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Executive summary of work package reports of the project E-Frame: Evaluation Framework for Commercial Vehicle Safety Systems and Services

Project within 2013-01306 FFI

Table of Contents

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General introduction

The objective of the EFrame FFI project was to develop a structured framework for traffic safety evaluation in an industrial (commercial vehicle manufacturer) context. The resulting framework facilitates more efficient development of crash/injury countermeasures by identifying and focusing on the most important safety (crash) problems, providing a toolset for analyzing crashes and estimating the potential and actual effectiveness of safety systems and services and, finally, identifying the data sources needed to perform these analyses. The project was divided into several work packages whereas all the work packages produced individual reports.

A general overview of the project and its results can be found in the Final VINNOVA and FFI Report (Engström and Wege, 2016) and in the final framework specification report which are equivalent to the WP1 reports (see below). Both reports are publically available and can be found in full text either on the project website or the VINNOVA FFI website.

The summary reports of each work package (marked with *)) can be found in this report in full text. The individual work package reports can be accessed upon request from the project leader and/or the author of the report.

Publications Work package 1

Engström, J. & Wege, C. (2016). Evaluation Framework for Commercial Vehicle Safety Systems and Services (EFrame). Final Report. Chalmers Publication Library (CPL), PubID. 247448.

Engström, J. & Wege, C. (2016). Final framework specification for Evaluation Framework for Commercial Vehicle Safety Systems and Services (EFrame). Chalmers Publication Library (CPL), PubID. 247449.

Publications Work package 2

Thomson, R. 2016. Summary of State of the Art – Work Package 2. *)

Bálint, A. (2014). EFrame WP2 State-of-the-art report: General crash statistics analysis.

Bärgman, J. (2014). EFrame WP2 State-of-the-art report: Analysis of crash contributing factors/mechanisms as a component for evaluating commercial vehicle safety-systems and services.

Engström, J. (2014), EFrame WP2 State-of-the-art report: Target scenarios_and_use_cases.

Engström, J. (2014), EFrame WP2 State-of-the-art report: Risk analysis.

Engström, J. (2014). EFrame WP2 State-of-the-art report: Methodologies for pre-crash modelling.

Fagerlind, H. (2014). EFrame WP2 State-of-the-art report: Exposure_data.

Fagerlind, H. & Bálint, A. (2014). EFrame WP2 State-of-the-art report: In-depth crash data.

Fagerlind, H. & Bálint, A. (2014). EFrame WP2 State-of-the-art report: Crash Statistics - Mass Data. In report *Executive summary of work package reports of the project E-Frame: Evaluation Framework for Commercial Vehicle Safety Systems and Services.*

Piccinini, G. (2014). EFrame WP2 State-of-the-art report: Experimental data for evaluating commercial vehicle safety-systems and services.

Piccinini, G. (2014). EFrame WP2 State-of-the-art report: Naturalistic driving data for evaluating commercial vehicle safety-systems and services.

Piccinini, G. (2014). EFrame WP2 State-of-the-art report: Experimental analysis for evaluating commercial vehicle safety-systems and services.

Piccinini, G. (2014). EFrame WP2 State-of-the-art report: Safety/cost benefit prediction for evaluating commercial vehicle safety-systems and services.

Piccinini, G. (2014). EFrame WP2 State-of-the-art report: Market penetration analysis for evaluating commercial vehicle safety-systems and services.

Thomson, R. (2014). EFrame WP2 State-of-the-art report: Crash Modelling.

Wege, C. (2014). EFrame WP2 State-of-the-art report: Societal data for evaluating commercial vehicle safety-systems and services.

Publications Work package 3

Piccinini, G. (2016). Summary of Work package 3. *)

Bálint, A. & Pirnia, E. (2015). Task report of work achieved in WP 3 Task 3.2. (EUC1a and EUC1b).

Engström, J., Piccinini G.B., & Törnvall, F. (2015). Task report of work achieved in Task 3.4: Target scenario and use case definition.

Piccinini, G., Törnvall, F., Thomson, R. & Engström, J. (2015). Task report of work achieved in WP 3 Task 3.5. (EUC3).

Pirnia, E. (2015). Task report of work achieved in WP 3 Task 3.3., subtask 3.3.3(EUC5): Systematic analysis of Non-Road accidents at a customer fleet.

Wege, C. & Pirnia, E. (2016). Methodology for customer safety analysis Task report 3.3.

Publications Work package 4

Thomson, R. (2016). Summary of Work package 4 – Proof of Concept of EFRAME Methodologies. *)

Bálint, A. (2016). Task report of work achieved in WP 4 Task 4.1. EUC1a: Following up the safety performance of Volvo Group trucks over time.

Engström., J., Bärgman, J. & Lodin, J. (2016). Task report of work achieved in WP 4 Task 4.3 (EUC2-4): Safety benefit estimation for an Advanced Emergency Braking System.

Thorn, S., Törnvall, F. & Thomson, R. (2016). Task report of work achieved in WP 4 Task 4.4.

Pirnia, E. (2016). Task report of work achieved in WP 4 Task 4.1. EUC1b: To understand which Safety System or Service has the highest potential benefit for heavy goods vehicles on specific markets.

WP2 Introduction

The work in EFRAME WP2 focused on describing the state of the art for key areas expected to be components of the EFRAME evaluation network. There were 17 components identified in the framework and of these components, 7 were data types. The remaining were analysis, modelling, or synthesis topics. The previously developed EFRAME structure is shown in *Figure 1*. The pure data elements are in the first (bottom) row. The next row highlights subsequent analysis of these data elements in different analysis activities. The information at this level is then used to compile the collected and processed field data into different scenarios. From these scenarios, use cases representing safety countermeasures are proposed which represent the problem formulation stage in 0. The final stage is the resulting development and evaluation process. This is represented in the modelling stage relevant for subsequent benefit analysis (highest level). This figure presents only the components and not the interconnections.

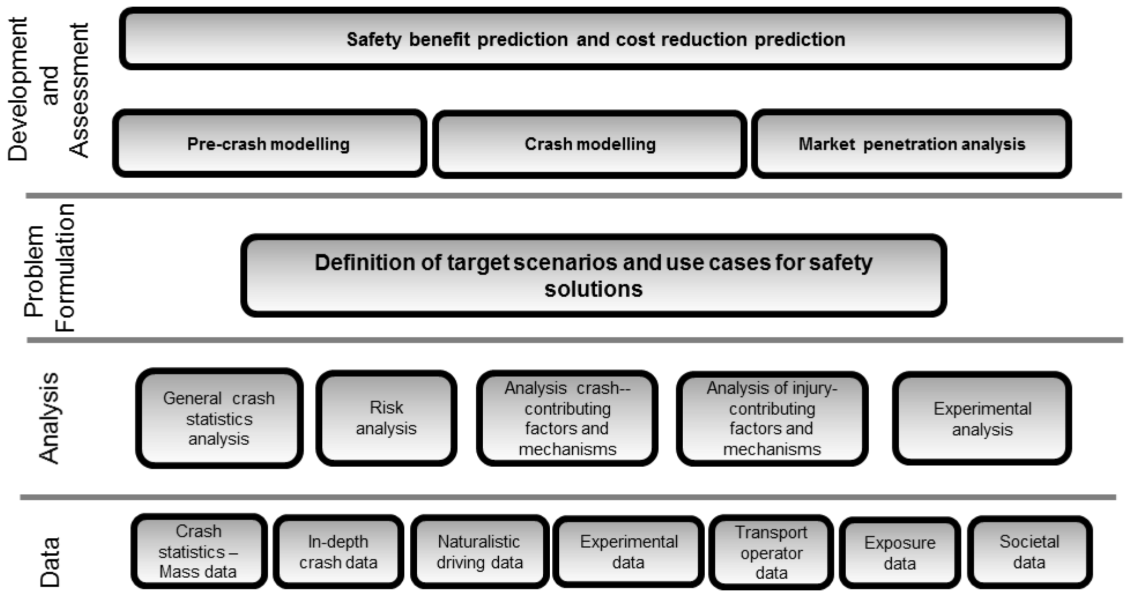

Figure 1 Information Structure in EFRAME

WP2 Evaluation Use Cases (EUC)

Reviewing the state of the art for all the elements in *Figure 1* was conducted using five main use cases listed below. Each element of *Figure 1* was reviewed and relevant application to the different use cases assessed.

- EUC 1a: Following up the safety performance of Volvo Group trucks over time
- EUC 1b: Understand which Safety System or Service has the highest potential benefit for heavy goods vehicles on specific markets
- EUC 2: Definition of target scenarios and use cases for passive and active safety systems
- EUC 3: Predictive safety/cost benefit assessment
- EUC 4: Iterative evaluation during development
- EUC 5: Evaluating the safety performance of a customer fleet or specific systems/services

The components of *Figure 1* that were identified relevant for each use case are identified and presented in the following figures.

Use Case 1 – Manufacture specific assessments

There were 2 related use cases identified as in the first use cases. EUC 1a was "Following up of the safety performance of Volvo Group Trucks over time" and EUC 1b was "Understand which Safety System or Service has the highest potential benefit for heavy goods vehicles on specific markets". The components related to this use case are limited to the Data and Analysis sections of the framework as illustrated in *Figure 2*. The use cases are focused on tracking performance.

Approach: This use case requires national usage data but will require assumptions on vehicle usage due to limitations in different reporting countries. Risk can be assessed using relative risk if there are surrogates (NDS, registration information, etc.). Some regions will be easier to analyze with representative sampling of crashes in in-depth databases like GIDAS:

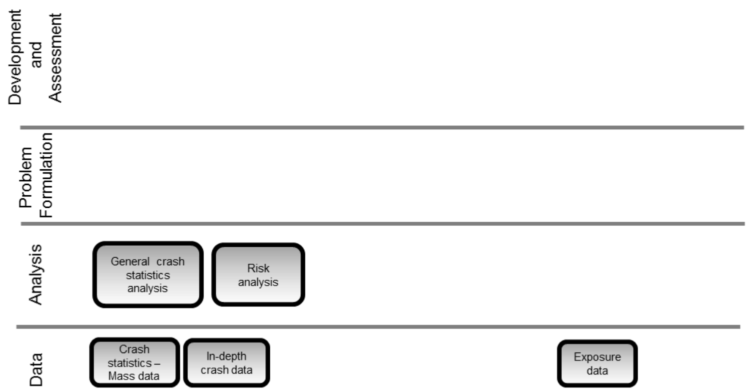

Figure 2: Information Components in Use Case 1

Use Case 2 - Definition of target scenarios and use cases for passive and active safety systems

A core activity of the EFRAME methodology development was to identify a process to create the scenario and use case definitions. This use case is heavily dependent on the data sources and analysis procedures as identified in *Figure 3*. The problem formulation is central to the activity and is a necessary step into the modelling activities needed for product development and assessment.

Approach: The most likely way to develop scenarios is to use national data to identify the level one scenarios and to identify priorities for level 2 scenarios. These more detailed scenarios will need information from detailed databases. Behaviour Based Scenarios (BBS) scenarios would require more specialised data like NDS or EDR type data.

Existing methodologies for creating these scenarios are available, particularly the level 1 descriptions. Level 2 will be a refinement of conventional scenarios where the InteractiVe method could be implemented.

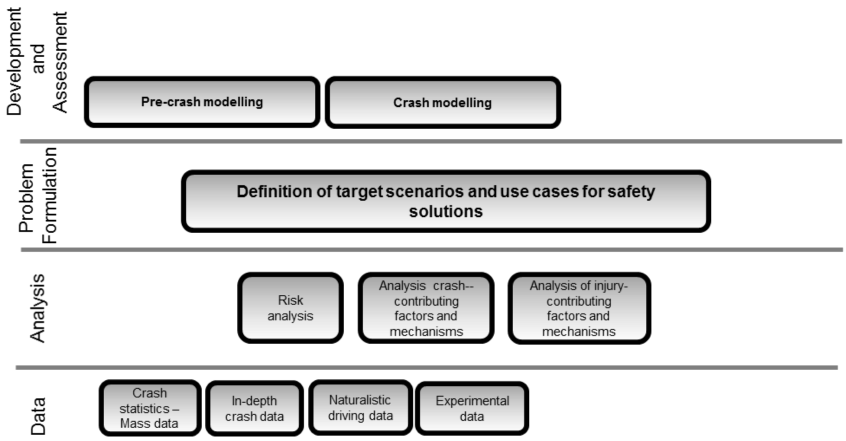

Figure 3 Information Components for Use Case 2

Use Case 3 - Predictive safety/cost benefit assessment

The full safety evaluation is based on how the safety system can be assessed in a real world context. This is seen in *Figure 4* which highlights the components in the final development and assessment stage of the framework. The input, coming from the data section, is essentially available already (from EUC 2) and additional data is needed to complete the analysis for exposure, market penetration, and additional risk analyses.

Approach: There is no existing methodology that can be directly applied to all potential systems. Passive safety systems can employ dose-response models where the response curve is modified due to system development and dose is established from national data. Active safety system prediction requires some simulation methodologies with driver models. What-if simulation approaches seem to be a good candidate. For normal driving behaviour it is difficult to establish an approach to predict the benefits.

Passive safety technologies can be employed to establish system performance based on numerical simulation or experimental testing. A challenge is still the injury prediction element if existing risk curves for the injuries of interest are not available. The active safety models will need some type of basis for the distribution of conflicts to assess the system. Driver models are also a challenge in these cases.

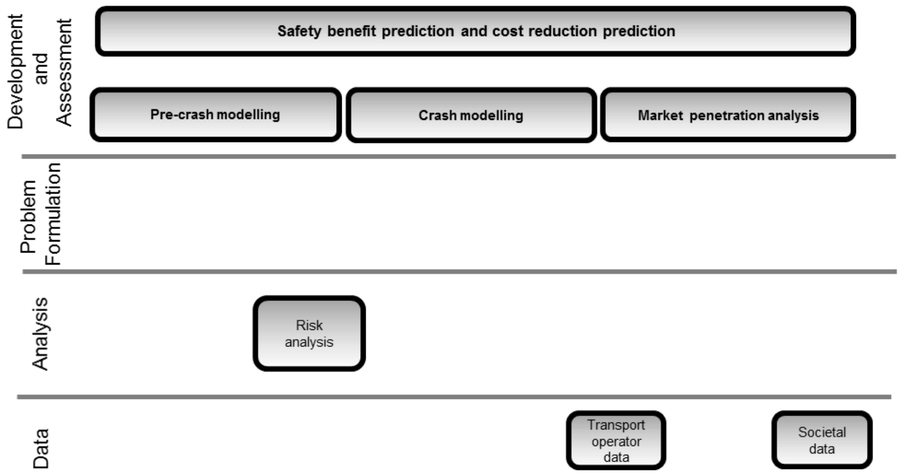

Figure 4: Information Components in Use Case 3

Use Case 4 - Iterative evaluation during development

When products or services are being developed, there is a need to evaluate the systems using modelling techniques and preliminary safety evaluations. This is reflected in the information sources identified in the upper part of *Figure 5*. The modelling activities may be replaced or supplemented with experimental data and analyses which are in the first two stages of the frame work.

Approach: System development will rely on the Computer Aided Engineering (CAE) tools available for system of interest. There are computer simulation environments for passive and active safety systems including simulating sensor performance. Experimental data for systems may be needed to calibrate or develop new models regarding human performance (volunteer tests, driving simulator, test track etc.).

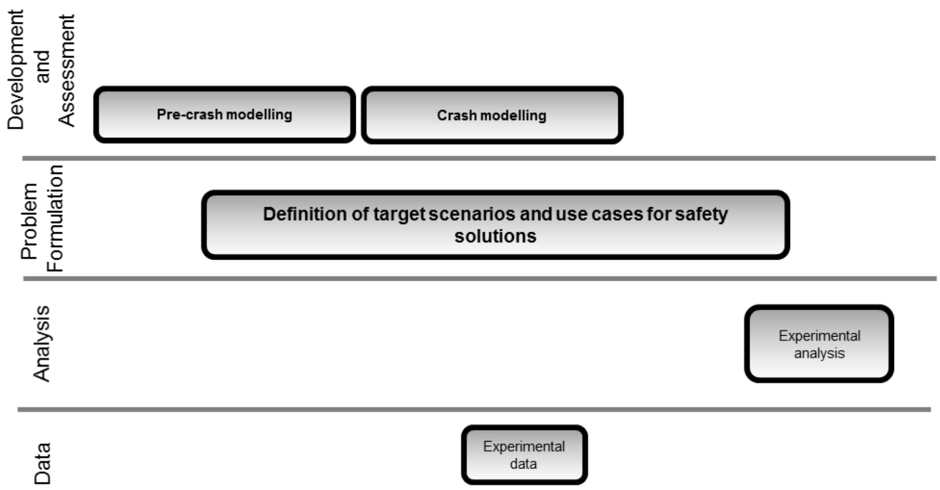

Figure 5: Information Components in Use Case 4

Use Case 5 - Evaluating the safety performance of a customer fleet or specific systems/services

This use case is limited to operator specific data and available baseline data for their operating environment. As this is customer based it may involve other services not addressed in road accident databases (incidents in distribution centers, ferry terminals, etc.).

Approach: Some of the methodologies developed for road safety issues can be applied to those systems relevant for these evaluation approaches. There seems to be limited procedures for evaluating non-road crashes. There are internal activities at Volvo using Lytx BBS services.

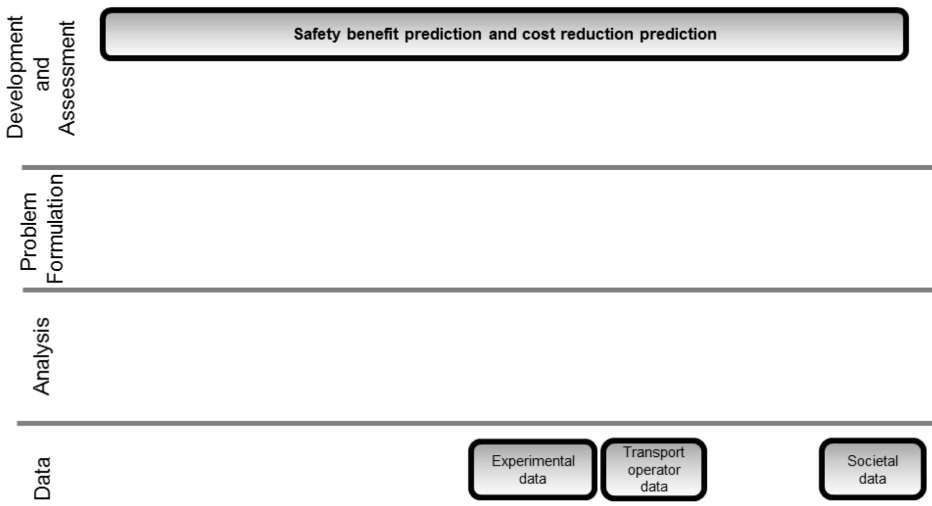

Figure 6: Information Components in Use Case 5

WP2 Key Results

The maturity of each information component identified in the EFRAME framework differs. There are data and tools available to address most safety issues for both active and passive safety applications. It is problematic to identify predictive evaluation tools and methods for normal driving, which are not readily available. General road safety data exists in the regions of interest for Volvo but some data must be purchased, particularly detailed accident data.

A challenge for the final evaluation tool will be to collect the cost data applicable for the region as well as data and methods to scale the collected road safety data to national levels. Most road safety data have limitations on sample size or have sampling biases that must be accounted for when determining costs and benefits.

WP3 Objective of overall WP3 and individual WP3 tasks

The purpose of WP3 was the adaptation, development and integration of methods and tools, based on the State of the Art (SoA) reports written during WP2. The overall WP3 was divided in 5 Tasks, linked to the Evaluation Use Cases (EUCs) described in WP1 (see Table 1 for details about the relation between WP3 tasks and EUCs). The objectives of each task are reported in Table 2.

Table 1: Relation between WP3 tasks and EUCs

WP3 Task	Related EUC
3.1 Framework integration	All EUCs
3.2 Methodology for general safety analysis of target markets	EUC1a: Following up the safety performance of Volvo Group trucks over time EUC1b: Understand which Safety System or Service has the highest potential benefit for heavy goods vehicles on specific markets
3.3 Customer safety analytics methodology	EUC5: Evaluating the safety performance of a customer fleet or specific systems/services
3.4 Target scenarios and use cases	EUC2: Definition of target scenarios and use cases for passive and active safety systems
3.5 Predictive safety benefit analysis	EUC3: Predictive safety/cost benefit assessment

Table 2: Objectives of WP3 tasks

WP3 Task	WP3 task objective
3.1 Framework integration	Adapt the framework developed in WP1, based on the results of WP3
3.2 Methodology for general safety analysis of target markets	Investigate how the safety performance of commercial vehicles can be measured through crash data in different markets
3.3 Customer safety analytics methodology	Develop methods for the systematic analysis of non-road accidents of commercial vehicles in customer fleets
3.4 Target scenarios and use cases	Design a framework to identify target scenarios and use cases to be addressed by safety systems and services
3.5 Predictive safety benefit analysis	Define a general framework for the predictive safety benefit analysis of systems and services

WP3 Main results of tasks

Framework integration (Task 3.1)

The Task was performed in order to ensure that the individual WP3 tasks contributed to the enhancement of the initial framework, described in WP1. Within Task 3.1, it was also verified that the individual WP3 tasks generated an improvement of the current methodologies to address the corresponding EUCs. The report for Task 3.1 will be delivered together with the final overall EFrame report, which focuses on the same topic.

Methodology for general safety analysis of target markets (Task 3.2)

Task 3.2 led to the definition of Key Performance Indicators (KPI) for the definition of the safety performance of commercial vehicles (e.g. number of fatalities, number of injured people with injuries above a certain level), with or without information about exposure (e.g. vehicle kilometers travelled, number of trips). The KPI are used to address both EU1a and EU1b.

In order to address EUC1a, two types of regions were considered: one is where neither Volvo, nor Chalmers has access to crash data, and the other type is where crash data is available to Volvo/Chalmers. India was taken as an example of the former, and in-depth crash data, national crash data and exposure data were considered. Unfortunately, the available information in India was deemed insufficient to address EUC1a both due to the lack of brand-specific crash data and uncertainties regarding data reliability.

For regions with available crash data, Sweden and USA were considered as an example. In both countries, information about fatal accidents, other types of injuries and exposure data is available (e.g. the "fatal in-depth study database" and "Fatality Analysis Reporting System (FARS)" provide information about fatal accidents respectively in Sweden and in the USA). Overall, based on the available data, it is possible to conduct the following comparisons in Sweden and in the USA, for EUC1b:

- Volvo Group trucks vs. all trucks;
- Volvo Group trucks vs. specific competitors.

Those comparisons can be conducted using various KPI, with and without exposure data.

Finally, Task 3.2 described the methodology to address EUC1a in a flow chart and reported the relevant formulas (e.g. odds ratios).

As for EUC1b, the aim was the identification of the main traffic-safety related issues in a region *in a purely data-driven way, i.e. with little or no input* from the analyst before the application of the method. An important conclusion was that the construction of decision trees is a promising method to explore the main safety issues in a region, based on crash data. A brief description of the decision tree method is given in the Task 3.2 report. It was noted that the method had not been described in sufficient detail in the context of traffic safety and further research was necessary to explore the full potential and practical implementation of the method. The corresponding work was performed in WP4.

Customer safety analytics methodology (Task 3.3)

Task 3.3 dealt with the development of a methodology to analyze non-road accidents (e.g. accidents occurring in parking lots, working sites, docking stations) for commercial vehicles, with special focus on crashes between a vehicle and other vehicles or stationary objects. In order to gather information about the state of the art on the topic, the following sources were considered:

- Statistics about number of fatalities/injured people in non-road accidents and related costs: based on this search, it was found that, even though non-road accidents seem less severe than other types of accidents, they can cause significant costs to fleets.
- Ongoing projects on similar issues: two FFI-projects were identified ("A holistic approach to increased traffic safety" and "Non Hit Car & Truck") in which AB Volvo is partner. According to the results of the projects, the classification of non-road accidents is difficult because

current classifications (e.g. the ones conducted by Volvo and GIDAS) focus on accidents happening in public roads.

- Information was collected about commercial companies offering systems and services to prevent non-road accidents, by identifying two companies (Haldex AB and Technologies Inc.).
- Meetings with experts from Volvo and external organizations (e.g. insurance companies) were organized to obtain information about costs related to non-road accidents and training programs to avoid those accidents.

Within the task, data available on non-road accidents were also sought, resulting in two main sources, Safe Work Australia (independent legal agency), and National Highway Traffic Safety Administration (NHTSA). The former reports fatal accidents in Australia involving a truck whereas the latter supplies several information (e.g. fatalities and injuries in non-road crashes) through the Not-in-Traffic Surveillance (NiTS) system. The codebook used by NiTs was considered for the development of a new codebook to address non-road crashes of commercial vehicles. For more details about the codebook, please refer to Task 3.3 report.

Target scenarios and use cases (Task 3.4)

Task 3.4 proposed a framework to identify target scenarios and use cases for the development of safety systems and services. Target scenario refers to the problem that should be addressed by a system or service (e.g. read-end crash AIS2+ injury, truck-car collision with oncoming traffic). On the other hand, use cases refer to a description of how a system/service could solve the problem identified by the target scenario (e.g. Forward Collision Warning redirects the gaze to the road).

The framework proposed within the task described the target scenarios at two levels. The Level 1 target scenario identifies and describes the general crash types (e.g. rear-end, run-off roads) whereas the Level 2 target scenario focuses on specific crash/injury causation mechanisms (e.g. tailgating). A key feature of the framework was the division of the crash development process into three phases: non-conflict phase, conflict phase and crash phase. For each phase, the generic methodology to develop Level 1 target scenarios, Level 2 target scenarios and use case was defined, taking into account that different Level 2 target scenarios and use cases are defined for the non-conflict, conflict and crash phase respectively.

In order to develop a generic methodology for defining Level 1 target scenarios, the accident classification scheme used in the Volvo Accident Research Team (ART) report was considered as a starting point. However, a new process was defined involving several steps that take into account the specific database considered (e.g. Swedish Traffic Accident Data Acquisition – STRADA) and the coding variables available (e.g. injury level, road user involved). For Level 2 target scenarios, a general distinction was made between sharp-end and blunt-end mechanisms, where the former relates to specific events occurring in direct connection to the conflict (e.g., distraction) while blunt-end factors refers to mechanism operating at a larger time scale (e.g., safety management practices). Within the task, a template was developed to describe the Level 2 target scenarios with a narrative, including both sharp-end and blunt-end mechanisms. In a similar way, also the use case template was prepared. Different templates were developed for the non-conflict, conflict and crash phase. For more details about the templates, please refer to Task 3.4 report.

Predictive safety benefit analysis (Task 3.5)

Task 3.5 developed a framework for the predictive safety benefit assessment of systems and services in the conflict and crash phases (as defined in Task 3.4). Within the framework, it was also included the identification of target scenarios and use cases through the methodology described in Task 3.4. The main objective of the predictive safety benefit assessment is to estimate the number of crashes, injuries or fatalities that can be avoided by the system / service described in the use case, before the introduction in the market of the system / service. The predictive safety benefit assessment is conducted through mathematical simulations aiming to understand the effect of a system / service in a specific target scenario. Overall, the following elements are required to conduct the predictive safety benefit assessment:

- Target scenario and use case description in order to illustrate the system / service supposed to solve the problem identified by the target scenario.
- Source data (e.g. crash data) representing the target scenario and to be used as input for the mathematical simulations.
- Models describing the reaction of the system / service in the driving situation described by the target scenario.
- Models of the driver, environment and vehicle (only for the predictive safety benefit assessment in the conflict phase)

Although the frameworks in the conflict and crash phases are similar, some differences exist. First of all, the source data can be different (e.g. at the moment, naturalistic data are not used for the predictive safety benefit assessment in the crash phase). Besides, the methodologies to assess the predictive safety benefit differ, being the counterfactual simulation used for the conflict phase and Finite Element Model (FEM) simulations for the crash phase. Finally, the timeframe of the mathematical simulation is different, requiring shorter time for the conflict phase compared to the crash phase. For more details about the framework, please refer to Task 3.5 report.

WP3 Summary of results

Table 3: summary of results

WP3 Task	Related EUC
3.1 Framework integration	- Ensure the contribution of WP3 to original framework
3.2 Methodology for general safety analysis of target markets	- Compile a list of potential key performance indicators (KPIs) that can define ”safety performance” - Design a methodology to address EUC1a and EUC1b
3.3 Customer safety analytics methodology	- Acquire information about non-road accidents - Develop a codebook to evaluate non-road accidents
3.4 Target scenarios and use cases	- Design a methodology to describe target scenarios and use cases - Develop a method to identify key crash causation mechanisms from naturalistic driving data
3.5 Predictive safety benefit analysis	- Develop a framework for the predictive safety benefit assessment of systems / services - Link the description of target scenarios and use cases to the predictive safety benefit assessment

WP4 Introduction

The EFRAME project had the global objective to produce an evaluation framework for different safety evaluation needs at Volvo. These needs were specified as Evaluation Use Cases (EUC) in the project. Earlier work packages reviewed the state-of-the-art and developed proposed methodologies that could be implemented in commercial settings. The EUCs of interest are provided in *Table 4*.

Table 4: Reviewed Safety Benefit Analyses

Evaluation Use Cases
<u>EUC1a</u>: Following up the safety performance of Volvo Group trucks over time <u>EUC1b</u>: Understand which Safety System or Service has the highest potential benefit for heavy goods vehicles on specific markets
<u>EUC5</u>: Evaluating the safety performance of a customer fleet or specific systems/services
<u>EUC2</u>: Definition of target scenarios and use cases for passive and active safety systems
<u>EUC3</u>: Predictive safety/cost benefit assessment

The primary objective of WP4 was to conduct trial analyses with the methods derived in WP3. This process would demonstrate the feasibility of the methods and identify potential modifications to the methodologies and implementation challenges for Volvo. The main implementation challenges anticipated were data availability and data quality. Logical or procedural issues could not be identified until test the methods with available data.

WP4 Method

All tasks in WP4 built on previous work in the project. Of the originally identified EUCs (Table 4), all but EUC 5 could be studied in WP4. Due to the differing types of data that were specific to the evaluation methodology, each task in WP4 conducted analyses with different data sources.

EUC 1a) evaluated brand comparisons of safety performance using selected Key Performance Indicators (KPIs) for Road Safety Outcome (RSO) and exposure data. US data was available from NASS GES (NASS-GES, 2015) for safety information and Statista (Statista, 2015) for exposure data related to vehicle sales.

EUC 1b) identifies the system or service with the best safety potential. A decision tree approach was used to group crash data into different categories which will allow safety issues to be prioritised. Data from STRADA (Transportstyrelsen, 2015) were used in the analysis.

EUC 2) and EUC 3) methodologies produce standardised descriptions of scenarios and use cases (EUC 2) which then are further analyzed in predictive safety benefit analyses (EUC 3). These activities were studied for active and passive safety systems separately. The active safety system studied was an Advanced Emergency Braking System (AEB) and the passive safety systems studied were rotating steering cab columns and high strength steel structures in the cab.

The process of applying the developed methodologies was necessary to determine if the method's logic is appropriate, if there are missing steps in the procedure, and if data is available that is both appropriate and sufficient.

WP4 Key Results

<u>EUC1a</u>: Following up the safety performance of Volvo Group trucks over time

The methodology for EUC1a) was successfully conducted within the scope of the available data. KPIs could be derived from the NASS database and divided into different truck categories for different manufacturers. This allowed for most KPIs to be derived per brand. Shortcomings in the vehicle classification systems limited analysis for the largest truck size, but other truck definitions were defined sufficiently for analysis.

Sales data provided by Statistica (Statista, 2015) was available for transformed data on exposure to be derived. Using the market share for each brand, the risk ratios for each brand could be calculated and compared to Volvo Group performance.

The process in WP4 identified no modifications to the methodology developed in WP3 (Bálint & Pirnia, 2015). The method originally proposed that exposure data should be provided in absolute terms (i.e. number of vehicles, number of kilometers, etc.). The use of risk ratios to compare brands allows for the market or mileage share for the brand to be used if absolute data is not available.

The general results of this activity were positive with the caveat that the data must have sufficient detail and quantity to provide reliable results.

<u>EUC1b</u>: Understand which Safety System or Service has the highest potential benefit for heavy goods vehicles on specific markets

The decision tree approach to determine the priorities for developing safety systems or services was adopted from WP3 (Bálint & Pirnia, 2015). The concept was not modified and the WP4 report (Pirnia, 2016) essentially demonstrated the process in detail. Decision trees can be developed in different ways and the procedure explored in EFRAME was a classification tree procedure using the “Random Forest” approach (Bühlmann, 2012).

The decision tree was implemented in the R software using existing scripts. The process allows the user to select appropriate variables for the classification procedure. The STRADA database could be successfully analyzed for a number of analyses. It was pointed out that knowledge of the database is necessary if one is to understand the implications for the region of interest. For example, are all injury accidents reported to the database.

An important additional result of this analysis is that the procedure can be applied to the target scenario definition process. When specific safety systems are being evaluated, the target population for the benefit analysis must be derived and this is possible using the decision tree procedure described in (Pirnia, 2016).

Active Safety: EUC2: Definition of target scenarios and use cases for passive and active safety systems / EUC3: Predictive safety benefit assessment

The analysis of AEBS in (Engström, Bärgman, & Lodin, 2016) required methodologies existing from the passive safety domain to be supplemented with additional methods that were recently developed or developed within the EFRAME project.

There were three main methodologies evaluated: Scenario and use case definitions, benefit estimations, and up-scaling.

- Scenario and use case definitions used traditional crash data (like STRADA (Transportstyrelsen, 2015) or NASS (NASS-GES, 2015) but need to contain information describing the conflict, not just the crash configuration. For example, a frontal collision in a crash database must be supplemented with information regarding the pre-crash conditions such as if it occurred at an intersection or was a single vehicle crash.
  Following the classic crash data sources, crash causation mechanisms must be integrated to further break down the crash regarding driver behaviour, lighting, and other issues. This requires data from in-depth databases or other sources such as event data recorders capturing driver behaviour just prior to a crash.

- The benefit estimations employed in EFRAME were counterfactual or “what-if” simulations. This is a numerically intensive procedure that requires building an environment approximating the traffic situation in a parameterised manner. Each parameter is described by some statistical distribution capturing driver, vehicle, or environmental factors and is dependent on the complexity and focus of the the model. Different traffic scenarios are simulated and resulting outcomes can then be used to indicate system performance.
- Upscaling of the benefit analysis is more difficult than for passive safety applications. The what-if scenarios are defined by crash distributions which can be scaled to national levels when sufficient data is available. The what-if scenarios are also defined by distributions of driver behaviour or event kinematics which may not be easily scaled to the national level when there are no direct linking statistics available. The proposed methodology manages to resolve this short coming using a weighting scheme based on the crash distributions.

The results from EFRAME were positive in that the general methodology seems to be able to provide a systematic way to develop safety analyses from target scenario definitions through the chain to benefit estimation. There are no indications that the general methodology should be changed, however refinement of the simulation approach and richer data sources will facilitate the implementation at Volvo.

Passive Safety: EUC2: Definition of target scenarios and use cases for passive and active safety systems / EUC3: Predictive safety benefit assessment

An approach for describing the scenarios and use cases for passive safety systems was developed in WP3 (Tornvall, Thorn, & Thomson, 2016) and applied in WP4 using a theoretical approach.

Data from the ETAS and STRADA databases were used to describe the conditions for truck driver injuries in frontal crashes. STRADA was shown to be awkward to use because of its limited information in a coded database. Much of the needed data was contained in free text. The ETAS database contained sufficient crash details but for a limited number of crashes. This data was still enough to use a decision tree (similar outcome as EUC 1b) but based solely on expert judgment to identify the key scenarios. This decision tree identified 2 scenarios with related use cases.

The benefit analysis method proposed in WP3 could be used but there were issues discovered in WP4 that were not anticipated in WP3. Two scenarios and 2 accompanying countermeasures were proposed and analyzed.

Safety evaluations of the countermeasures were used to determine how the injury risk curves for the driver would be improved with the implementation of the system. Although the system is designed for one use case, the benefit calculations are done for all crash scenarios. This highlighted the case that a system designed for one use-case may affect the safety outcomes in other scenarios. The performance on one countermeasure must then be assessed for other crash cases to ensure the true benefit is assessed.

Passive safety analysis of predictive systems is dependent on quantifying the injury risk given a crash type and severity. This information is currently only available from historic crash data and is the greatest challenge for the industry. The analysis in EFRAME only used hypothetical risk curves as not enough data is available for heavy truck occupants. A challenge for Volvo is to find detailed injury data in order to derive the baseline injury risk curves needed to describe the safety of people involved in crashes with heavy trucks.

WP4 Conclusion

The proof-of-concept for the EFRAME safety benefit assessments was considered positive. The methodologies develop earlier in the EFRAME project were suitable in all applications and only require some slight modifications when addressing passive safety. The methods used to document Volvo's product performance were shown to be informative when sufficient and suitable data was available. Non-crash related incidents were not possible to study due to data issues.

The only methodological issue that requires obvious modification is the influence of one countermeasure on a number of target scenarios and use cases. Although this was only identified in the passive safety analysis, it is conceivable that many active safety systems and services will have similar properties. This issue is not insurmountable and may have positive consequences in many situations.

The application of the methods in WP4 underlined the difficulty in finding data suitable for analysis. Many of the methods rely on detailed driver or system performance information that are usually only available from expensive, in-depth studies.

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