DSS are the iRAP toolkit (toolkit.irap.org/) and the Safety Performance Factors Clearinghouse (spfclearinghouse.org). The former is developed by iRAP and has information on 58 treatments, 43 of which concern infrastructure. On the other hand, the Safety Performance Factors Clearinghouse developed by Tatum Group LLC and Dr. Andrew Kwasniak (USA) contains only a few Safety Performance Functions (SPF) and is available only to subscribers.

The overall review of existing DSS showed the existing gap in evidence based policy making as there is no European DSS. In addition to that, the vast majority of information regarded infrastructure. Finally, no information on risk factors were included. At this point, the present DSS is addressing these gaps by providing new knowledge about accident risk factors and the effectiveness of measures, with emphasis on the European context, on the basis of a systems approach explicitly addressing and at the same time linking a) behaviour, b) infrastructure and c) vehicle issues.

4.2.2 Analysis of user needs - stakeholders engagement

Stakeholders play a crucial role in developing the DSS and in achieving excellence. The SafetyCube project had identified a core group of stakeholders from government, industry, research, and consumer organizations covering the three road safety pillars: vehicle, infrastructure, road user.

In order to identify user needs three workshops were carried out. The first workshop on June 2015 was carried out in Brussels in order to start a dialogue between the project participants and a number of key stakeholders for road safety in Europe. The workshop both introduced the audience to the SafetyCube project and also solicited input from the stakeholders that will form the structure and priorities of a DSS. An extensive list of "hot topics" was also created on the basis of feedback from stakeholders, enhancing the SafetyCube initial lists. A total of 30 delegates attended the event.

A second workshop was organized on October 2015 in Ljubljana, Slovenia. The first part of the workshop was a plenary session with approximately 150 participants from the Slovenian Road Safety Councils and IRTAD meeting. The SafetyCube project was presented as well as the plans for the Road Safety Decision Support System (DSS) and the "hot topics" from the previous workshop. All participants were asked to give their feedback to the DSS and "hot topics". Feedback was collected both in spoken and written form. The second part of the workshop was a breakout session continuing with participants from the IRTAD group. The breakout session started with a discussion where the 23 participants were giving more detailed feedback on their wishes and questions on the DSS. Thereafter the participants were asked to add, comment and prioritize the "hot topics". This was done on six posters showing the "hot topics" from previous stakeholder consultation.

A more dedicated workshop was carried out on February 2016, in Brussels, where 12 road infrastructure stakeholders participated. 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 ranking of infrastructure related "hot topics".

On the basis of the workshops 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". In addition, 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.

Moreover, it was important that the DSS should have the following characteristics: include robust data which allows critical analysis and transparency, access to the studies used and to all generated results, information of the best quality studies and recommendations. A platform built in the project should be operational after the project.

4.2.3 Development Methodology

A comprehensive common SafetyCube methodology was designed and applied in existing and new studies of road safety risks and measures evaluation.

First, a complete taxonomy of human behaviour, infrastructure and vehicle was created, where specific risk factors and measures were assigned to the respective category. In that context, around 60 risk factors and 100 measures in infrastructure areas, more than 115 risk factors and 250 measures for behaviour, and more than 60 risk factors and 60 measures for the vehicle area have been initially identified. A detailed and recorded literature research is carried out so that key studies are identified (at each detailed level of the taxonomy, i.e. for each specific risk factor or measure). A taxonomy of study designs was created as well so that different estimators of effects are identified (e.g. CMFs, absolute difference, regression coefficient, odds ratios etc.).

In the next step, a template for coding research studies and existing results in excel form and a template for summarising results / meta-analysing were also created. The templates of coded studies undergo a thorough checking and debugging process, in order to eventually be stored in a relational database, which will serve as the back-end of the DSS. The database includes numerous Tables, however the main ones concern the study details, and the safety effects details. The database is designed and structured so that DSS user queries will be returning results in terms of key studies for each topic, safety effects reported in the studies, and SafetyCube synopses of the effects per topic. For each topic, the database will allow a customised search for results from specific countries, road user types, road types etc.

4.2.4 Design principles and inclusion criteria

The DSS is created on the basis of the following design principles:

- A Modern web-based tool
- High Ergonomic interface
- Simple structure
- Powerful Search Engines
- Fully Documented information
- Easily Updated

Furthermore, the design should be consistent throughout all tools (e.g. unique visual identity, colours, design, messages, etc.). The design should be modern and ergonomic utilizing multimedia (photos and videos) wherever possible. The system should allow for updates by receiving feedback not only from the users but also from visits traffic monitoring. Lastly, a robust promotion policy will be developed during and after the project via newsletters, social media and so on.

The content of the DSS is also of high importance. The inclusion criteria are briefly illustrated. Quantitative results are required, therefore qualitative studies and literature reviews are not a priority (although may be useful). Information completeness is very important and should be taken into account as well. In order to prioritize the information entered on the DSS, a set of priority criteria have been developed. In general, meta-analyses are preferred over simple analyses. Methodological soundness and high clarity (adequate sample size, appropriate statistical methods), are basic criteria for studies to be included in the DSS. Moreover, the year of each study is important, as recent studies are more likely to apply more appropriate methods, consequently, more recent studies are preferred.

4.3 DSS DESIGN

4.3.1 Overview of the DSS

This section provides an overview of the DSS. The DSS consists of the backend (relational database), the front end (website) and the way they integrate (queries). At first, the templates of coded studies are undergoing a thorough checking and debugging process. The templates are eventually stored in a relational database, which will serve as the back-end of the DSS. Front-end DSS results will be retrieved through queries on the back-end database (DSS search engine).

Figure 7 illustrates the Main Menu of the DSS as well as the entry points which will be described later on. The main menu provides Basic Information about SafetyCube and the DSS ("About") as well as details about Road Safety Tools ("Tools") including background information, resources and methodology, including extensive glossary.

Figure 7: Overview of the Main Menu and entry points of the DSS.

The heart of the DSS consists of the searchable/dynamic and static aspects; five entry points and three levels.

More specifically, these five entry points of the DSS are:

- **Text search** (database key-words search engines)
- **Road Safety Risk Factors** (Risk factors search engine)
- **Road Safety Measures** (Measures search engine)
- **Road User Groups** (Risk factors and Measures search)
- **Accident Scenarios** (Risk factors and Measures search)

The three levels of the DSS are briefly summarized as follows:

- **Home Page** - Level 0
- **Search Pages** - Level 1
  - Text / Risk Factors / Measures / Road User Groups / Accident Scenarios
- **Search Results** - Level 2
  - In table form - synopses and studies available for the selected search topic(s)
  - Refine search
  - Links to related risk factors / measures
- **Individual study results** - Level 3
- **Tools and documentation Pages** - Level 1

More specifically, the Home Page, provides a general description of the system and enables an initial selection of the element of interest (e.g. risk factor or measure, via one of the entry points). The next level (Level 1) consists of the specific search that the user wishes to carry out on the basis of the five entry points. Tools and documentation pages are also illustrated at Level 1.

Level 2 provides the results of the search. A list of studies available with the respective estimates (in table form) as well as the synopses of risk factors or measures are provided at this level. Two more options are provided. The one is the refine search. The other is the link to related risk factors or measures as users will be able to find measures associated with each road safety problem, by means of links between risks results and measures results. It is considered that the DSS may also allow addition of new measures by users of the DSS in the future.

Finally, the individual study results are provided in Level 3 through a risk factor or a measure individual study form.

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.

Figure 8 that follows provides an illustration of the whole DSS interface design, consisting of all entry points and levels.

As for the DSS Search Engine, the following characteristics are pursued:

- Fully linked search
  - 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
- Fully detailed search
  - search by any parameter in each data table (road safety problems, measures)
- Fully flexible search
  - adjust search according to results
- Fully documented search
  - access background information at any stage (links, etc.)

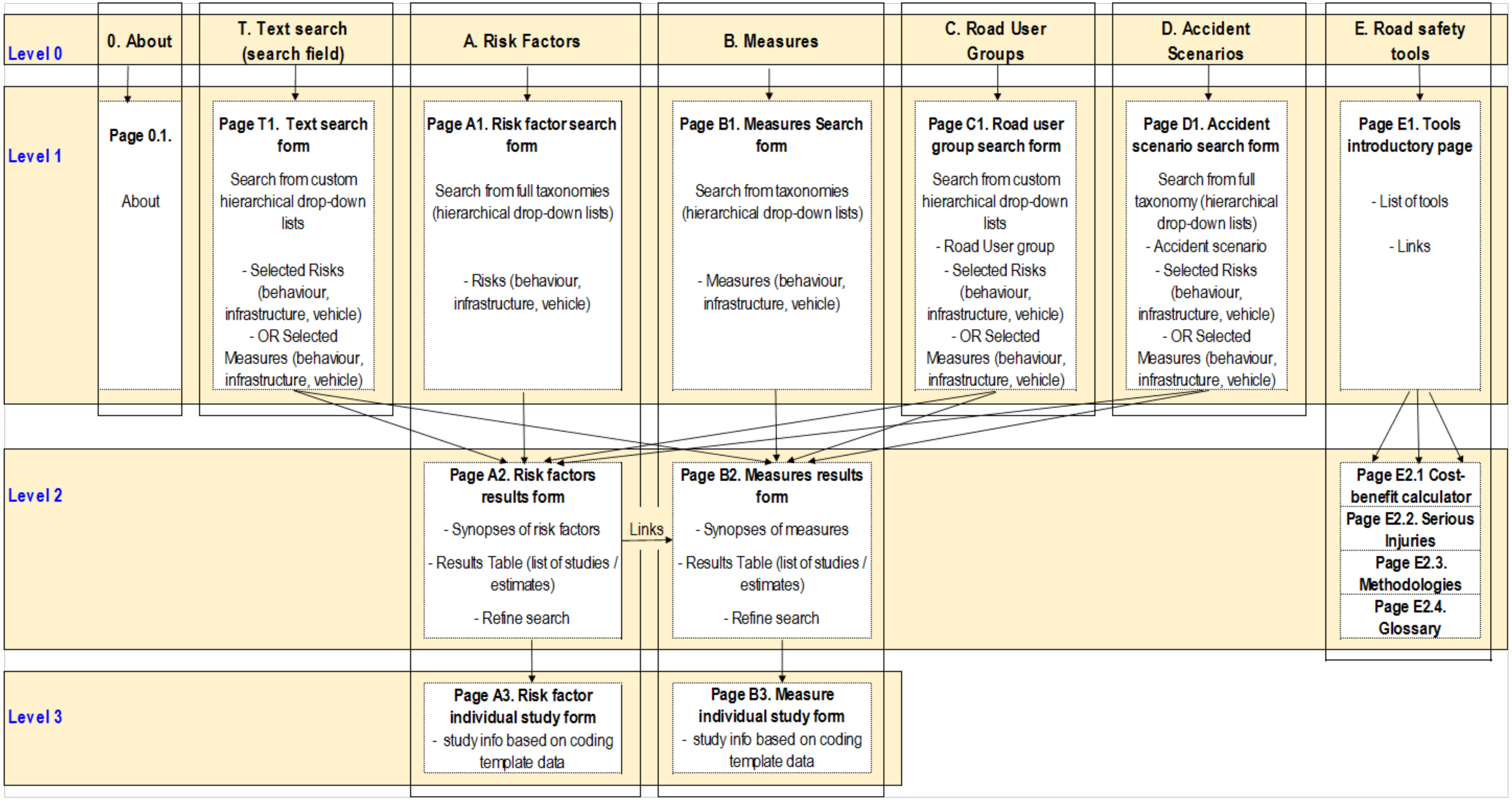


Figure 8: Overview of the DSS interface.

4.3.2 Integration of the Work packages

The design principles of the DSS ensure a smooth integration of the Work Packages in two ways. First, the SafetyCube common methodology applied results in common rigorous study selection criteria, studies analysis and findings presentation, as well as summary and meta-analysis of research findings.

Second, the fully linked search allows to combine risk factors related to particular road user groups, accident types etc., from road user, infrastructure or vehicle viewpoint, eventually allowing the end user to better perceive the interactions between these components in road safety. Moreover, measures from all three components (road user, infrastructure and vehicle) will be proposed for each risk factor / problem, and vice versa.

4.3.3 Hot topics

The hot topics will be strongly represented in the DSS by means of the more detailed analysis that has been carried out for these topics in the various Work Packages. The hot topics will be indicated by an appropriate mark in the DSS interface.

4.4 DSS DEVELOPMENT

4.4.1 Entry points

As mentioned earlier, five entry points exist, namely text search, road safety risk factors, road safety measures, road user groups and accident scenarios, as they were illustrated in Figure 7 in section 4.3.1. Therefore, the users will be able to select one of these five entry points depending on the type of search that they wish to conduct. More specifically, the text search allows the users to enter database key-words, the road safety risk factors/measures entry points allows them to seek specific risk factors or measures from the SafetyCube taxonomies respectively. On the other hand, the road user groups entry point enables a dedicated search of both risk factors and measures related to the selected group of road user. The same applies to accident scenarios as well.

4.4.2 Search Pages

Level 1 of the DSS offers a strong and flexible series of search pages on the basis of the five entry points. In this section, a number of examples are demonstrated in regard with search possibilities of the DSS.

The first example is about the risk factor search. After the user has selected the risk factor tab, they will be able to carry out a next search on the basis of the three categories of taxonomy fields (road user, infrastructure and vehicle). At this point, the SafetyCube taxonomy of risk factors is exploited and the DSS offers a free choice of topic (e.g. roadside deficiencies, distraction inside vehicle, inappropriate speed etc.). A more specific selection of risk factor (e.g. no clear-zone, mobile phone, too fast / too slow) will be available at the search refinement in the results page (Level 2). Figure 9 illustrates the first example regarding the search of risk factors.

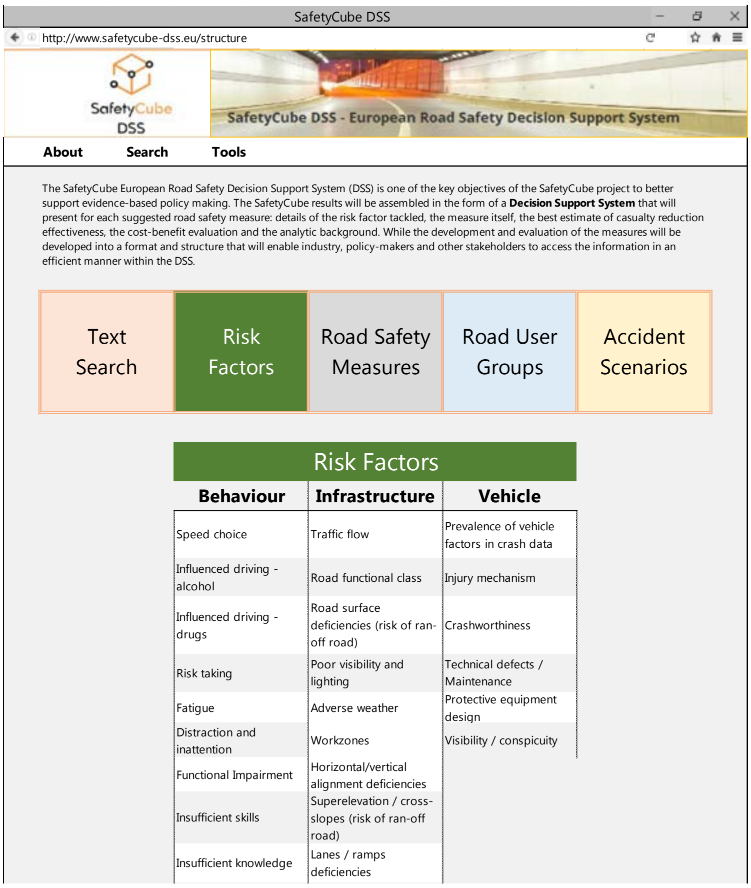


Figure 9: Example of search page regarding risk factors.

The next example concerns the search for road safety measures. The philosophy of this search is identical to that of risk factor search. At first the user has to select the measures tab in order to be able to do the next search (for road user, infrastructure or vehicle). Similarly, the measures taxonomy is exploited and they can then choose for a general family of measures (e.g. formal tools to address road network deficiencies, speed regulation etc.). A more specific measure such as road safety audits, campaigns, lower speed limits and so on may be selected in the search refinement at Level 2. Figure 10 illustrates the first example regarding the search of measures.

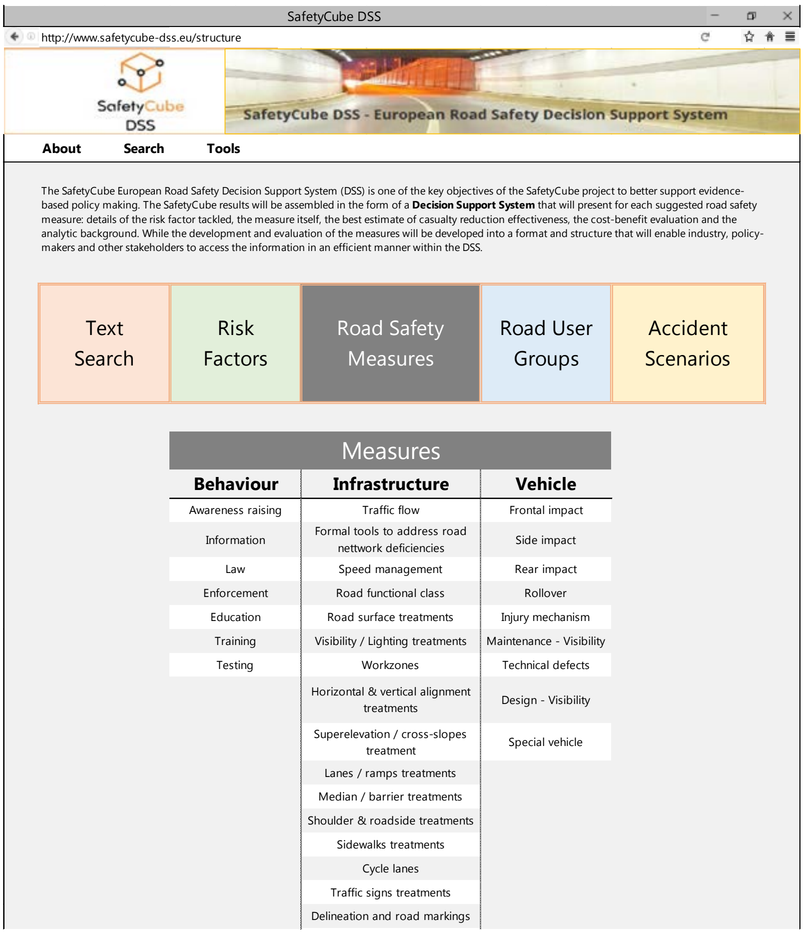
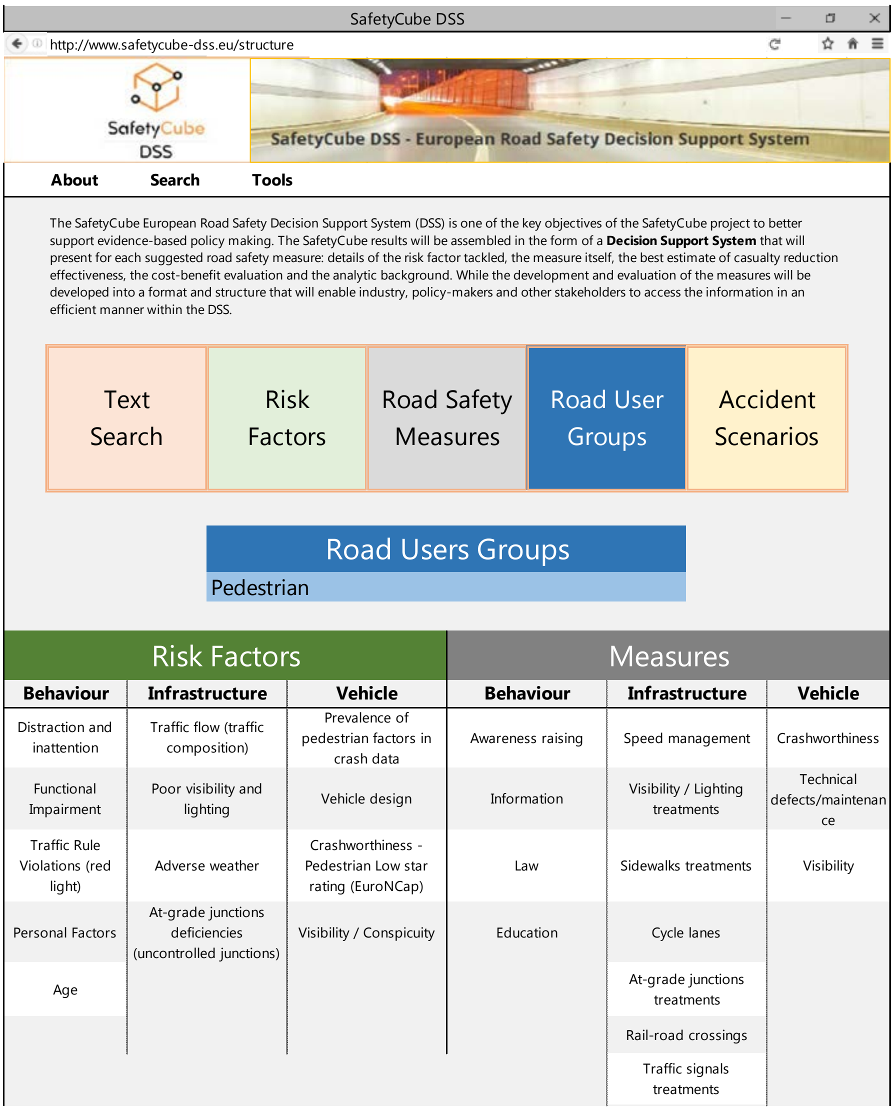


Figure 10: Example of search page regarding measures.

The next example demonstrated regards the road user group entry point. The user can choose among various road user groups, namely, pedestrians, bicycles, PTW / ATV, passenger Cars, LGV or Trucks / Bus. For each group, six categories of taxonomy fields appear (three for risk factors and three for measures), that is road user, infrastructure, vehicle for risks and measures. Afterwards, the user can select the topic of interest, i.e. a specific risk factor or measure for the chosen road user group. The next figure (Figure 11) demonstrates an illustration of that search regarding pedestrians.



SafetyCube DSS

http://www.safetycube-dss.eu/structure

SafetyCube DSS

SafetyCube DSS - European Road Safety Decision Support System

About Search Tools

The SafetyCube European Road Safety Decision Support System (DSS) is one of the key objectives of the SafetyCube project to better support evidence-based policy making. The SafetyCube results will be assembled in the form of a **Decision Support System** that will present for each suggested road safety measure: details of the risk factor tackled, the measure itself, the best estimate of casualty reduction effectiveness, the cost-benefit evaluation and the analytic background. While the development and evaluation of the measures will be developed into a format and structure that will enable industry, policy-makers and other stakeholders to access the information in an efficient manner within the DSS.

Text Search | Risk Factors | Road Safety Measures | Road User Groups | Accident Scenarios

Road Users Groups

Pedestrian

Risk Factors			Measures		
Behaviour	**Infrastructure**	**Vehicle**	**Behaviour**	**Infrastructure**	**Vehicle**
Distraction and inattention	Traffic flow (traffic composition)	Prevalence of pedestrian factors in crash data	Awareness raising	Speed management	Crashworthiness
Functional Impairment	Poor visibility and lighting	Vehicle design	Information	Visibility / Lighting treatments	Technical defects/maintenance
Traffic Rule Violations (red light)	Adverse weather	Crashworthiness - Pedestrian Low star rating (EuroNCap)	Law	Sidewalks treatments	Visibility
Personal Factors	At-grade junctions deficiencies (uncontrolled junctions)	Visibility / Conspicuity	Education	Cycle lanes	
Age				At-grade junctions treatments	
				Rail-road crossings	
				Traffic signals treatments	

Figure 11: Example of search page regarding road user groups-pedestrians.

The next example demonstrates the search configuration regarding accident scenarios. After the user has selected the Accident scenarios tab, the DSS provides a series of accident scenarios as defined by the taxonomy. More specifically, accident scenarios include pedestrian accidents, bicycle accidents, single vehicle accidents, head-on collisions, rear end collisions, junction accidents – no turning, junction accidents – turning and railway level crossings. Similar to road user groups search, for each scenario, six categories of taxonomy fields exist; related Risks: road user, infrastructure, vehicle and related Measures: road user, infrastructure, vehicle). Afterwards, the user can select a topic in order to find a specific risk factor or measure. The next figure (Figure 12) demonstrates an illustration of that search regarding single vehicle accidents.

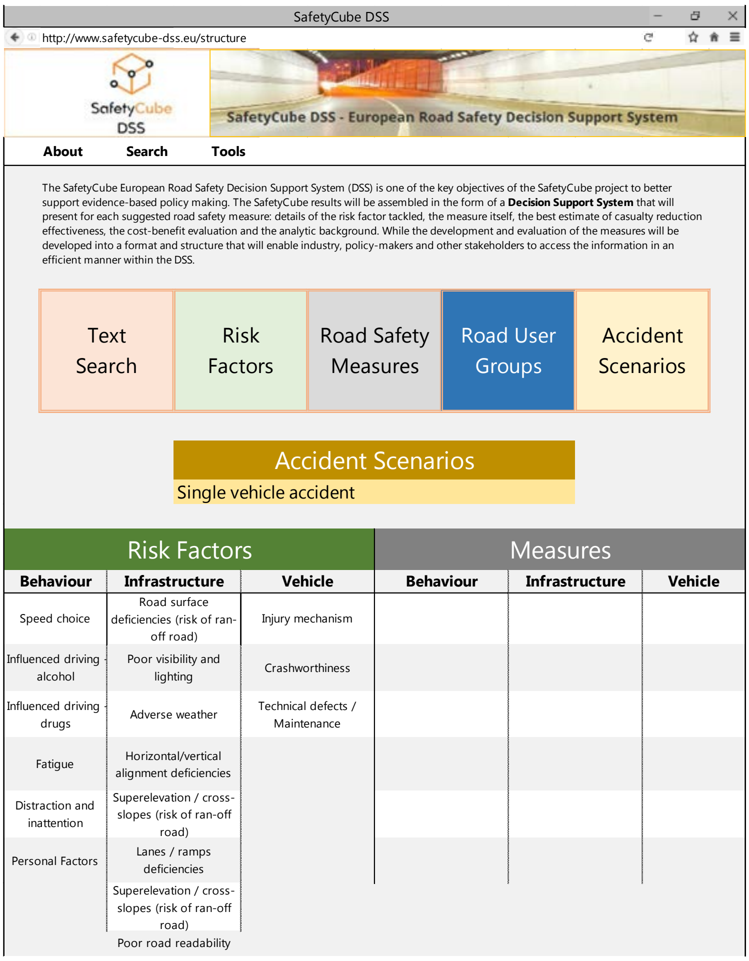
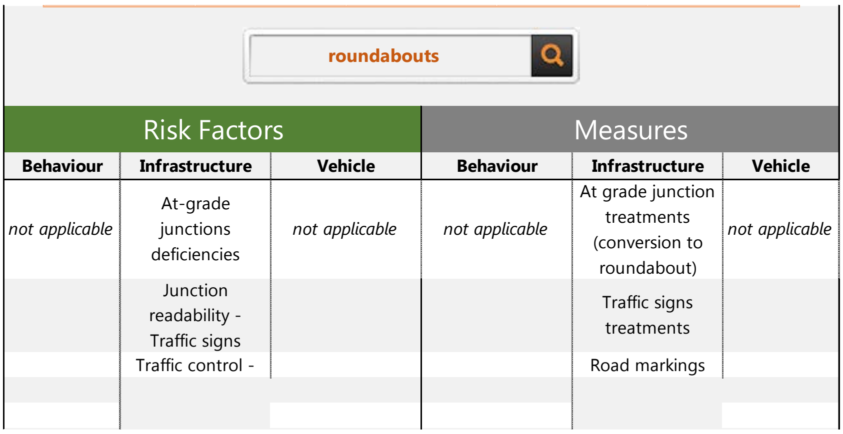


Figure 12: Example of search page regarding accident scenarios-single vehicle accidents.

The last of the five entry points concerns the most flexible search available; the key-word search. This option is an auto-complete field among all key-words in the database of SafetyCube. In that context, for each key-word, six categories of taxonomy fields exists; three for the related Risks (road user, infrastructure, vehicle) and three for the related Measures (road user, infrastructure, vehicle). Next, a specific risk factor and measure can be selected. The next two figures (Figure 13 and Figure 14) demonstrate the text search page and the search page for roundabouts respectively.

Figure 13: Example of text search page.



roundabouts

Risk Factors			Measures		
Behaviour	Infrastructure	Vehicle	Behaviour	Infrastructure	Vehicle
not applicable	At-grade junctions deficiencies	*not applicable*	*not applicable*	At grade junction treatments (conversion to roundabout)	*not applicable*
	Junction readability - Traffic signs			Traffic signs treatments	
	Traffic control -			Road markings	

Figure 14: Example of text search page-roundabouts.

4.4.3 Results Pages

General

This section provides an example of the operation of the Results Pages in the DSS, for risk factors in particular. As described, the result page provides the results in table form, a refine search and links to related risk factors/measures.

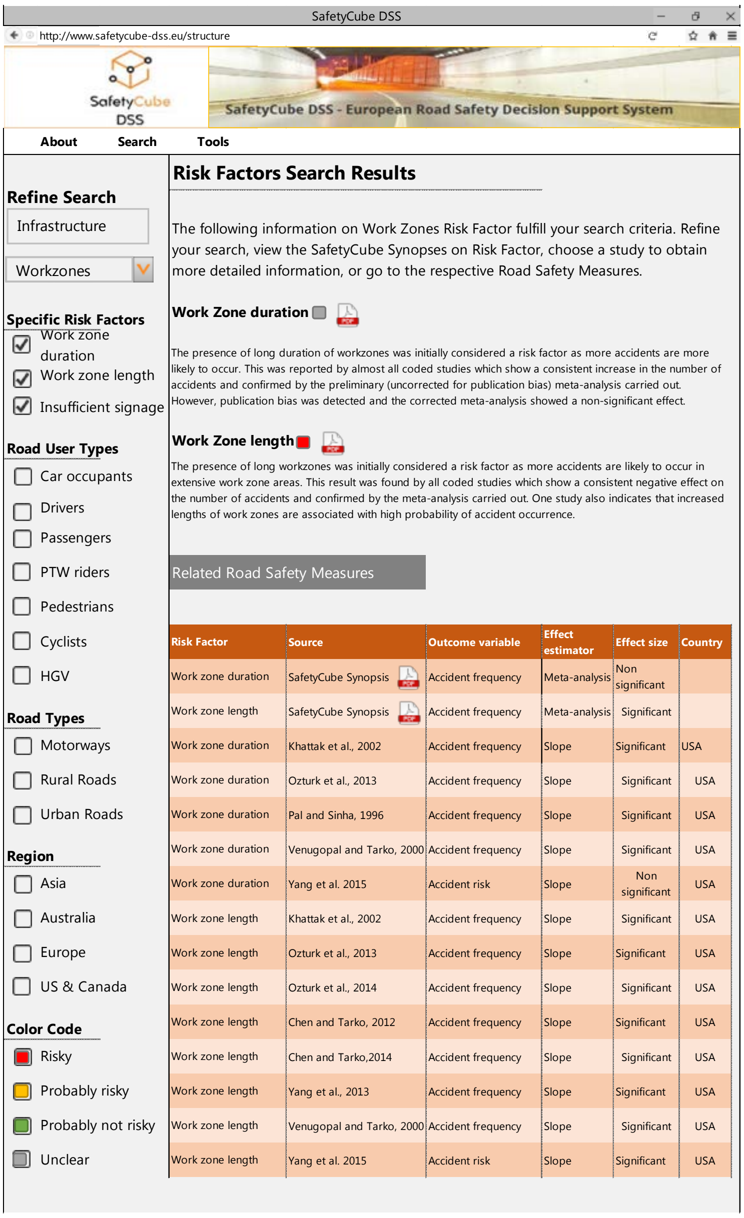
The search results consist of a table listing the available synopses, meta-analyses and other studies in the SafetyCube database. In addition, table columns that concern main study characteristics (design, outcome variable, effect estimator and size, country, year etc.) are illustrated.

Refine search and links

As far as the refine search is concerned, it consists of the following choices (search filters):

- specific risk factor,
- road user types (all, car occupants, drivers, passengers, PTW riders, pedestrians, cyclists, HGV),
- road types (all, motorways, rural roads, urban roads),
- region/country (EU, EU countries (all names), US and Canada, Australia, Asia) and,
- “colour code” (risky, probably risky, unclear, probably not risky).

Finally, the user has access to links to related measures by going to a respective measures search / results page, where the list of related measures is displayed as a pre-filled search. The next figure provides an illustration of risk factors search results regarding workzones.



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SafetyCube DSS

SafetyCube DSS - European Road Safety Decision Support System

About Search Tools

Refine Search

Infrastructure

Workzones

Specific Risk Factors

- [x] Work zone duration
- [x] Work zone length
- [x] Insufficient signage

Road User Types

- [ ] Car occupants
- [ ] Drivers
- [ ] Passengers
- [ ] PTW riders
- [ ] Pedestrians
- [ ] Cyclists
- [ ] HGV

Road Types

- [ ] Motorways
- [ ] Rural Roads
- [ ] Urban Roads

Region

- [ ] Asia
- [ ] Australia
- [ ] Europe
- [ ] US & Canada

Color Code

- Risky
- Probably risky
- Probably not risky
- Unclear

Risk Factors Search Results

The following information on Work Zones Risk Factor fulfill your search criteria. Refine your search, view the SafetyCube Synopses on Risk Factor, choose a study to obtain more detailed information, or go to the respective Road Safety Measures.

Work Zone duration

The presence of long duration of workzones was initially considered a risk factor as more accidents are more likely to occur. This was reported by almost all coded studies which show a consistent increase in the number of accidents and confirmed by the preliminary (uncorrected for publication bias) meta-analysis carried out. However, publication bias was detected and the corrected meta-analysis showed a non-significant effect.

Work Zone length

The presence of long workzones was initially considered a risk factor as more accidents are likely to occur in extensive work zone areas. This result was found by all coded studies which show a consistent negative effect on the number of accidents and confirmed by the meta-analysis carried out. One study also indicates that increased lengths of work zones are associated with high probability of accident occurrence.

Related Road Safety Measures

Risk Factor	Source	Outcome variable	Effect estimator	Effect size	Country
Work zone duration	SafetyCube Synopsis	Accident frequency	Meta-analysis	Non significant	
Work zone length	SafetyCube Synopsis	Accident frequency	Meta-analysis	Significant	
Work zone duration	Khattak et al., 2002	Accident frequency	Slope	Significant	USA
Work zone duration	Ozturk et al., 2013	Accident frequency	Slope	Significant	USA
Work zone duration	Pal and Sinha, 1996	Accident frequency	Slope	Significant	USA
Work zone duration	Venugopal and Tarko, 2000	Accident frequency	Slope	Significant	USA
Work zone duration	Yang et al. 2015	Accident risk	Slope	Non significant	USA
Work zone length	Khattak et al., 2002	Accident frequency	Slope	Significant	USA
Work zone length	Ozturk et al., 2013	Accident frequency	Slope	Significant	USA
Work zone length	Ozturk et al., 2014	Accident frequency	Slope	Significant	USA
Work zone length	Chen and Tarko, 2012	Accident frequency	Slope	Significant	USA
Work zone length	Chen and Tarko,2014	Accident frequency	Slope	Significant	USA
Work zone length	Yang et al., 2013	Accident frequency	Slope	Significant	USA
Work zone length	Venugopal and Tarko, 2000	Accident frequency	Slope	Significant	USA
Work zone length	Yang et al. 2015	Accident risk	Slope	Significant	USA

Figure 15: Example of risk factors search results-Workzones.

Synopses

Synopses in SafetyCube are basically syntheses on risk factors/measures and provided in the DSS results. The explanation of the risk factor colour code assigned on the basis of the analysis results for each risk factor is provided in the results page. The full text of the synopsis can be viewed as a pdf file.

The first part of the full synopsis is the summary which is about two pages long and briefly describes the following:

- effect of risk factor / measure and ranking (colour code),
- risk/safety effect mechanisms,
- risk/safety effects size,
- transferability of effects.

The second part is the scientific overview in which more technical details about the analysis of the risk factor are included in four to five pages:

- a comprehensive comparative analysis of available studies designs and results,
- the analysis results;
  - a meta-analysis (if carried out to summarize the effects across various studies),
  - a vote-count analysis (if meta-analysis was not possible) or ,
  - a qualitative analysis (if the number of studies was low).

Additionally to the scientific overview an analysis of in-depth accident data was conducted using the German GIDAS database and the French VOIESUR in-depth database. By this means the influence of certain risk factors on the accident characteristics is displayed using standardized graphs (radar plots), e.g. to show that the share of speeding accidents is significantly higher at night time than during day time.

The last part of the synopsis is the supporting document which is about three to ten pages and consists of:

- literature search strategy and study selection criteria,
- more detailed analyses.

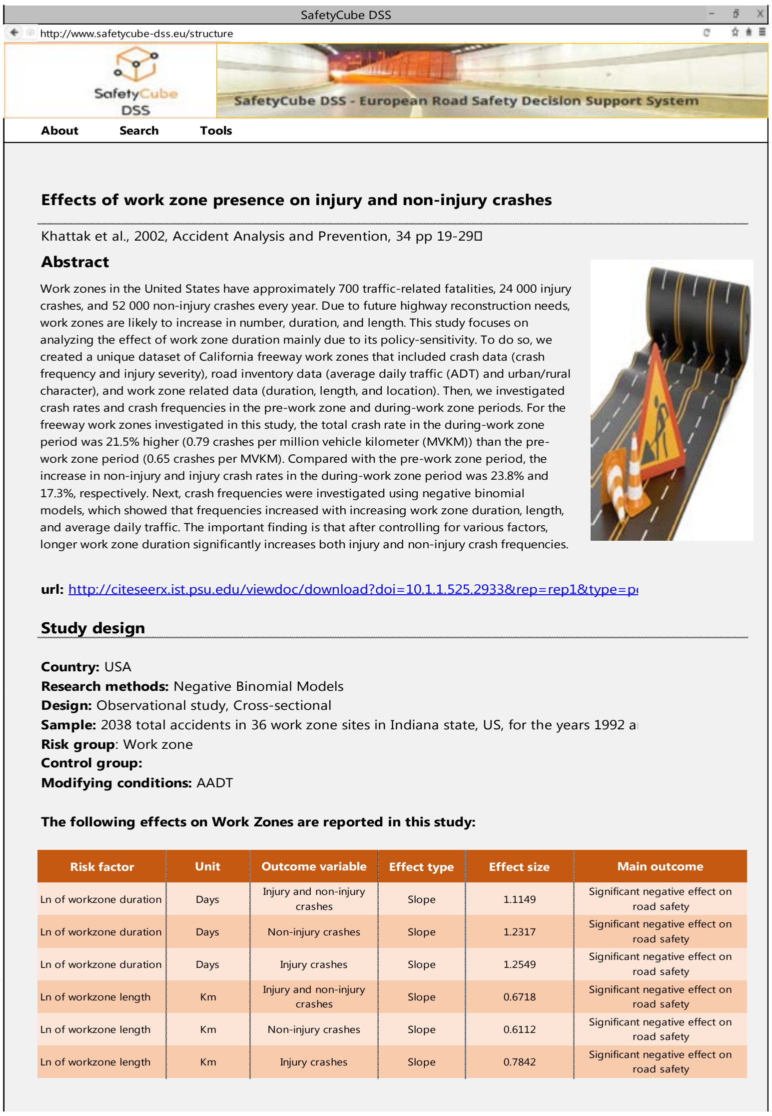
4.4.4 Individual study Pages

Another important characteristic of the SafetyCube DSS is the capability of providing the user all the necessary information for each specific individual study through the Individual study Pages at Level 3. The following information is given:

- Title, author, source, abstract.
- Study design info.
- Study results.

At first, all the general information about the selected individual study (title, author, source and abstract) is provided as well as a link to URL for full-text download[6]. As for the study design info, it includes more specific information about the country, the undertaken research method, the design, the study sample, the control group, risk group, modifying conditions etc. Finally, the study results are provided which include a table listing the effects reported in the study and table columns concern main study / effect characteristics (outcome variable, effect type, size and confidence intervals, statistical significance). The next figure (Figure 16) is an example of individual study results (Khattak et al.,2002, workzone duration).

[6] Access will depend on Institute permissions.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SafetyCube DSS

SafetyCube DSS - European Road Safety Decision Support System

About Search Tools

Effects of work zone presence on injury and non-injury crashes

Khattak et al., 2002, Accident Analysis and Prevention, 34 pp 19-29

Abstract

Work zones in the United States have approximately 700 traffic-related fatalities, 24 000 injury crashes, and 52 000 non-injury crashes every year. Due to future highway reconstruction needs, work zones are likely to increase in number, duration, and length. This study focuses on analyzing the effect of work zone duration mainly due to its policy-sensitivity. To do so, we created a unique dataset of California freeway work zones that included crash data (crash frequency and injury severity), road inventory data (average daily traffic (ADT) and urban/rural character), and work zone related data (duration, length, and location). Then, we investigated crash rates and crash frequencies in the pre-work zone and during-work zone periods. For the freeway work zones investigated in this study, the total crash rate in the during-work zone period was 21.5% higher (0.79 crashes per million vehicle kilometer (MVKM)) than the pre-work zone period (0.65 crashes per MVKM). Compared with the pre-work zone period, the increase in non-injury and injury crash rates in the during-work zone period was 23.8% and 17.3%, respectively. Next, crash frequencies were investigated using negative binomial models, which showed that frequencies increased with increasing work zone duration, length, and average daily traffic. The important finding is that after controlling for various factors, longer work zone duration significantly increases both injury and non-injury crash frequencies.

url: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.525.2933&rep=rep1&type=p

Study design

Country: USA
Research methods: Negative Binomial Models
Design: Observational study, Cross-sectional
Sample: 2038 total accidents in 36 work zone sites in Indiana state, US, for the years 1992 a
Risk group: Work zone
Control group:
Modifying conditions: AADT

The following effects on Work Zones are reported in this study:

Risk factor	Unit	Outcome variable	Effect type	Effect size	Main outcome
Ln of workzone duration	Days	Injury and non-injury crashes	Slope	1.1149	Significant negative effect on road safety
Ln of workzone duration	Days	Non-injury crashes	Slope	1.2317	Significant negative effect on road safety
Ln of workzone duration	Days	Injury crashes	Slope	1.2549	Significant negative effect on road safety
Ln of workzone length	Km	Injury and non-injury crashes	Slope	0.6718	Significant negative effect on road safety
Ln of workzone length	Km	Non-injury crashes	Slope	0.6112	Significant negative effect on road safety
Ln of workzone length	Km	Injury crashes	Slope	0.7842	Significant negative effect on road safety

Figure 16: Example of individual study results-Khattak et al. (2002)-workzone duration.

4.4.5 Tools pages

In the main menu of the DSS website, there is also the option to select the tab "Tools". Through this option, links to SafetyCube tools are offered, more specifically, a cost benefit calculator, relevant information about serious injuries, information about the SafetyCube methodology and also the SafetyCube Glossary. The next figure (Figure 17) demonstrates the tools page.

Figure 17: Example of DSS tools page.

4.5 NEXT STEPS

A wealth of risks, countermeasures and studies related to behaviour, road infrastructure and vehicle exist in the database. So far, more than 500 studies have been analysed in the area of road risks with more than 3,500 risk estimates, summarised in more than 60 synopses (including approximately 10 meta-analyses and analysis of in depth-accident databases), and the related measures analyses are in progress. In particular, more than 20 existing meta-analyses on measures are updated and about 65 more are in progress. A high number of summary reports (synopses) which will provide a critical synthesis of each risk factor and measure are already prepared and more are under development. Thus, this wealth of information will all be incorporated into the DSS and become its core outputs.

As for the design of the DSS, it is finalised and the first static prototype of the DSS (wire frames) is available since the end of June 2016 and is further improved incorporating comments from the workshop which took place in Brussels on 27th of September 2016. Regarding the SafetyCube DSS Development phase, it will take place between September and December 2016 including all risk factors and several measures. The DSS Pilot Operation is starting in early 2017. The final opening of the DSS is scheduled for mid-2017 and will be constantly updating from April 2018 (end of the SafetyCube project) and onwards.

The DSS is intended to become a major source of information for industry, policy-makers and the wider road safety community; it will incorporate the knowledge base of accident causation, risks and measures that will be developed in the project and the underlying methodological systems. It will be developed in a form that can readily be incorporated within the existing European Road Safety Observatory of the European Commission DG-MOVE. The development of the DSS presents a great potential to further support decision making at local, regional, national and international level, aiming to fill in the current gap of comparable measures effectiveness evaluation across Europe and worldwide.

5 Conclusion

The plea for more evidence based decision making in road safety has been around for decades – and has largely remained unfulfilled to date. One of the reasons is that comprehensive information on crash causation & risks intertwined with the opportunity to make objective comparisons between potential interventions have simply not been available.

SafetyCube is likely to provide a game-change in this respect, by developing a Decision Support System (DSS) to support European policy making at all levels. A road collision is rarely the result of a single factor and several types of interventions are usually available – hence the quest is for a systemic approach to road safety. SafetyCube will establish a framework featuring relevant – usually multiple – links between crash-causing risk factors and safety measures – both together with their scientifically proven impact on safety – in order to facilitate the quest for more effective road safety strategies in the future.

This report outlined the first successful steps of SafetyCube's Work Package 8 towards developing the DSS. More specifically, WP8 task 8.1's objectives were to

- Define the **systems approach** within SafetyCube.
- Develop **taxonomies** for both risks and measures.
- Identify a common set of **accident scenarios.**
- Initiate the work on **DSS development.**

For SafetyCube, the application of the systems approach translates into the provision of evidence-based information that takes account of the interrelationship of both risks and the appropriate measures for infrastructure, road user behaviour, vehicles and injury prevention. In practice, the quantitatively validated risk factors which relate to behaviour, infrastructure or vehicle technology will therefore be linked to measures in any or all of these areas if appropriate. Establishing both the validation and these links in such a consistent and comprehensive way is done for the first time in history; the work will not only be carried out on the basis of available literature but also using information from in-depth-databases. The joint methodology for the analytical process has been developed in WP3. Similar links will have to be established between further future entry points of the DSS – road user types & accident scenarios – and relevant risks and measures.

For both risks and measures, comprehensive taxonomies have been set up, for each of the "columns" of driver behaviour (WP4), infrastructure (WP5), Vehicles (WP6), and for measures in the field of post impact care (WP7). They all feature a three-layered structure and will be reflected both in the architecture of the DSS as well as in the DSS's search options. WP8 coordinated the taxonomy process and assigned analyses to WPs 4, 5 or 6 where there was potential for overlap: 1) several risks & measures could have been assigned to more than one of the above work packages, 2) certain behaviours or infrastructure features could have been treated both as risks and measures.

Based on analyses in in-depth databases – especially from MHH/GIDAS and LAB – a common set of accident scenarios was set up. They will serve two purposes: 1) to provide entry points for the DSS's search engine and 2) to objectify how frequently risk factors (and partly measures) identified by SafetyCube appear in in-depth records of real accidents. For this latter exercise, it was crucial to develop a common method to statistically validate the resulting frequency matrices.

A draft architecture for the DSS development has been designed on top of the above taxonomies and accident scenarios, as well as on the basis of a vast amount of scientific studies on crash-relevant risks as already coded and analysed by work packages 4, 5 and 6 (see Deliverables D4.1, D5.1, D6.1). The DSS will consist of a backend (relational database) and a front end (website, including a query interface). The ambition is to provide a user friendly and interactive decision support tool. To this end, user requirements towards such a system have been discussed with stakeholder communities at various occasions during the first half of the project (see D2.5). At these occasions, also "hot topic" areas were collected from stakeholders, i.e. those fields that the SafetyCube teams would be required to treat with highest priority in their work. Based on user feedback, a set of five so-called entry points were set up: Text search, Risk Factors, Measures/ Interventions, Road User Groups, and Accident Scenarios. At this stage, exemplary wire frames are available for various search paths from these entry points. It is yet to decide how to go about areas where little or no studies or data exist, such as for combinations of interventions or organisational aspects of road safety (such as Road Safety Management).

An international review of existing DSS revealed that a) no European DSS is currently available, b) risk factors are nowhere included in any of the existing systems – only measures, and c) most information is focused on infrastructure. The SafetyCube DSS is therefore unique in its setting and will – once finalised – close a substantial knowledge gap in the road safety (decision making) community.

The further steps in WP8 will be as follows:

- The already existing results in terms of scientifically assessed risk factors (WP4-6) will be completed by assessed measures (WP4-7) and compiled in task 8.2. This includes also the establishing of scientifically sound links between risks and measures. In the framework of this task it will also be made sure to make further steps of DSS development available for further discussion & feedback with stakeholders.
- A tool for the assessment of effectiveness and cost-benefit estimates (to be integrated in the DSS) will be developed under task 8.2. One of the specific challenges here may be the poor availability of intervention costs. An additional challenge will be to establish predictive estimates such as on the safety impacts of new driver assistance or automation technologies which are only currently becoming available.
- Under task 8.3 a fully operational version of the DSS will be established. It will enable the user to start queries from different entry points and receive results at various levels of depth, depending on actual user background and requirements.
- Task 8.4 will prepare training courses for stakeholders with different backgrounds.
- Task 8.5 will be concerned with making sure that the results and tools developed in SafetyCube will be available – and updated at a regular basis – also beyond the end of the project.

References

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

Cuny, S., Krishnakumar, R. (2012) CACIAUP Report D4.1: Identification des configurations d'accidents et des causes associées, 2012 (French language text)

DaCoTa. (2012a). Roads, Deliverable 4.8q of the EC FP7 project DaCoTA.

DaCoTa. (2012b). Speed and Speed Management, Deliverable 4.8s of the EC FP7 project DaCoTA.

Fancello, G., Carta, M., & Fadda, P. (2015). A decision support system for road safety analysis. Transportation Research Procedia, 5, 201-210.

Frey, K. (2010). Revising road safety policy: The role of systematic evidence in Switzerland. Governance, 23(4), 667-690.

Hughes, B. P., Anund, A., & Falkmer, T. (2016). A comprehensive conceptual framework for road safety strategies. Accident Analysis & Prevention, 90, 13-28.

Hughes, B. P., Newstead, S., Anund, A., Shu, C. C., & Falkmer, T. (2015). A review of models relevant to road safety. Accident Analysis & Prevention, 74, 250-270.

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

Larsson, P., Dekker, S. W. A., & Tingvall, C. (2010). The need for a systems theory approach to road safety. Safety Science, 48(9), 1167-1174.

Martensen, H. et al. (2016). Preliminary guidelines for priority setting between measures. Deliverable Number 3.4 of the H2020 project SafetyCube.

Naing, C., Bayer, S., Van Elslande, P., Fouquet, K. (2007). Which Factors and Situations for Human Functional Failures? Developing Grids for Accident Causation Analysis. Deliverable of the EU FP6 project TRACE.

Papadimitriou, E., & Yannis, G. (2014). Needs and priorities of road safety stakeholders for evidence-based policy making. Transport Policy, 35, 286-294.

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

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

OECD/ITF. (2016). Zero Road Deaths and Serious Injuries: Leading a Paradigm Shift to a Safe System. Paris.

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.

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

Salmon, P.M., Lenné, M.G., Stanton, N.A., Jenkins, D.P., Walker, G.H., 2010. Managing error on the open road: the contribution of human error models and methods. Saf. Sci. 48 (10), 1225–1235

Salmon, P. M., McClure, R., & Stanton, N. A. (2012). Road transport in drift? Applying contemporary systems thinking to road safety. Safety science,50(9), 1829-1838.

Salmon, P. M., & Lenné, M. G. (2014). Miles away or just around the corner? Systems thinking in road safety research and practice. Accident analysis and prevention, 74, 243-249.

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.

Uittenbogaard, J., Rodarius, C., & Od den Camp, O. (2014) CATS Report D1.2: Car to cyclist accident scenarios, TNO R11594

Underwood, P., & Waterson, P. (2013). Systemic accident analysis: Examining the gap between research and practice. Accident Analysis & Prevention, 55, 154-164.

Van Elslande, P., Fouquet, K. (2007) TRACE Report D5.1: Analyzing human functional failures in road accidents

Van Elslande, P et al (2012) DACOTA Report D5.5: Drivers needs and validation for technologies

vFSS (no date) Accident Analysis: Accident analysis and results related to pedestrian accidents. Available at http://www.vfss.net/fileadmin/Redakteur/Downloads/WP1_Pedestrian_01.pdf. [Accessed Oct 2016]

Wallén Warner, H., Ljung Aust, M., Sandin, J., Johansson, E., Björklund, G. (2008). Manual for DREAM 3.0, Driving Reliability and Error Analysis Method. Deliverable D5.6 of the EU FP6 project SafetyNet.

Wegman, F., Berg, H. Y., Cameron, I., Thompson, C., Siegrist, S., & Weijermars, W. (2015). Evidence-based and data-driven road safety management. IATSS research, 39(1), 19-25.

Appendix A

Taxonomy of driver behaviour risks and measures dealt with in WP4. Please note that the taxonomy of measures is still preliminary and will be further developed within task 4.2.

RISKS

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 situation	Conversation with person, passenger/codriver
		Music, entertainment systems
		Cellphone use - talking - handheld mode
		Cellphone use - talking - hands-free mode
		Cellphone use - texting
		Operating devices (IVIS, navigation systems etc.)
		Animals, insects, others
		Consumation of goods (eating, drinking, smoking)
	Distraction outside vehicle	Watching persons, situations
		Static objects (advertisement, traffic management information ..)
		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)
	Reduced hearing	Decreased driving performance under presence of distractors
		Missing out auditory 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 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 pedestrian 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 (0-12 years)	Children (0-12 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
		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

MEASURES

Topic	Subtopic	Specific Measure	Addressed by WP5 or WP6
Speed choice	Speeding	Change Speed limits	
		Demerit point system	
		Implementation of 30-zones	WP5
		Increase sanctions	
		Installation of Speed Cameras	WP5
		installation of section control	WP5
		variable traffic signs	WP5
		mobile speed enforcement	
		Zero tolerance/ reduction of tolerance	
		Installation of individual dynamic speed warning - Smiley	WP5
		Speed awareness course	
		Speed Campaign	
		installation of speed humps	WP5
		implementation of traffic calming scheme	WP5
		Intelligent Speed Adaptation	WP6
	Inappropriate speed	Change speed limits	
		weather-variant speed limits	WP5
		Campaign	
		installation of speed humps	WP5
		implementation of woonerfs / narrowing's	WP5
		Road safety audit	WP5
Influenced driving	Drunk driving or drunk riding (cyclists/mopeds)	Alcohol ignition interlock device implementation	WP6
		Implementing zero tolerance (0,00 promile)	
		Reduction of tolerance	
		Demerit point system	
		Increased sanctions	
		Increased enforcement (traffic control)	
		Licence withdrawal	
		Driver improvement	
		Testing Drunk Busters (+Simulator)	

		Fitness to drive assessment	
		Workshops in driving school	
		Campaign	
		Leaflets	
		Alcohol ignition interlock device in the car	WP6
	Drugged driving/riding, legal (medicine)	Per se laws determining cut-offs	
		Demerit point system	
		Increased sanctions	
		Increased enforcement (police checks)	
		Targeted enforcement (at risk populations)	
		Licence withdrawal	
		Fitness to drive assessment	
		License renewal	
		Campaigns aimed at general public	
		Campaigns aimed at physicians, pharmacists, …	
		Information aimed at general public	
		Information aimed at physicians, pharmacists, …	
	Drugged driving/riding, illegal	Per se laws determining cut-offs - saliva testing/ analysis - blood testing/analysis	
		Demerit point system	
		Increased sanctions	
		Increased enforcement (police checks)	
		Targeted enforcement (at risk locations, times, populations)	
		Licence withdrawal	
		Driver improvement	
		Fitness to drive assessment	
		Several media	
	Combined usage	Per se laws determining cut-offs - saliva testing/ analysis - blood testing/analysis	
		Demerit point system	
		Increased sanctions	
		Increased enforcement (police checks)	
		Targeted enforcement (at risk locations, times, populations)	
		Licence withdrawal	
		Driver improvement	
		Fitness to drive assessment	
		Several media	
Risk taking	Risky overtaking	laws concerning dangerous driving	
		Demerit point system	
		increased controls	
		driver improvement training (dangerous behaviour)	
		fitness to drive assessment	
		topic in driver training	
		campaigns	
		Self-explaining roads	WP5
	Headway distance	laws concerning dangerous driving	
		Demerit point system	
		increased controls	
		driver improvement training (dangerous behaviour)	
		topic in driver training	
		campaigns	
		auxiliary markings on the lanes	WP5
		Advanced Cruise Control (ACC)	WP6
		Following Distance Warning (FDW) system	WP6
Fatigue	Driven a long time/not enough sleep	Driving times	
		Rest periods	
		tachometer	WP6
		Campaigns - hours driven, stopping for rests, drinking caffeine based drinks	
		Signs - reminding of need to rest	
		Availability of rest spaces	Wp5
		warning system based on physiological measure	WP6
Distraction and inattention	distraction within vehicle (if car user) or within the riding or walking situation	Introducing law against cellphone use	
		Demerit point system	
		Increase penalties for cellphone use while driving	
		Intensify enforcement against distracting activities	
		Intensify cellphone use law enforcement	
		Education of high risk groups with respect to distracted driving risks	
		Campaigns targeting specific distracting activities	
		Driver assistance systems (e.g. lane departure technologies, crash avoidance systems)	WP6
		Blocking cellphone calls technologies	WP6
	distraction outside vehicle (if car user)	Laws to prevent roadside installation of advertising signs	
		Campaigns	
		Removal of advertising signs	WP5
		Road safety audits	WP5
		implementation of design principles for signs	WP5
	distraction through state of mind and cognitive overload	on-road testing with distracting tasks	
		Education of high risk groups with respect to distracted driving risks	

		Raise awareness of high risk groups	
		Campaigns about effective/safe use of in-vehicle devices	
		Effective ergonomic design of the interface of in-vehicle devices to minimize mental workload under unsafe situations (rain, heavy traffic, curves etc.)	WP6
	Inattention	Campaigns for high risk groups	
		Driver assistance systems (e.g. lane departure technologies, crash avoidance systems)	WP6
Functional impairment	cognitive impairments	mandatory age based checking	
		medical privacy exception	
		increase control	
		reduction of tolerance	
		driving sessions	
		cognitive training	
		education training	
		fitness to drive assessment	
		self-estimation of driving abilities	
		campaign	
		implication of general practitioners	
		monitoring of the driver	WP6
Functional Impairment	reduced vision	Vision requirements in driving license	
		Useful Field-of-View	
		Glare sensitivity	
		Contrast sensitivity	
		Visual acuity	
		Age-based assessment	
		Driving performance	
	reduced hearing	Audiogram	
Insufficient skills and knowledge	Skills (motor, ..), operating errors	Licensing (Graduated driving licences- GDLs)	
		Basic driver training in driving schools	
		Specific trainings (Skid training, Night driving course, Improvement courses for older drivers…)	
		Driving test	
		Moped and motorcycle riders driving test	
		Road Safety Campaign	
		Advanced Driver Assistance Systems	WP6
	knowledge	Workplace Traffic Rules and Regulations	
		Licensing (Graduated driving licences- GDLs)	
		Basic driver training in driving schools	
		Course in defensive driving for experienced drivers	
		Improvement courses for older drivers	
		Driving test	
		Moped and motorcycle riders driving test	
		Education in schools	
		Education in workplace	
		Road Safety Campaign	
		In-vehicle Signing System	WP6
Emotions & Stress	intrinsic/extrinsic stress/time pressure	Driving and rest times for driving services, lorries,… (tachograph)	
		control of tachographs, adherence of rest times	
		time management for truck drivers	
		stress management training	
		campaigns	
		control sites for lorries	WP5
		tachograph	WP6
	positive/negative emotions	laws like " it is forbidden to act in such a way that menace on the road is caused or can be caused, or that road traffic is hindered or can be hindered"	
		sanction specific expressions of driver aggression, such as major speeding offences and tailgating	
		driver improvement courses	
		Fitness to drive assessment	
		campaign (e.g. http://runtervomgas.de/aktionen/aggression-ist-nicht-lustig/aggression-ist-nicht-lustig/)	
		shorten the waiting time for red lights (aggression)	WP5
		informing drivers about delays(aggression)	WP5
Misjudgement & Observation Errors	Misjudgement of oneself	Practical driving courses (available driver assistance systems; speed awareness)	
		collision warning/collision mitigation	WP6
		information about speeding	WP6
		optimization of HMI	WP6
	Misjudgement of others / situation	collision warning/collision mitigation	WP6
		enhance experience of driver	
		optical guidance (suggestion of other traffic situation)	WP5
		condition of road (e.g. visible road markings)	WP5
	Observation errors	car2car communication	WP6
		Night-vision systems; Parking cameras	WP6
		Gaze attention training	
		condition of road (e.g. visible road markings)	WP5
		defrost windows before driving; clean headlights	
		raising awareness of risks e.g. from side roads such as bicycles	
Use of safety devices	seat belt	Mandatory use of seatbelts	

		Demerit point system	
		Increased patrols/checks	
		Increased sanctions	
		Insurance penalty	
		correct positioning (adjustment/fitting)	
		campaigns	
		road signs	
		Seatbelt reminder	WP6
		Reduced function without belt	WP6
	Child restraints	Mandatory use	
		Demerit point system	
		Increased patrols/checks	
		Increased sanctions	
		Insurance penalty	
		Child restraint training	
		Demonstration of fitting	
		campaigns (Awareness/ Education of parents and/or children)	
		Manual	
		Isofix and I-Size	WP6
	Seat/Head restraint	correct positioning (adjustment/fitting)	
		campaigns	
		manual	
		Easy adjustment mechanism	WP6
		Memory of seat position	WP6
	protective clothing (excluding helmet)	Correct use of clothing	
		campaign	
	Helmet	mandatory fitment	
		Demerit point system	
		Increased patrols/checks	
		Increased sanctions	
		correct use of helmet	
		campaigns	
violations	red light running	Demerit point system	
		Red light cameras	
		Increased sanctions	
		local signs/warnings	
		Awareness campaign	
		Signs showing remaining waiting time	WP5
		reconstruction of intersection into not traffic light regulated	WP5
		Car-to-Vehicle Communication	WP6
	Disregard of right of way	Demerit point system	
		Increased sanctions	
		Increased patrols/checks	
		Car-to-Vehicle Communication	WP6
	Disregard of obligatory usage of car devices	Increased sanctions	
		Increased patrols/checks	
	Wrong way driving	Increased sanctions	
		Increased patrols/checks	
		Car-to-Vehicle Communication	WP6
	Using road lane dedicated to other road user or for other function	Increased sanctions	
		Increased patrols/checks	
		Car-to-Vehicle Communication	WP6
	Lack of vehicle maintenance & cargo securing	Demerit point system	
		Increased sanctions	
		Increased patrols/checks	
personality	Sensation seeking	Hazard perception training	
	ADH/AAD	driving sessions	
		education training	
		cognitive training	
		standard protocol	
		self-estimation of driving abilities	
		campaign	
		implication of general practitioners	
		monitoring of the driver	WP6
Age	Elderly	Mandatory fitness to drive test	
		Training use of new vehicle types (e.g. e-bike, mobility scooter, stability bicycles- three wheelers)	
		Voluntary driving test and advice	
		Refresher courses traffic rules	
		functional losses, physical vulnerability and the consequences	
		Behavioural compensation strategies (safer routes, safer transport modes, safer travel circumstances)	
		Availability and use of support systems (car/bicycle)	
		ADAS	WP6
		senior proof infrastructure	WP5
	Children (0-12 years)	mandatory fitment of cycle helmets	
		cycling proficiency training	
		pedestrian training (safe way to school)	

		cycling proficiency test	
		road safety education in school/kindergarden	
		campaigns	
		safe way to school maps	
		teaching materials for schools	
		safety inspections/audits including children needs	WP5
	adolescents (12-18 years)	driving licence on probation	
		road safety education in secondary school	
		campaigns (Close to)	
		teaching materials for schools	
	young people (18-24 years)	driving licence on probation	
		campaigns	
diseases	Diabetics, Epilepsy, Influenza, Psychiatric Disorders,	Information from doctor/pharmacists	

Appendix B

Taxonomy of infrastructure risks and measures dealt with in WP5

RISKS

Infrastructure element	Risk factor	Specific risk factor
Exposure	Traffic flow	Average Annual Daily Traffic, congestion
		congestion
		incident / accident
		traffic composition (share of pedestrians, cyclists, PTW, HGV)
		distribution of flow over arms at junctions
Road type	Road functional class	Road functional class
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
		snow / ice / low temperatures
		wind
Workzones	Workzones	small workzone length
		high workzone duration
		insufficient signage
Alignment - 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
		tunnel
		poor sight distance - vertical curves
Cross-section - Road segments	Superelevation / cross-slopes (risk of ran-off road)	superelevetion at curve
		cross-slope
	Lanes / ramps deficiencies	number of lanes
		narrow lane
	Median / barrier deficiencies (risk of crash with oncoming traffic)	undivided road
		narrow median
	Shoulder and roadside deficiencies (risk of ran-off road or crash with obstacle)	absence of shoulder
		narrow shoulder
		absence of guardrails or crash cushions
		absence of clear-zone
		roadside obstacles (per type of obstacle e.g. trees)
		sight obstructions
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	inadequate ramp capacity
		insufficient ramp length
		insufficient acceleration / deceleration lane length
		absence of channelisation
		absence of access control
		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
		absence of marked crosswalks

MEASURES

Infrastructure element	Measure	Specific measure
Exposure	Traffic flow	flow diversion
		2+1 roads
		full contra flow
		one-way traffic
		ramp metering
		increase number of lanes
		increase lane width
		HGV traffic restrictions
		creation of HGV lanes
Road safety management	Formal tools to address road network deficiencies	implementation of road safety audits
		implementation of road safety inspections
		identification of high risk sites
		improvement of land use regulations
	Speed management	reduction of speed limit
		weather-variant speed limits
		installation of individual dynamic speed warning
		installation of speed cameras
		installation of section control
		installation of speed humps
		implementation of woonerfs / narrowings
		implementation of 30-zones
		implementation of traffic calming scheme
Road type	Road functional class	Upgrade road class
Road surface	Road surface treatments	improve friction (type of surface)
		road re-surfacing to improve evenness
		ice prevention
Lighting	Visibility / Lighting treatments	installation of road lighting
		improvement of existing lighting
Workzones	Workzones	installation of workzone signage
		improvement of workzone signage
		increase of workzone length
		decrease workzone duration
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)
		creation of by-pass road
		creation of weaving area
		reduce tangent length
		address limited sight distance
		reduce gradient (re-alignment)
		increase vertical curve radius (curve re-alignment)
		address limited sight distance
Cross-section - Road segments	Superelevation / cross-slopes treatment	improve superelevation
		improve cross-slope
	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 centreline
	Shoulder & roadside treatments	implement shoulder (shoulder type)
		increase shoulder width
		change shoulder type
		installation of guardrails or crash cushions
		change type of guardrails
		create clear-zone / remove obstacles
		increase width of clear-zone
		removal of sight obstructions
		installation of chevron signs at curves
		implementation of edgeline rumble strips
	Sidewalks treatments	installation of sidewalk
		increase of sidewalk width
	Cycle lanes	installation of cycle lane (type of cycle path)
		increase of cycle lane width
Traffic control - Road segments	Traffic signs treatments	installation of traffic sign
		replacement of traffic sign
	Delineation and road markings	implementation of road markings
		installation of chevron signs at curves
		implementation of edgeline rumble strips
		implementation of marked crosswalk
	Driver information and alert	installation of variable message signs: incident / accident warning
		installation of variable message signs: congestion / queue warning
		installation of dynamic speed warning

		implementation of V2I scheme
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
		address limited sight distance
		implementation of access control
		convert junction to roundabout
		convert to 4-leg junction to staggered junctions
		provision of left-turn lanes
		provision of right turn lanes
		improve skewness / junction angle
Traffic control - junctions	Rail-road crossings	installation of rail-road crossing traffic sign
		installation of automatic barriers
	Traffic signs treatments	installation of STOP / YIELD signs
		replacement of STOP / YIELD signs
	Road markings	implementation of road markings
		implementation of marked crosswalk
	Traffic signals treatments	installation of traffic signals
		improve traffic signals timing
		implementation of pedestrian signal phase

Appendix C

Taxonomy of vehicle risks and measures dealt with in WP6

RISKS

Topic	Subtopic	Specific Risk Factor
Pedestrian	Prevalence of pedestrian factors in crash data	Pedestrian accidents characteristics (pedestrian, impact, type of vehicle striking, time of crash, …)
		Injury level
	Vehicle design	Vehicle shape
	Crashworthiness	Pedestrian Low star rating (EuroNCap)
	Visibility / Conspicuity	Prevalence with the presence of sight obstructions (parked vehicles, traffic, street furniture, uneven lighting condition, etc.)
Bicycles	Prevalence of cyclists factors in crash data	Accident characteristics (cyclist, vehicle striking, infrastructure, type of impact, time of crash…)
		Injury level
	Visibility / Conspicuity	Prevalence with the presence of sight obstructions (parked vehicles, traffic, street furniture, uneven lighting condition, etc.)
PTW / ATV	Prevalence of PTW factors in crash data	Accident characteristics (driver, vehicle, infrastructure, impact, time of crash, …)
		Injury level
	Protective equipment design	Poor helmet performance
		other equipment
	Technical defects / Maintenance	Faulty headlights & taillights
		Problem related to tire
		Faulty steering system and suspension
		Faulty brakes
		Engine modification
	Visibility / Conspicuity	Visibility / Conspicuity / sight obstruction / small size
Passenger Cars	Prevalence of vehicle factors in crash data	Accident characteristics (driver, vehicle, infrastructure, impact, time of crash, …)
		Injury level
	Injury mechanism	Risk to be injured in frontal impact (driver, front passenger ,rear passenger)
		Risk to be injured in rear impact
		Side impact : risk to be injured following nearside/farside impact
		Risk of injury in Rollover
		Risk of injury in single v/s multiple impacts
		Risk of injury in case of fire
		Risk for children
		Submarining & abdominal injury risk
		Risk of injury with airbag deployment (burn, blast, out of position, airbag generation, etc.)
		Load limiter with occupant characteristics (age, pregnant, gender, etc.)
		risk with intrusion
		risk of occupant projection (against rigid part or interaction with occupants and/or restraint)
		risk of ejection (body or part of the body outside the vehicle)
	Crashworthiness	Compatibility (self protection / partner protection)
		Age of the vehicle
		Crash with animals
		Low star rating (EuroNCap)
	Technical defects / Maintenance	Faulty headlights & taillights
		Tire blow out
		Faulty steering system and suspension
		Faulty brakes
		Airbag deployment at untimely moment
	Visibility / conspicuity	Blind spot issue
		visibility limitation du to design (A pilar, rear view, etc.)
	Specificities	Risk associated to SUV
LGV	Prevalence of vehicle factors in crash data	Accident characteristics (driver, vehicle, infrastructure, impact, time of crash, …)
		Injury level
	Crashworthiness	Compatibility (self protection / partner protection)
	Technical defects / Maintenance	Faulty headlights & taillights / retroreflective stripes
		Problems related to tire (blow out, defects, etc.)
		Faulty steering system and suspension
		Faulty brakes
		Load / Distribution of the load / cargo securing
	Visibility / conspicuity	Blind spot issue
		Visibility limitation du to design
Trucks / Bus	Prevalence of vehicle factors in crash data	Accident characteristics (driver, vehicle, infrastructure, impact, time of crash, …)
		Injury level
	Injury mechanism	Bus : Risk for unbelted occupants
		Risk with intrusion
		Risk of injury in case of fire
	Crashworthiness	Compatibility (self protection / partner protection)

		Risk for VRU
	Technical defects / Maintenance	Faulty headlights & taillights / retroreflective stripes
		Tire blow out
		Faulty steering system and suspension
		Faulty brakes
		Truck: Load / Distribution of the load / cargo securing
		Truck: Risk associated with transport of dangerous goods
	Visibility / conspicuity	Blind spot issue
		Visibility limitation du to design

MEASURES

Vehicle safety category	Subtopic	Specific counter-measure
Crashworthiness	Frontal impact	Directive 96/79/CEE et ECE.R94
		EuroNcap (Full width & ODB)
		Pre-crash (PreSafe)
		Collapsible steering column
		Collapsible pedal box
		Frontal airbag
		Seat belt
		Seat Belt reminder (SBR)
		Bag in Belt
		Load limiter
		Seatbelt pretensioner
		Reversible seatbelt pretensioner
		Front underrun protection
		Frontal padding
		Knee Airbag
		Anti-submarining airbags
		Seat Bossage
	Side impact	Directive 96/27/CEE et ECE.R95
		Regulation UN R135 (Pole side-impact protection)
		EuroNCap (MBD & Pole)
		Side underrun protection
		Side airbag (Head only)
		Side airbag (Head + Thorax)
		Side airbag (Thorax + Abdomen + Pelvis)
		Door padding
		Farside airbag
	Rear impact	Regulation UN R32 (Behavior of the structure in rear-end collision)
		Anti-Whiplash seat
		Active Headrest system
		Rear underrun protection
		EuroNCap (whiplash)
	Rollover	Bag in Roof
		Curtain airbags
		Active Rollover protection
	Pedestrian	Active bonnet
		Pedestrian airbag
		EuroNCap (Pedestrian)
	Child	ISOFIX / I-Size
		Child Restraint System (CRS) fitting
		Integrated CRS
		EuroNCap (Child)
Active safety / ADAS	Longitudinal	Emergency Braking Assistance system
		Autonomous Emergency Braking (vulnerable road users)
		Autonomous Emergency Braking (City)
		Autonomous Emergency Braking (Interurban)
		Predictive Assist Braking
		ABS (Motorcycle)
		Collision Warning
		Intelligent Speed Adaptation (ISA)
		Speed Limiter
		Speed Regulator
		Automatic Cruise Control (ACC & ACC Stop & start)
	Lateral control	Electronic Stability Control (ESC)
		Lane Departure Warning (LDW)
		Lane Keeping Assist (LKA)
	Visibility enhanced	Design specifications (A Pilar)
		Automated headlights
		Adaptive Head Lights
		Advanced Adaptive Head Lights System
		Night Vision
		Vehicle backup camera
		Blind Spot Detection
		Blind Spot mirror (truck)
	Connected	Communication V2V

		Communication V2C
	Technical defects	ISO 26262 (road vehicles - functional safety)
		Tire Pressure Monitoring and Warning
		Vehicle inspection
		Regulation ECE R13 (braking systems)
Tertiary Safety	Post-crash	eCall
		Rescue Data Sheet
		Rescue Code
		ECE R100 (Battery electric vehicle safety)
		Event Data Recorder

Appendix D

Taxonomy of post-impact care measures dealt with in WP7

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