Bringing intelligent vehicles to the road

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This deliverable has been compiled by the above authors, but it is a summary of individual contributions from many other authors as indicated in the relevant cited references. All results are scientific findings which are only valid inside the statistical assumptions and other limits of application. All findings have to be considered with the associated range of significance. The affiliation of the authors with any organization involved in this project does not indicate that those organizations endorse all the findings contained within this report.

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Executive summary

The potential of technologies tested in euroFOT to bring positive impacts to road safety, traffic efficiency and the environment is well recognised. Yet these technologies have not penetrated the market, largely due to a lack of understanding about the potential benefits to driving behaviour and quality of life. Field Operational Tests represent an important measure to get these technologies into the market and better understood. The euroFOT project, by testing and assessing the performance of eight key functions on European roads, aims to contribute to the market introduction of and wider uptake for such intelligent vehicle systems.

Socio-economic impact assessment constitutes an important part of carrying out a Field Operational Test (FOT). Guidance on how to prepare and carry out a FOT and analyse its results is provided by the FESTA Handbook, more precisely by the FESTA V concept.

This deliverable informs about the socio-economic dimension of the impacts derived from euroFOT and the costs associated with these technologies. This analysis requires not only information available from testing in the field but also additional information on safety and traffic performance in the EU-27 in order to provide the overall picture of European scale effects. Considerations here reported make use of results stemming from other activities of the data analysis within euroFOT, and the related deliverables (i.e. D6.2-6.5). This information was mostly provided at micro level, representing vehicles or vehicle test fleet data. The present work on the contrary looks at potential socio-economic effects at European level. Obviously, this requires several other elements for upscaling from FOT results to a general EU level.

Important methodological choices of this cost-benefit study comprise the following elements:

- The assessment framework is kept as pragmatic as possible. The main motivation for doing so is to keep the credibility of the measured FOT results and to avoid amalgamation with high level assumptions and uncertainties.
- The cost-benefit analysis assumes as base cases a full penetration and a 10% penetration scenario of the systems, each of them combined with medium economies of scale (10% reduction of unit cost when output volume is doubled). In addition different levels of economies of scale as well as various equipment rates are considered. with respect to their impact on the benefit-cost results.
- The boundary conditions (road safety performance, traffic performance) reflect recent conditions, year 2010 wherever possible. This approach has the advantage that no projections for fleet, performance and price development have to be integrated in the model.
- Although the calculation model is ready to perform a full set of cost-benefit analyses for each tested function the CBA feasibility is narrowed down due to non-applicable and / or insignificant impacts found in the FOT, as well as performance restrictions in up-scaling to EU-27 level. Based on the quality criteria and the limitations of the measured impacts, only ACC+FCW results (based on all test sites, where this bundle was tested, i.e. German-1 and Sweden) have been taken into account for both cars and trucks, to determine the socio-economic impacts.
- The cost unit rates regarding accidents have been chosen according to the most recent good practice at European level. Key values include 1.6 Mill. EUR per avoided fatality, 70,000 EUR per avoided injury, efficiency benefits of avoided casualties (add on to road safety): 15,500 EUR per avoided fatality accident, 5,000 EUR per avoided injury accident, Time cost-unit rates (per vehicle hour): 20 EUR per vehicle hour for

cars and 30 EUR for Heavy Goods Vehicles, Net fuel costs (i.e. without taxes, per l): 0.75 EUR for gasoline as well as Diesel, Environmental costs: 70 EUR per ton CO2.

- The unit costs per system are derived top-down from current market prices of ACC+FCW. Using the FESTA/eIMPACT approach the resource costs of such a system can be calculated by applying factor 1/3.

The main results of the cost-benefit assessment can be summarized as follows:

- The costs of equipping the entire fleet of passenger cars and heavy trucks with the combined system ACC+FCW lead to annually approx. 1.6 Bn EUR (passenger cars) and approx. 28 Mn EUR for heavy trucks (because of the smaller fleet). When only parts of the fleet will be equipped (e.g. 10% of the car fleet), the costs amount to 240 Mn EUR.
- Annual benefits for cars add up to 0.8 to 1.2 Bn EUR (full penetration) respectively 126 to 175 Mn Euro (10% penetration rate), depending on the magnitude of safety impact. The result is dominated by the safety impact which accounts for approximately half of the benefits in the lower bound scenario and two thirds in the upper bound scenario. However, also traffic impacts and environmental effects provide substantial contributions to the benefits.
- Annual benefits for trucks amount to approximately 108 and 146 Mn EUR. The same pattern of results as for cars appears also here. Safety is dominant in the upper bound scenario whereas traffic represents the biggest impact in lower bound scenario
- For trucks, the ACC+FCW bundle is clearly profitable from society point of view. The benefit-cost ratio is between 3.9 and 5.2.
- For cars, the attainable benefits (based on the assumptions introduced to the assessment) are not sufficient to outweigh the costs. The benefit-cost ratio ranges between 0.5 and 0.7. The system is either too expensive or users on average drive too less km for pay off of the “investment”. It has to be kept in mind that the tested system ACC+FCW represents foremost a comfort system. These effects are however not subject of monetisation in a transport-focused cost-benefit analysis.
- Sensitivity of the results was tested for the cars scenario. The overall result was that modifying input parameters (such as higher cost-unit rates for impact appraisal, considering potential underreporting of injury accidents) would bring the benefit-cost ratio close to or even above 1. Changing of the penetration rate and taking different levels of economies of scale into account provides a BCR above 1 for a scenario assuming large economies of scale and a penetration rate of at least 50%.
- Former ex-ante impact assessment studies have indicated more favourable benefit-cost results (e.g. eIMPACT). The differences for euroFOT can be explained by making use of in-depth databases for modelling the accident target group, considering empirical evidence of usage rates and the estimation of system cost (expert estimations vs. market price based assessment).
- For passing the profitability threshold it would require to widen the scope of the assessment by including also benefits from avoiding property damages. In this context, a first best estimate study on the basis of Allianz insurance databases with PDO claims (minor, TPL and MoD) using euroFOT results revealed, that in EU-27 each year approximately 500,000 PDO claims could be avoided or at least mitigated if all passenger cars would be equipped with ACC+FCW (generation 2008). This is particularly remarkable as for newer generations of ACC+FCW even higher accident avoidance is probable. Further benefits are expected if wider economic impacts in terms of growth and employment will be considered.

The cost-benefit analysis has also led to a number of lessons learned in the fields of process as well as conceptual framework. These experiences are relevant for reviewing and updating the FESTA handbook:

- It can be stated that this study carried out – for the very first time – a cost-benefit analysis which is not based on ex-ante expert assessment of impacts but on results proven in the field.
- The FESTA methodology has proven its applicability to this type of research question. Unfortunately, performance restrictions of the impact assessment (no measured or insignificant effects, up-scaling to EU-27) have limited the applicability of CBA to systems tested in euroFOT.
- Hence, socio-economic assessment as final assessment step of FESTA-V must lead to limited results, since only the most trustable and verifiable results can be used in quantitative terms for CBA. But for other functions, it could be possible to make further use of the FOT data, e .g. to test assumptions from ex-ante assessments or to improve simulation models. Without the need for statistical proof from previous stages (which is anyway out of scope for safety impacts in terms of real-world accident avoidance), simulation models could transfer intermediate results into benefit estimations which would reflect the real world impact on a larger scale. If this is not considered, the benefits and hence, the overall BCR results suffer from a “pessimism bias”. This must be considered in early phases of future projects e.g. by providing a contingency plan to make use of simulation or further expert assessments.
- It can be also discussed whether to use other evaluation methods than cost-benefit analysis, e.g. cost effectiveness analysis, multi criteria analysis etc. would be more appropriate. This would lead to different output figures, e.g. when impacts are not transformed to units of money. It would however not avoid or help out of interpreting measured data for deriving impacts (e.g. the crucial “bridge” from incidents to accidents).
- Upscaling from micro level (FOT) to macro level (EU-27 databases for accidents etc.) provides still considerable challenges, especially concerning the granularity of information. CBA makes typically use of averages of variables whereas distributions of variables would be valuable to keep the value added of FOT data. Research in this direction would help to solidify the derivation of socio-economic impacts from Field Test data.
- Generally, it can be recommended that the socio-economic impact assessment should allow for a wider scope of impacts, including those beyond transport, i.e. for the overall economy. Such impacts for productivity, growth and employment represent important results for policy making (e.g. Lisbon agenda, CARS 2020). There are concepts available to broaden the scope of CBA and to include macroeconomic / wider economic impacts in a “twin approach” [Banister Berechman 2002]. Obviously, this class of impacts can be assessed based on models. On the other hand, these figures have a different quality or nature than measured effects within a Field Operational Test. To summarise this, it should be preferred to assess impacts in a wider scope than to stick to a too narrow set of effects derived from measured data.

1 Introduction

Road safety is a major societal issue for the Member states of the European Union. In 2009, more than 35,000 people died on the roads of the European Union, i.e. the equivalent of a medium town, and no fewer than 1,500,000 persons were injured. The cost for society is representing approximately 130 billion Euros in 2009 [EC 2010]. Therefore, as described in its "Road safety action plan for 2011-2020", the EU is interested at raising the level of road safety and ensuring safe and clean mobility for citizens everywhere in Europe. Automotive industries are strongly committed towards these objectives. Road safety policy measures should put citizen at the heart of the actions, by encouraging them to take primary responsibility for their safety and the safety of other persons.

The same line of argumentation can be identified in the European Commission's 2011 Transport White Paper [EC 2011] (Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system). It reinforces the accident reduction goal of the 2001 White Paper, i.e. halving the number of fatalities on EU roads by the end of decade. The goal for this decade is to halve the road casualties (fatalities and injuries) by 2020 while the long term vision towards 2050 should move close to zero fatalities in road transport.

Harmonisation and deployment of road safety technology such as driver assistance systems, seat belt reminders and cooperative systems is regarded as a major contributor to road safety improvement. Such technologies, which for the most part are already in existence, have the ability to help drivers make driving safer but also more comfortable and more efficient.

The potential of those technologies to bring a positive impact to traffic safety and efficiency is well recognised. Yet these technologies have not penetrated the market, largely due to a lack of understanding about the potential benefits to driving behaviour and hence to quality of life. Field Operational Tests represent an important measure to get these technologies into the market and better understood. The euroFOT project, by testing and assessing the performance of eight key functions on European roads, should contribute to the market introduction of and wider uptake for such intelligent vehicle systems.

Socio-economic impact assessment constitutes an important part of carrying out a Field Operational Test (FOT). Guidance on how to prepare and carry out a FOT and analyse its results is provided by the FESTA Handbook [FESTA consortium 2008]. The underlying concept of the FESTA V is illustrated in Figure 1.

The goal of this Deliverable is to inform about the socio-economic dimension of the impacts derived from euroFOT and the costs associated with these technologies. This requires not only information available from testing in the field but also complementing information on safety and traffic performance in the EU-27 in order to provide the bigger picture of European scale effects. Figure 2 illustrates this difference in dimension.

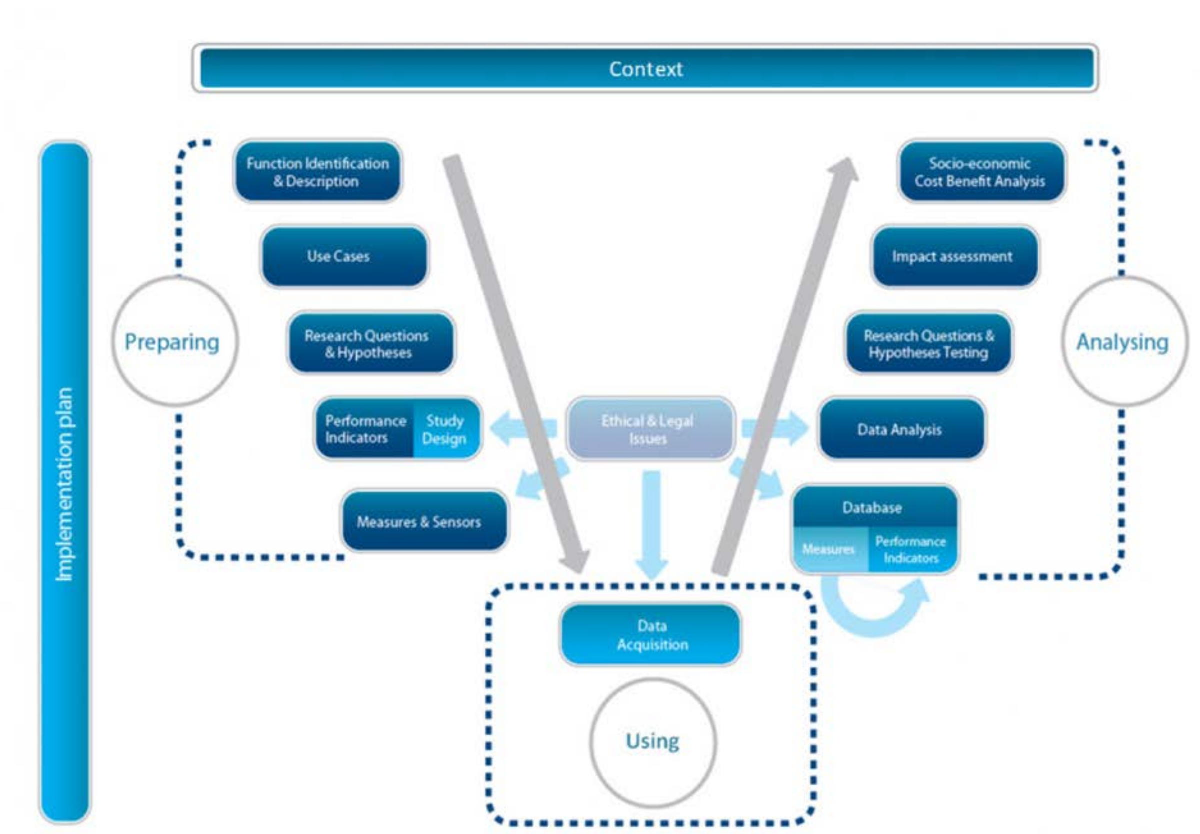

Figure 1: Concept of FESTA V for Field Operational Tests

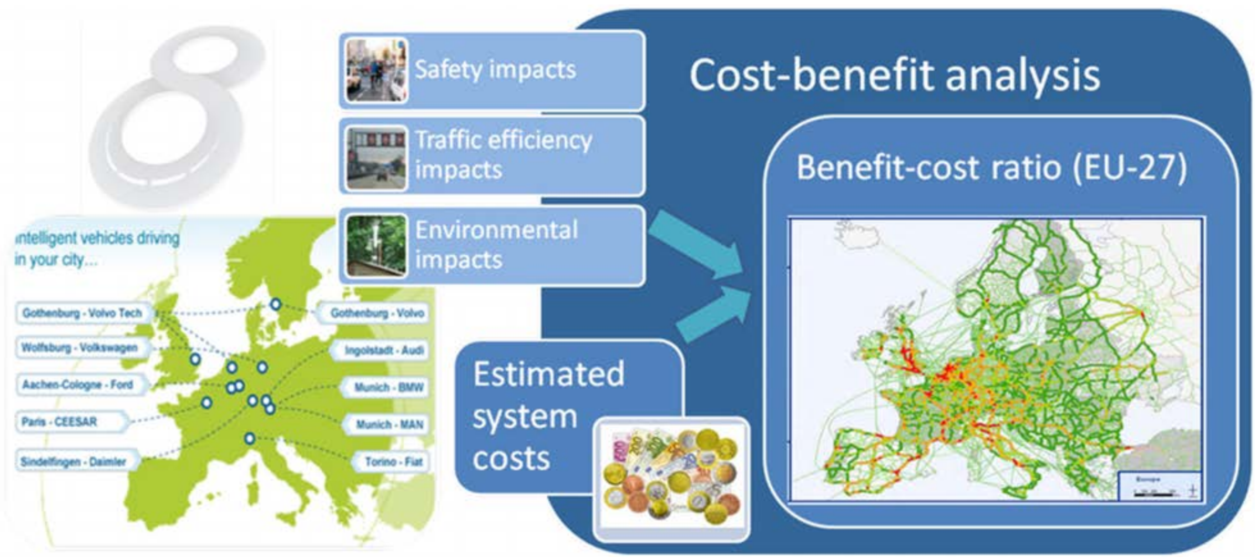

Figure 2: Cost-benefit assessment design within euroFOT

All the considerations reported in the present document make use of results stemming from other phases of the data analysis within euroFOT and the related deliverables (i.e. D6.2-6.5).

This information was mostly provided at micro level, representing vehicles or vehicle test fleet data. The present work on the contrary looks at potential socio-economic effects at European level. Obviously, this requires several other elements for upscaling from FOT results to a general EU level.

This deliverable is organized as follows:

- Chapter 2 informs about the methodology and the assessment framework. This involves topics such as the scope of cost-benefit analysis (CBA), cost unit rates for impact appraisal, system costs and background data on safety and traffic performance.
- Chapter 3 features the use of cost-benefit analysis as an ex-post assessment tool. It comprises the impacts on safety, efficiency and environment of the tested functions and technologies. Based on this information it narrows down the focus of the euroFOT CBA to particular systems or system bundles. Chapter 4 contains the core of the D6.7: the cost-benefit analysis itself.
- Subsequently, the sensitivity of the cost-benefit results is tested in Chapter 5. Furthermore it enlarges the overall society perspective to viewpoints of particular stakeholders such as users and insurance industry and it also covers wider economic impacts (income, growth and employment effects).
- Finally, chapter 6 summarises the main results and provides conclusions for further directions of work.

2 Methodology & Assessment framework

2.1 Background of socio-economic assessment of Intelligent Vehicle Safety systems (IVSS)

Intelligent vehicle safety systems are designed to assist the driver in situations in which warnings might trigger mitigating or evasive manoeuvres, so it is likely to be beneficial to raise awareness of available systems and highlight potential benefits if driver equip their vehicles with these systems. Therefore, this study addressed two particular questions:

- What benefit can be expected from current vehicle assistance features based on long-term field testing and detailed impact modelling and assessment?
- Given real-world insights from the field, what can user, private and public stakeholders learn from the assessment of assistance systems in euroFOT?

In welfare economics, driver assistance systems are a sort of “mixed good” in having private and public elements. Clearly, car drivers and their passengers will benefit from using safety systems by improving the driver´s control of the car in difficult driving situations. But, since using in-vehicle safety systems might lead e. g. to avoiding collisions with other cars, all road users might benefit from them. In general, in-vehicle safety systems are introduced into the market by private industry as additional equipment to their vehicles. Quantity planning and pricing decisions lead to rational business strategies which lay down how these systems are offered, typically in functional bundles. Bringing these assistance features to the market depends on private business calculations that involve weighting costs for R&D, components and “overheads” like marketing, quality and administration against expected revenues. On the demand side, private customers buy the system, according to utility functions which comprise the user’s private safety benefits, but might also include comfort or value appraisal for technological innovation.

Other studies took various other assessment approaches into account, since they intended to highlight potential cost-benefit scenarios from an ex-ante perspective [Baum et al. 2008, COWI 2006, Grover et al. 2008]. That required modelling future traffic and accident scenarios. But these scenarios necessarily rely on simplifications and assumptions regarding impacts in future traffic systems or future market characteristics which lead to uncertainty.

In euroFOT, field data collected in the trial and the advanced impact assessment based on the analyzed FOT data are the key outcome and hence, this source of insights should be exploited for the socioeconomic assessment – as far as possible and methodological correct. The results of hypothesis testing about the potential effects based on data gathered in real traffic thereby allow partially basing the impact assessment on objective, empirical findings. But expanding the data analysis to a wider scope means interpreting these effects of the systems and estimate societal outcomes.

Large-scale field data allows being precise, when describing speed or driving style changes when systems are used in real driving conditions. But the analysis is still limited when it comes to make statements about generalised safety benefits and related socioeconomic terms like accident cost reduction. Even though in euroFOT, a comparably large number of vehicles were involved and several millions of kilometres tracked, a reduction of accidents or casualties due to the application of the IVSS could not be observed. To estimate any effect on this level, the effects observed in euroFOT must be abstracted to potential surrogate safety benefits and linked to accident statistics. This is a methodological gap and logically interrupts the assessment process which seems to be continuous in the FESTA V-model.

Testing hypothesis by analysing FOT data might have shown that there are changes in driver behaviour and car control in conflict situations due to the presence of the system. Further analysis – the safety impact in terms of “how many are accidents are reduced?” – could not be proven by hypothesis testing. How these changes on a large scale make the traffic actually any safer and how the system's effectiveness reduces accident cost still remains subject of further research – both in terms of detailed FOT data mining and ex post accident data evaluation. CBA can only indicate potentials for optimisation in the factor endowment of a society and help ranking priorities.

2.2 Scope of cost-benefit analysis in euroFOT

Core of the cost-benefit study in euroFOT is the **cost benefit assessment**, similar to the concept described in the FESTA handbook. In this guide, it is stated that any socio-economic impact assessment of system analysed in a FOT should be based on a cost-benefit analysis that accounts for all benefits and all cost on a society level and includes all relevant effects on all groups. By appraising benefits and cost in comparable monetary terms, the benefits-cost ratio (BCR) provides an easy to understand judgement of road safety measures.

CBA is the most widespread, commonly accepted and practised method used in transport research to prove the profitability of a measure on societal level and to support policy making, since it commits researchers and developers to give a quantitative indication, what is feasible in terms of accident reduction, environmental or time benefits. Results for different potential investments can be compared with each other, if a common assessment basis – an integrated framework – is used which is capable of accounting for all relevant impacts on societal level – positive (benefits) as negative (costs). Then, cost-benefit ratios can be derived from comparing potential costs of a particular FOT system to potential benefits (e.g. accident and time cost savings for users, other traffic participants and the general public. If the benefits exceed the costs (benefit-cost ratio is above 1), the system is profitable from the society point of view.

However in practise, still various cost-benefit approaches exist which might lead to different results. This is mainly because costs and benefits to society are virtual figures and no exact metrics, which are defined by the scope and described in potentials, even though the underlying "real-world effects" are unambiguous data. Therefore, choosing a different definition of scope may lead to different assessment results, which might still be – within their given scope – all correct. Important is to adjust the scope to the given problem to assess.

In particular, the following aspects require special consideration:

- **General scope of assessment:** in general, the concept of cost-benefit assessment can be implemented in various approaches. For example, an impact assessment methodology established by the EU aims at comparing different policy strategies to support the political decision. In euroFOT, the focus is to use effects seen in the FOT data, so the CBA is linked to it as closely as possible. The question to answer is, if the results allow up-scaling, what would be the impact of a system, if all vehicles were equipped.
- **Scope definition in detail**: in chapter 3, the functions and their assessment results are compared and reviewed in order to provide a consistent scope that is applicable and accurate in terms of consistency (quantity of observed changes can be compared across functions) and quality (interpretation of results in WP6400 allows expanding the FOT level results to EU level). This analysis takes into account how the scope of euroFOT CBA can be matched with the methodology and scope previous studies (on which FESTA and euroFOT methodology mainly base, see Figure 3 based on FESTA Consortium 2008) and what WP6400 delivers in terms of significant effects, usage rate and reliable sample in terms of drivers, mileage and time taken into account in the FOT.
- **Cost:** Net single-unit cost of embedded safety features are difficult to grasp and almost impossible to actually measure. Net cost include costs easy to determine e. g. component prices for sensors, control equipment and production cost, but the "real investment" – virtually all resources and efforts spent to implement a technology compared to a world without it – always remains subject of scope definitions,

depending on the view point of the assessment. For a “bottom-up” approach (start with components and give a unit-specific mark-up), detailed marginal manufacturer cost and net over-head (e. g. time and effort spent for quality assessment, iterative customer clinics) would be needed. The “top-down” approach has the advantage to start with what is available in terms of market prices for functional bundles. Given the assumption, that manufacturers were able to plan investments well, the price incorporates the market characteristics regarding specific customer needs, sourcing decisions and supplier power. This pragmatic approach limits the degrees of freedom when assessing cost compared to bottom-up estimations of virtual net cost. But by considering a range of different cost estimations in sensitivity analysis, all available cost assessment concepts can be covered.

- **Time scope:** a cost-benefit ratio describes the static impact of a measure on overall societal welfare at a certain point of time. But welfare theory itself is considered a dynamic field of research, where growth, economic trends and technological progress may form different environments. Parts of the assessment framework like accident numbers, fleet and mileage change over time, but also abstract parameters like cost-unit rates and time preference need adjustment [Kranz 2010]. Since most of the trends have to be assumed by advanced and elaborate models, they result in variance and uncertainty. Far-distant points of time (>2025) which require these models should be avoided if they are not the particular object of analysis (e. g. for technologically advanced cooperative ITS which are not yet realised). This is not the case for euroFOT which has the objective to use real-world test results as benefits.

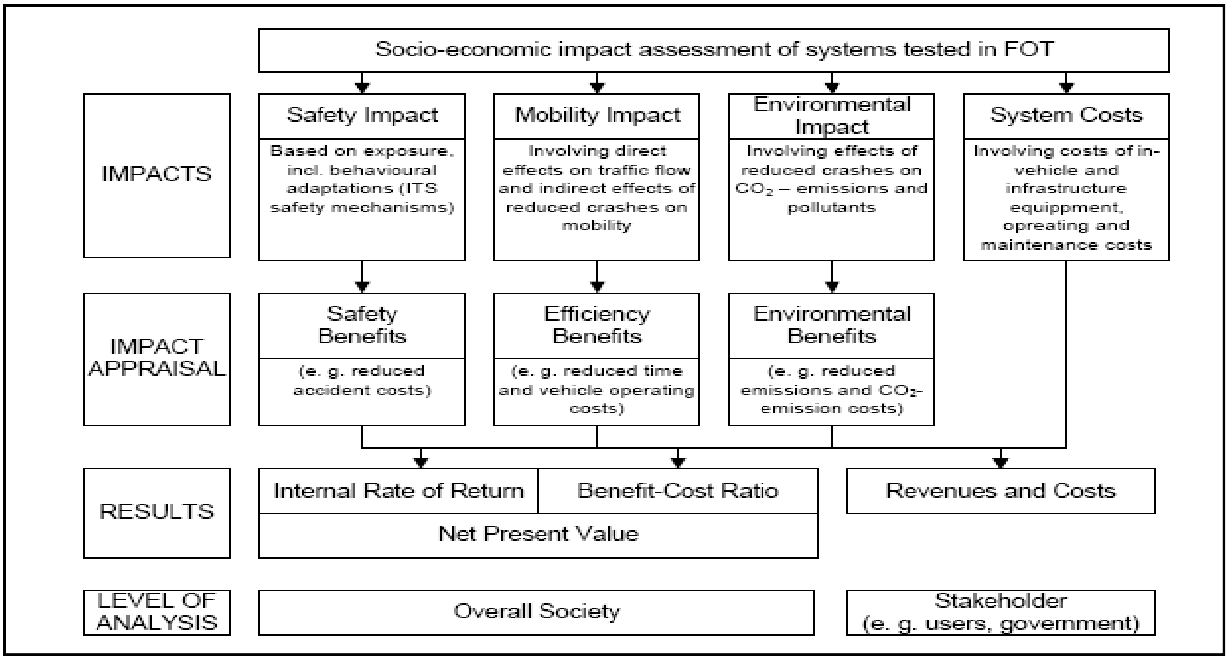

Figure 3: Socio-economic impact assessment according to FESTA Handbook

The general characteristics of this method that are specific to the euroFOT cost-benefit analysis are as follows:

- Main inputs to the cost-benefit analysis are results of the **impact assessment in WP6400**. In fact, main objective of this study is to limit all further socioeconomic evaluation to these results as far as possible. The potential economic impact of each defined function is given as a range and sums up all effects in terms of safety, traffic efficiency and environmental impacts (e. g. fuel savings, CO_2 reduction).

- System-specific scope for separate functions: to acknowledge the given specifications and the nature of FOT results, this study focuses on **features as they are available on the market** by assessing integrated functions. In euro FOT, similar functions and behavioral and driving mechanisms they influence were not independent. Impacts were not evaluated separately (e. g. by first deactivating single functions and combining them stepwise). For example, the same camera or radar sensor can be used to address different safety mechanisms, since it may detect different risk factors or processed to information (warnings) the interface is designed potential accident causes. For functional bundles, no further cost separation is needed and the net cost estimation can be done based on market prices.
- Apply cost-unit rates: Conducting a CBA always means to some extent interpreting potential effects from an economic perspective. Physical impacts – e. g. estimated reduction of accidents – are transferred into monetary benefits for society. **The cost-unit rates** used in euroFOT represent the current state of the art in research. These rates come from advanced econometric models and aggregated modelling of economic cost. In chapter 5, these values are varied in a sensitivity analysis within the scope available in previous studies to eliminate hypothetical error.

In conclusion, CBA in euroFOT combines the state-of-the-art of socio-economic analysis of advanced driver assistance systems from theoretical studies with insights derived from real world testing on changes occurring due to the presence of these systems. This means basing the integrated framework on established methodologies (scope, cost-unit rates), but using surrogate safety measures – and statistical significance testing on their robustness - to estimate potential safety impacts.

Important methodological choices of this cost-benefit study comprise the following elements:

- The assessment framework is kept as pragmatic as possible. The main motivation for doing so is to keep the credibility of the measured FOT results and to avoid amalgamation with high level assumptions and uncertainties. There have been research projects in the past (e.g. eIMPACT, iCars-Network) which had specific focus on the modelling of developments of safety and traffic performance etc.
- Cost-benefit analyses can produce different summary measures of performance. It is common to calculate the Net Present Value (NPV) by summing up all discounted values of benefits (plus sign) and costs (minus sign) over the lifecycle of the measure but it is also common to preselect one or several target years and to calculate snapshot benefit-cost ratios (BCR) for these target years. In the second case, the costs will be transformed to annual values (using the discount rate) and will be compared to the target year benefits. Both ways are feasible and represent good practice. Which way is selected depends on information needs and to some extent also on “evaluation culture”. Whereas transport appraisal guidelines in the United Kingdom (e.g. WebTAG) prefer the lifecycle analysis, the German guidelines for infrastructure investment planning prefer the snapshot method. When study clients are interested in detailed information on the timeline of market success of a measure the lifecycle analysis has its merits. Since the goal of economic assessment within euroFOT is to assess the profitability of the tested systems in general a snapshot CBA analysis is appropriate.
- The cost-benefit analysis assumes different penetration rates of the systems ranging from 5% to 100% (5%, 10%, 25%, 50%, 100%). This also implies a non-linear relationship between market penetration and the share of driven fleet mileage. Usually, new cars have a higher mileage than their respective share of the fleet penetration rate. For instance, a fleet penetration rate of 10% equipped cars equals a driven mileage share of approximately 14%.

- In order to reflect reductions in system unit costs due to the improvement in technology and production efficiency we consider three levels of economies of scale (5%, 10%, 20%).
- The boundary conditions (road safety performance, traffic performance) reflect recent conditions, year 2010 wherever possible. Since the test results from euroFOT were performed in recent traffic conditions it seems reasonable to link these also with actual boundary conditions data.
- Considering what has been said above we deliberately have not included projections for fleet and safety performance as well as price development. It has been demonstrated elsewhere (Wilmink et al. 2008, Schindhelm et al. 2010, Bühne et al. 2012) that incorporation of such trends is possible in principle. But this does not add on the quality of the measured effects in euroFOT. Nevertheless, a brief discussion of such parametric changes can be found in chapter 5.

2.3 Impact appraisal regarding safety, traffic and fuel efficiency impacts

In euroFOT, the methodology development focuses on an exhaustive review (and involvement) of previous stages of the project like WP6400 and how the respective results can be integrated. Key objective was to *not* develop an entirely new methodology, but keep the approach simple and comparable in order to avoid uncertainties and assumptions e. g. when taking national data where EU data is not available. Therefore, it is most important to understand how the benefits are derived from the impacts provided by the previous WP6400 that conducted the impact assessment. The euroFOT cost-benefit study is in line with the general methodology definitions of FESTA and – regarding how to define scope and content in detail – with scientific studies like eIMPACT, CODIA or comparable TRL studies or EU impact assessments [EC 2011b].

Cost-benefit assessment determines – generally ex-ante – the net benefits and net costs, given the scenario e. g. a technology was in place at the current state of time and hence, traffic, emissions and accidents accordingly. If there are positive or negative impacts that could be up scaled to EU-27 level, these are reflected in potential monetary benefits, summed up and compared with net cost for technology deployment. In chapter 2.4, the selected cost unit rates are explained – and how to break down technology cost in order to get to comparable net cost.

The **safety benefits** are calculated by applying **cost-unit rates** for casualties and accidents that have been calculated in order to estimate the average cost to society due to the resources (labor, material damage, time) that are lost due the accident. Throughout Europe, there are various frameworks with different boundary conditions in which these figures are determined. In chapter 2.4 the selected cost-unit rates for the safety benefits are explained and discussed.

Traffic efficiency benefits are defined as the monetary value of time savings that are not lost in traffic jams or on unnecessary long trips on the road due to the system assisting to driver more efficient. The cost-unit rates for hours lost in traffic take into account differences between travel time of passenger cars and commercial vehicles, since e. g. commercial vehicles stuck in traffic might cause delays in productions facilities, while the value of time spent in cars could depend on the person driving it, the time of day and purpose of the trip.

The **environmental benefits** are defined as reduced damage to the environment e. g. avoided cost of climate change due to the fact that emissions can be reduced. There might be system-wide effects that can be modeled by considering route choices, differences in exposure or more efficient combustion due to harmonized driver or traffic behavior. But in euroFOT, all emission changes are directly linked to the fuel consumption changes, hence they also include the net savings of fuel (see D6.5).

2.4 Cost unit rates for impact appraisal

After assessing the impacts on safety, congestion and efficiency, fuel consumption and emissions it is necessary to transform these physical numbers into monetary values. This step is done by applying cost-unit rates per impact, meaning per avoided fatality, injury, hour lost in traffic etc. From a process point of view, impact appraisal is simply a transitory step between impact assessment and benefits. Therefore, this issue is featured here in the section assessment scope and design. It should however not be neglected that impact appraisal constitutes a whole stream of research between different branches of technical and natural sciences, and economics. Good practise on EU level, aiming at harmonised cost-unit rates, as provided by HEATCO [Bickel et al. 2005] and IMPACT [CE Delft 2007] is taken into account in this study. The same holds true for national evaluation manuals such as WebTAG in the U.K. and BVWP in Germany.

Generally, it is not a straightforward issue to place a value to each impact. Economics provides different principles which can be used for impact appraisal:

- The damage cost principle deduces the economic assessment directly from the consumption of resources and the damages which are induced by traffic in the economy respectively. This approach is called "resource approach".
- The avoiding cost principle determines the costs potentially incurred by individuals or society either to avoid damages due to traffic or to reduce the damages to an acceptable level. The costs are borne by e.g. the pollutees or by the society who had to suffer the damages.
- The willingness-to-pay principle obtains value by asking people how much they would be willing to pay for avoiding casualties, congestion etc. In contrast to the principles above it acquires values from stating preferences and therefore involves a subjective component.

Which method suits best, creates quite a debate among scientists and also users of evaluation manuals. What we can observe is that there are different methods which are to a different extent suitable for different cost categories. In addition, there is also quite a bit of different appraisal culture with some Member States (e.g. Germany) focussing largely on cost-based values whereas some others (e.g. UK, the Netherlands) involve willingness-to-pay-based values to a larger extent.

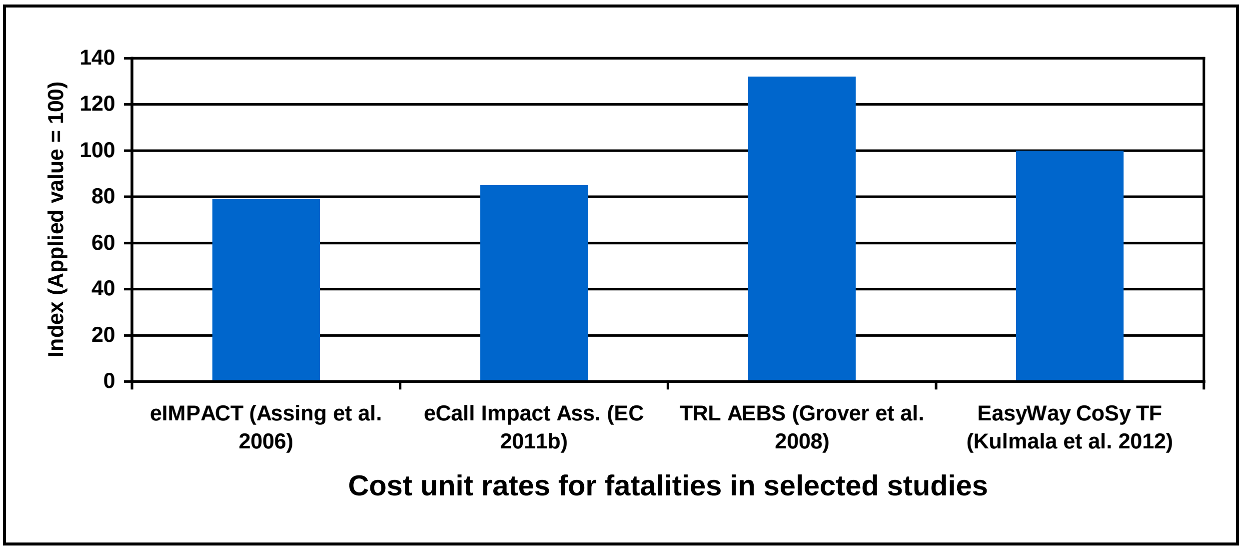

Figure 4: Comparison of fatality cost-unit rates applied in different studies

In order to illustrate the issues discussed above, Figure 4 shows exemplarily the cost-unit rates for fatalities on the basis of values provided by several studies [Assing et al. 2006, Grover et al. 2008, EC 2011b, Kulmala et al. 2012]. It becomes obvious that besides impacts (effectiveness and target groups) also appraisal rates have a distinct influence on results.

Beyond this debate it should briefly commented upon central values which have been applied for calculating the benefits. They are listed below:

- Road safety cost-unit rates: 1.6 Mill. EUR per avoided fatality, 70,000 EUR per avoided injury,
- Efficiency benefits of avoided casualties (add on to road safety): 15,500 EUR per avoided fatality accident, 5,000 EUR per avoided injury accident,
- Time cost-unit rates (per vehicle hour): 20 EUR per vehicle hour for cars and 30 EUR for Heavy Goods Vehicles,
- Net fuel costs (i.e. without taxes, per l): 0.75 EUR for gasoline as well as Diesel,
- Environmental costs: 70 EUR per ton CO2.

2.5 Economic cost of IVSS

In general, net system cost of intelligent vehicle safety systems (IVSS) are defined as marginal manufacturer cost that include all resources (R&D, production marketing) necessary to equip the fleet with a system and income of manufacturers and suppliers for the market entry or establishing a market for these technologies. These assumptions should grasp the net effect on societal factor endowment and also consider market characteristics of driver assistance systems as optional equipment.

Since market prices are meanwhile available, cost can be determined in relation to market prices. Cost price estimations range between 33 % and 60 % of the current retail price for the systems, depending on selected scope and interpretation of OEM cost structure and definitions. Furthermore, economies of scale may lead to further variation when estimating net cost to equip all vehicles. Besides a basic current cost price also three different level of economies of scale (5%, 10%, 20%) are discussed in the study.

There are different methods from several former research projects available that either focus on cost for components (bottom-up) or try to break down the retail price in tax, profit and net cost. In the following explanations the different approaches and their reasoning are shortly presented:

- The first approach to gain reliable cost estimation is based on an ANL/TNO calculation scheme. The retail price of a certain IVSS can therefore be fragmented in percentage shares for different price components [EC 2011b]. 60% of the retail price represents the manufacturing costs as well as production and corporate overhead costs. Other price components such as manufacturer profit (3%), dealer costs (16%) and profits (2%) and value added tax (VAT) (19%) add up to nearly 40% of the end user price. Accordingly, net costs of the euroFOT systems can be estimated as 60% of the retail price.
- A different, more simplified approach comes from the recent cost-benefit study on advanced primary safety systems of a TRL study [Robinson 2011]. For an advanced emergency braking system (AEBS) information about retail prices was collected from the internet. Assuming these values found were full market costs to the consumer including a high mark-up and production costs will decrease because of economies of scale, a reduction of the discovered prices by nearly 50% was estimated as manufacturing costs.
- The last approach is based on the CBA methodologies within the EU project eIMPACT and the FESTA Handbook. In eIMPACT the term of the cost price was introduced which comprises the price of the ICT system paid by the manufacturer to

its supplier plus a mark-up for in-vehicle implementation [Assing et al. 2006]. Generally, in the face of limited evidence it is useful to apply the “Factor 3” rule of thumb, which means that in the automotive industry market prices for ICT systems differ from the cost prices by a factor of 3 [Malone et al. 2008].

Exemplary for an ACC+FCW system the following table shows actual market prices for such functions as an optional feature as well as the manufacturing costs according to the above mentioned approaches. The retail prices for an ACC+FCW of cars from the in euroFOT involved manufacturers range between 560 and 1,980 Euro. On the upper bound of manufacturing costs / cost price amounts to approximately 1,190 Euro whereas the lowest overall cost price amounts to approximately 190, Euro.

Table 1: System costs for ACC+FCW systems (own calculation based on market prices)

System cost for ACC+FCW in Euro				
	Calculation Approach			
Car/Brand	Market/ Retail Price	TNO/ANL Approach	TRL Approach	eIMPACT/ FESTA Approach
Audi A3	560	336	280	187
Ford Mondeo	980	588	490	327
VW Passat	1,210	726	605	403
Volvo S60	1,980	1,188	990	660
*All market prices are based on 2012 German price lists for the respective car, price difference are dependent to some extent on slight differences of system functionalities				

Taking reductions in system unit costs due to the improvement in technology and production efficiency into account the cost price will be further reduced by higher volumes of produced and implemented systems. Typically average costs go down through mass production due to the realisation of economies of scale. Former studies on the implementation of intelligent vehicle safety systems determined cost degression rates ranging between 5 and 20% per doubling of the production output respectively the market penetration rate (Grawenhoff 2006, Schindhelm 2010). As a base case we consider medium economies of scale of 10%. The impact of economies of scale on system unit costs is illustrated in Figure 5. Starting from a cost price of approximately 190 Euro for the current penetration rate of 5% the cost price is decreasing for higher penetration rates accordingly.

The estimation of the manufacturing costs / cost price for an ACC+FCW system for cars will also be used for the cost-benefit analyses of trucks. In contrast to price mark-ups for safety systems such as Electronic Stability Control (ESC) due to the large number of axles and the relatively low production volumes of heavy good vehicles, the additional costs for components of ACC+FCW systems are relatively low. Once ESC is already integrated in a truck the additional hardware cost for e.g. an AEBS system are limited since the sensors can be produced in high volumes and at a similar cost to sensors used for cars [EC 2008]. Therefore it is very unlikely that the system cost for an ACC+FCW system are very dependent on the vehicle category.

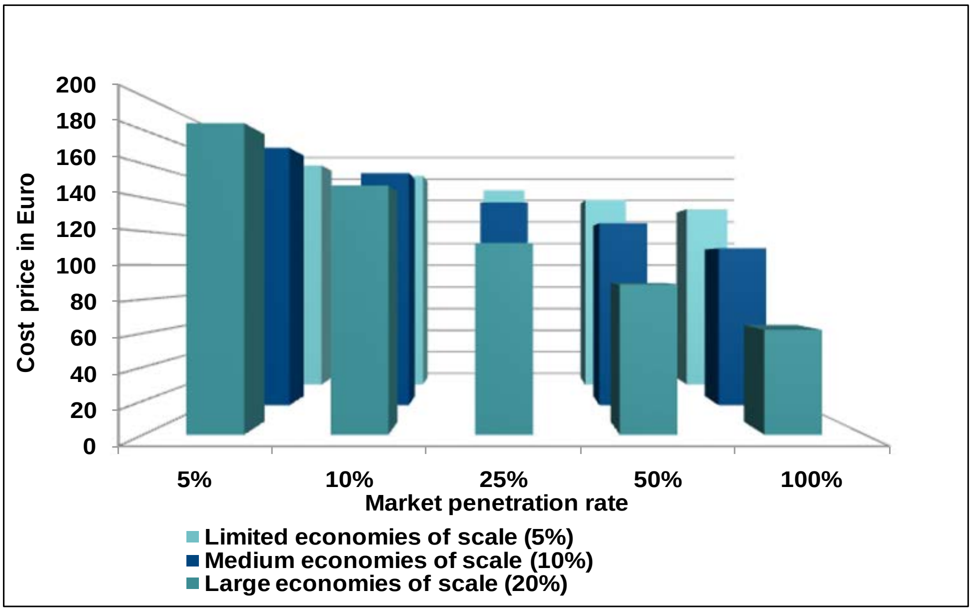

Figure 5: The impact of different economies of scale levels on the cost price for various market penetration rates

2.6 Accident data for EU-27 for car systems

To determine potential benefits on EU-27 level, the FOT safety impacts are linked with an applicable European accident target population. This step is closely linked to determining safety benefits on national level in D6.4. The safety impact assessment in D6.4 is already up-scaling the findings from FOT level – expressed in hypothesis regarding surrogate safety measures – to estimations regarding real-world accidents. The interpreted results from each hypothesis are used to determine a generic benefit range which is linked to accidents. The main difference between national and European level safety impacts is the target population which is used as basis for the assessment.

2.6.1 EU-27 accident data sources

Potential safety impacts on European level have to be determined by estimating European accident populations as accurate as possible, instead of focusing e. g. only on potential accident reductions in Germany or Great Britain which would use data from a single national accident database. There is a lack of integrated European accident data and hence, different data sources need to be combined. There are general figures on fatalities per EU-27 country [Eurostat 2012], but only e. g. the number of injured car occupants. This is not the level of detail that would be needed to analyze safety impacts. That is why the detailed safety impacts determined on national FOT level in D6.4, are up scaled to provide input for the cost-benefit analysis. By standardizing and harmonizing the definitions for data analysis across Vehicle and Test Management Centers (VMC), generic impacts were derived, which apply under the same assumptions to target group estimations on European level as on national level.

When addressing the same issue (how to obtain usable accident data sets for European safety impacts), the eIMPACT / TRACE project developed a cluster-based spreadsheet in 2006 with additional accident parameters (collision type, weather, road type) [Wilmink et al. 2008] . This spreadsheet includes accident forecasts for 2010 and 2020 and may serve as comparison for the data set used in this analysis. But to update it in order to use it for the euroFOT analysis, this data set would need to be “synched with current trends”. Hence, in euroFOT it is appropriate to estimate European effects by using available accident data – in line with current data analysis results from similar studies.

To generate EU-27 target groups, country-specific differences between national accident scenarios across Europe are reflected by using most current, detailed and consistent accident data available from each country. On European level, number of accidents and casualties can be divided by vehicle type and road type to single out involved car occupants per road type. After this filter, the particular target groups are narrowed down to relevant accidents by extrapolating more detailed findings on national or in-depth study level from D6.4. Key figures for the systems in euroFOT to be linked with impacts in terms of incident reductions are the relevant numbers of injured car occupants per road type.

The following data sources were used to get to the estimations:

- Eurostats & CARE: Pan-European data available for each country such as number of fatal car occupants, accidents and casualties divided by location and overall injury accident figures by national definition and reporting.
- STRADA, STATS19, DESTATIS: Accidents available further divided by collision type, by impact direction and characteristics of accident site (posted speed limit, weather, time).
- GIDAS: In-depth data on accident kinematics (pre-crash behaviours, collision speeds & decelerations, sequential manoeuvres) to filter for stationary vehicles and system relevant boundaries.

Hence, the results of the national target group estimations are brought to same level of accident filtering and integrated to average shares per road type. The differences between countries (e. g. high share of motorway traffic Germany vs. mostly rural traffic in Eastern Europe) are taken into account by identifying the number of involved car occupants per road type for each country.

Figure 6 shows the relationship between the databases on each level used for the target group estimations.

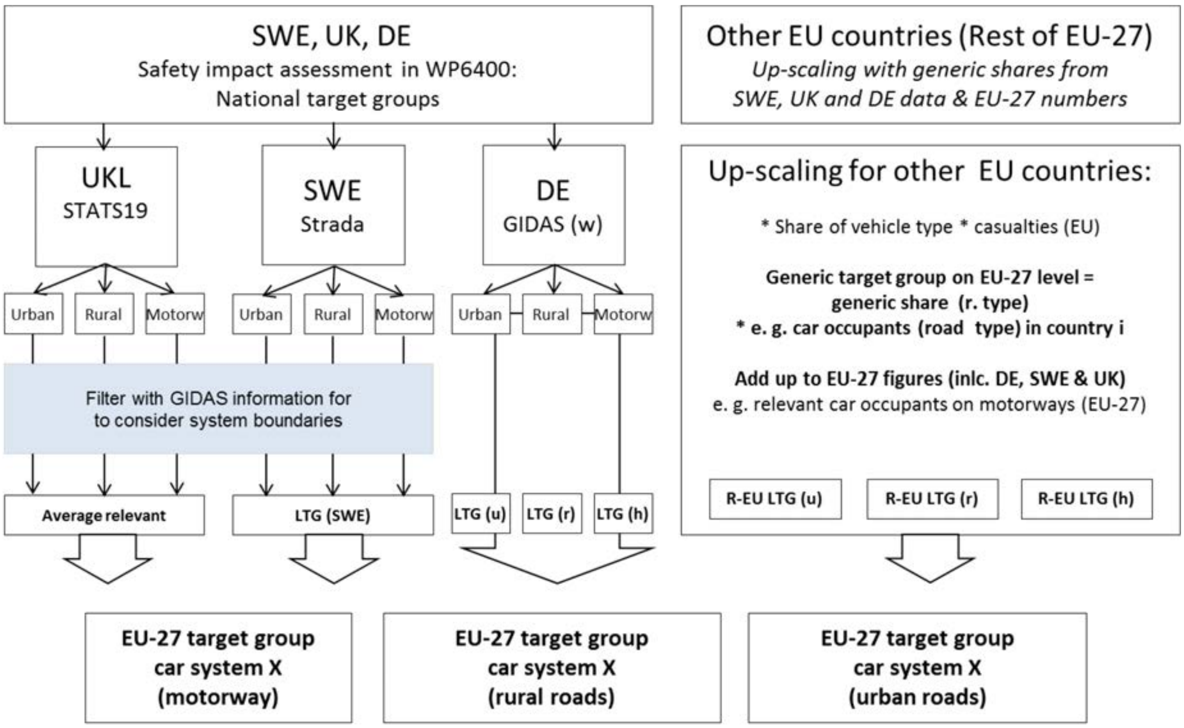

Figure 6: Up scaling framework „EU 27 target group estimation"

From the safety impact assessment in D6.4, figures regarding accident type, car involvement and accident location are available for the countries involved in FOT (DE, SWE, UK). For Germany, the use of GIDAS allows a more detailed filtering: accidents in GIDAS are reconstructed to the extent that pre-crash scenarios (driving speed, location) and accident kinematics (collision speed, deceleration) are available for all accidents. This allows filtering out the accidents and casualties that are likely to be addressed by advanced assistance systems. By using the ratio between potential (accident type, car involvement) and likely accidents for EU-27 target groups, it is assumed for euroFOT that the accident properties identified in relevant accident match throughout the available accident databases.

Table 2 shows the accident and casualty numbers available for EU-27 countries. The UNECE road accident statistics only provide e. g. the number of all fatalities on motorways, but not the numbers of fatally injured car occupants in accidents with rear-end collisions on motorways.

Table 2: Casualty numbers of road accidents for EU-27 countries (UNECE RAS 2011).

UNECE Transport Division, 2008	Total of fatally injured car occupants	Total of sli./sev. injured car occupants	All road fatalities	All injured individuals in road traffic accidents
Austria	367	28.945	679	50521
Belgium	479	32.541	944	64437
Bulgaria	622	5.575	1.061	9952
Cyprus	26	1.016	82	1963
Czech Republic	573	16.939	1.076	28501
Denmark	196	2.820	406	5923
Estonia	69	1.360	132	2398
Finland	202	4.486	344	8513
France	2.205	40.339	4.275	93783
Germany	2.368	224.755	4.477	409047
Greece	708	7.428	1.555	19010
Hungary	448	13.936	996	25369
Ireland	160	6.847	280	9747
Italy	2.116	177.698	4.731	310739
Latvia	167	3.007	309	5408
Lithuania	237	-	499	5818
Luxembourg	20	823	35	1239
Malta	4	566	9	859
Netherlands	299	9.850	649	27507
Poland	2.540	35.115	5.230	62097
Portugal	358	23.382	885	43824
Romania	1.323	16.506	3.061	36177
Slovakia	292	6.795	606	10886
Slovenia	82	6.389	214	12742
Spain	1.516	71.983	3.100	130948
Sweden	234	17.612	385	26248
United Kingdom	1.312	154.240	2.546	237811
	18.923	**910.953**	38.566	1.641.467

Therefore, the shares were derived from national target group estimations where they are available. E. g. the share of accidents in the FCW relevant likely target group on motorways is determined for Germany, Sweden and UK and then expanded as EU-27 share on all fatally injured car occupants on motorways.

Table 3 shows the number of fatalities on European level clustered into road types and the number of fatally injured car occupants based on these European databases [UNECE 2011] for the year 2008, which is the latest year for which data is available from all EU-27 countries. The approach for truck accidents is slightly different.

Table 3: Road fatalities in EU-27: car occupants & distribution over road type.

UNECE Transport Division, 2008	Fatally injured car occupants	All road fatalities (EU-27, 2008)		
		Motorways	Rural	Urban
Austria	367	71	419	189
Belgium	479	139	474	174
Bulgaria	622	38	580	443
Cyprus	26	8	11	63
Czech Republic	573	30	602	444
Denmark	196	31	246	129
Estonia	69		91	41
Finland	202	9	227	108
France	2.205	233	2807	1235
Germany	2.368	495	2721	1261
Greece	708	120	198	744
Hungary	448	54	523	419
Ireland	160	2	216	62
Italy	2.116	452	2203	2076
Latvia	167		212	97
Lithuania	237	24	328	147
Luxembourg	20	6	20	9
Malta	4			9
Netherlands	299	86	325	238
Poland	2.540	35	2696	2499
Portugal	358	96	372	417
Romania	1.323	21	1121	1919
Slovakia	292	14	312	280
Slovenia	82	13	128	73
Spain	1.516	109	2357	634
Sweden	234	18	271	96
United Kingdom	1.312	160	1302	1084
	18.923	**2.264**	**20.762**	**14.890**

The number of injured individuals in this EU-27 accident data set is available as well, but not divided by accident severity (slight, severe). There are heterogeneous severity definitions throughout Europe, furthermore because of under reporting of non-fatal accidents, benefit estimations related to all-Europe injury reduction need to be treated with further reservations.

Several examples from previous studies (TRL study AEBS, IRTAD report) try to correct the assumedly too low figure of injured traffic participants, but for reasons of consistency, this assessment uses the figures as they are given in the UNECE report. The sensitivity analysis in chapter 5 addresses this issue by analyzing if and what changes with higher injury numbers. Table 4 shows in summary the accident numbers from EU-27 countries that were used to link safety impacts based on FOT results to the European accident scenario.

Table 4: All road fatalities and injury accidents and involved car occupants (own calculations based on CARE, EUROSTATS, IRTAD and UNECE RAS 2011).

EU-27 - Summary of Road Accidents & Casualties				
	Motorway	Rural	Urban	all
Fat. inj. car occupants	1.571	13.678	3.673	18.922
Injured car occupants	79.952	364.875	468.470	913.297
Injury accidents	60.682	324.876	847.152	1.232.710
	Motorway	Rural	Urban	all
Road fatalities	2.264	20.762	14.890	37.916
Injured road users	90.678	453.299	1.058.366	1.602.344
Injury accidents	60.682	324.876	847.152	1.232.710

Accident data for injured car occupants and injury accidents is available in a similar format (see D6.7, Annex). Due to different severity definitions and quality of police reporting systems, they are not as comparable between countries as the numbers of road fatalities are across Europe [Derriks, Mak 2007].

Underreporting is taken into account when controlling the results on the level of socio-economic assessment on sensitivity to check whether uncertainties or changes of single parameters of the assessment framework change the overall outcome of the cost-benefit assessment. In this step, the EU-27 safety impacts are calculated by using the injury numbers as reported in Road Accident Statistics 2011.

For Germany, the German In-Depth Accident Study (GIDAS) database was used to limit addressable accidents with in-depth information. GIDAS is not a national database in the same sense as STATS19 and STRADA. Rather it contains in-depth investigations of accidents in the Dresden and Hannover areas since 1999 and contains more than 20,000 accident files. GIDAS provides a unique level of report data including full accident reconstructions, vehicle and injury data for each event and due to the way accidents are sampled, the dataset is assumed to be representative for whole Germany with regard to traffic accidents involving personal injuries. See Figure 7 for a comparison of the GIDAS dataset with German and European figures.

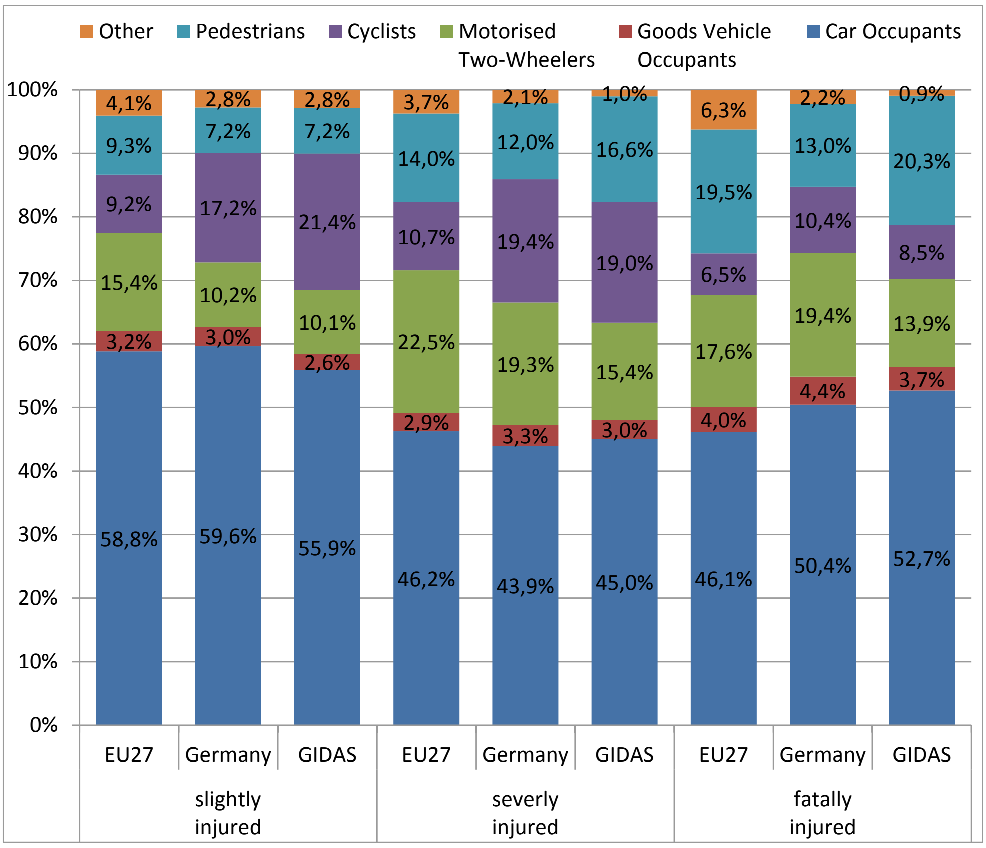

Figure 7: Comparison of casualty shares in road accidents by traffic participation and injury severity: EU27, Germany, and GIDAS.

2.6.2 EU-27 target group estimation

In order to provide applicable input for further assessment of the function in WP6500, the safety impacts of ACC+FCW cars and ACC+FCW trucks are provided, under the assumption that all vehicles were equipped:

- Number of addressed road fatalities in EU-27
- Number of addressed injured road user in EU-27
- Number of addressed injury accidents in EU-27.

Car functions in euroFOT are due to their current technological development stage not intended to specifically address accidents involving vulnerable road users. So the traffic participants that are in the scope of the system's function are car occupants themselves. Accident data related to traffic participation (car occupants) is available for all European countries (see Figure 8). For ACC+FCW, that includes both occupants of leading and following cars in addressable rear-end accidents. Therefore, the EU accident target group is given in terms of shares of involved injured car occupants and accidents in which cars were involved according to the identified accident mechanism.

For **truck functions** in euroFOT, the target group is not limited to occupants of heavy goods vehicles, but includes a rather large share of car occupants that are involved in accidents caused by trucks. On EU level, information on occupant level is not available divided by involved vehicle type pairing, but need to be estimated based on available national information. In a similar approach, the TRL impact assessment of AEBS [Grover et al. 2008] determined a share of addressable accidents in which N3 (heavy goods vehicles larger than 12 tonnes) were the guilty party, a front-to-rear shunt occurred and no stationary lead vehicles were involved. This matches with the objective of identifying accidents relevant for ACC+FCW in trucks. In euroFOT, the resulting shares were compared with the national target groups from STATS19 and STRADA. Despite not using the same filtering procedure on European data, an overlap between car and truck system shares is avoided due to the fact, that both accident data analysis approaches consider the respective guilty party – and this can only be one truck or one car.

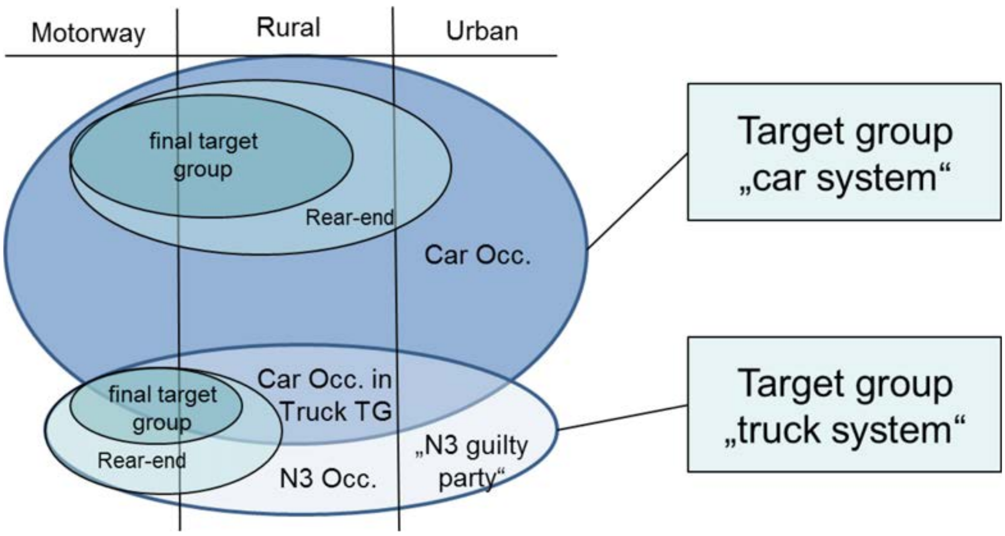

Figure 8: Qualitative illustration of filter process of relevant accidents and casualties for euroFOT safety impacts – Note: sizes do not reflect actual shares of target groups.

Given the EU-27 accident and casualty estimations, the European level impacts could be determined ("up-scaled") by linking them in consistence with other framework data used to depict economic conditions under which the assumed changes take place.

For **ACC+FCW (cars)**, the applicable national casualty shares were integrated to determine relevant accidents on EU level. By comparing filter criteria and definitions (e. g. in UK matching manoeuvres are coded instead of collision types), it was assured that complementary GIDAS filter could be applied to the UK and SWE shares where needed, in order to virtually harmonise the target group. GIDAS is the most exhaustive data source since it allows statistics based on data from accident reconstruction, so information such as typical vehicle kinematics in rear-end accidents and exact constellations in accident sequences can be used. This approach resulted in averaged shares, so the integrated results from these three sources were then up scaled by assuming this share to be relevant on EU-27 level.

- For Sweden, national data contains information on impact direction (e. g. car hitting the rear of another two-track vehicle), road type and posted speed limits (see D6.4). But in addition, the share of accidents with stationary vehicles and of those outside the applicable system limits (low speeds) was filtered out by calculating the applicable ratios in GIDAS.
- For UK, national data contains information on impact direction, posted speed limits and road type and also, if the vehicle in front was in motion. But to ensure, only addressable accidents are regarded as relevant for a target group, this share was further limited by applying the needed fitting ratio from GIDAS.

The average share can be applied to overall national figures, so the resulting EU-27 target group is as illustrated in the table below. The target group consists of approximately 350 fatalities and 60,000 injuries.

Table 5: Applicable casualty shares for cars

Shares - Car systems (integrated from DE; SWE & UK) — *Note - casualties related to EU-27* ***car occ.*** */road type; accidents: on all accidents per road type*

FCW/ACC		DE			SWE			*UK*		
		Motorway	Rural	Urban	Motorway	Rural	Urban	Motorway	Rural	Urban
LTG	Fatalities	12,09%	0,41%	0,65%	7,74%	0,66%	2,05%	11,02%	1,64%	2,16%
	Injured	10,95%	3,27%	2,63%	14,82%	5,37%	3,70%	20,88%	7,14%	11,33%
	Acc. Inj.	10,28%	3,06%	2,15%	14,47%	3,04%	1,67%	16,47%	7,98%	2,88%

Table 6: European target group for cars

EU-27 target group for ACC+FCW (cars)	Motorway	Rural	Urban	**SUM**
Fatalities	162	124	60	345
Injured	12433	19194	27582	59209
Acc. Fat.	162	124	60	345
Acc. Inj.	8177	15124	18856	42157

For **ACC+FCW (trucks)**, the accident analysis in the TRL report already integrated different European data sources, hence the derived share of injuries and fatalities is assumed to be applicable as EU-27 target group for euroF.O.T as well. In accident data analysis, AEBS and ACC relevant accidents match to a large degree, since the filter are set according to the system limitations of the radar – which depends on the generation of systems and not the way the system assists (braking vs. warning). Furthermore, it was assured that the shares were in line with the national target group estimations which were used for the safety impact assessment in D6.4.

The resulting shares on all casualties and accidents per road type can be applied to the aggregated national figures from all EU-27 countries, so the EU-27 target group for the truck system is as presented in the following table.

Table 7: Applicable casualty shares for trucks

	DE	GB	FR	EU Estimates	all road cas. EU-27	Share
	GIDAS (br. to 2008)	Annual aver. 2005-2008		estim. TRL (2010)	estimation TRL	N3 rel. in EU-27
Fatalities	57	9	9	275	42433	**0,65%**
Severely inj.	290	63	78	933	299484	**0,31%**
Slightly inj.	2175	799	198	6537	1391234	**0,47%**

STATS19 & STRADA distr. of rel. acc. over road type	Motorway	Rural	Urban
Fatalities	51,7%	46,6%	1,7%
Injuries	38,3%	35,4%	26,2%
Accidents	40,7%	31,3%	28,0%

Overall EU-level target group share for FCW/ACC (trucks)	Motorway	Rural	Urban
..on road fatalities	**0,34%**	**0,30%**	-
..on all injured road users	**0,17%**	**0,16%**	-
.. on all injury accidents	**0,18%**	**0,14%**	-

Table 8: European target group for trucks

EU-27 target group for ACC+FCW trucks	Motorway
Fatalities	127
Injured	2714
Acc. Fat.	127
Acc. Inj.	2087

2.7 EU-27 information for vehicle mileage & vehicle fleet

The deliverables D6.5 and D6.4 used the mileage forecast for passenger cars and commercial vehicles according to eIMPACT in order to up scale the effects found in euroFOT to EU-27 level. For the cost of the systems to be deployed throughout EU-27, the straightforward approach from TRL that is applicable for euroFOT – what if all vehicles have the system as observed in the FOT? – and requires to compare the cost to equip all new cars with the system with full impacts per year.

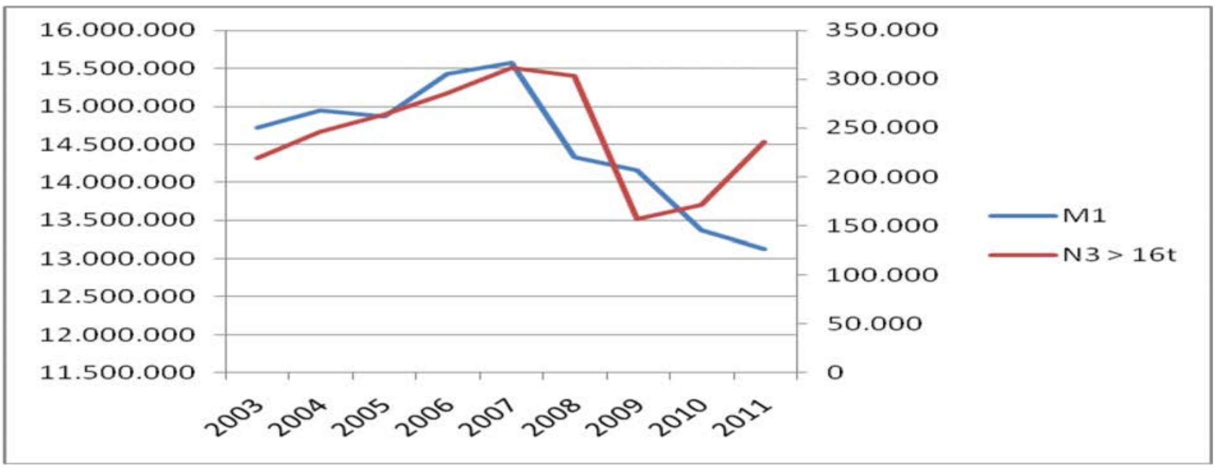

Figure 9: Annual new registrations of cars and trucks (M1, N3>16t) in EU-27 [ACEA]

To determine the size of these fleets, average yearly registrations from ACEA were taken into account (Figure 9). For the system in commercial vehicles, N3 vehicles greater than 16 tonnes were identified as the comparable group to put the system cost on the EU scale. The basic information which is used later in the cost-benefit analysis is hence an average vehicle fleet to be annually equipped of 14.5 million cars (M1) and 250,000 trucks (N3>16t).

3 Scope of socioeconomic assessment in euroFOT

3.1 Making use of CBA in terms of an ex-post assessment tool

The socioeconomic impact assessment in euroFOT follows the methodology provided by FESTA and coordinated with the several subtasks of impact assessment in WP6400 focusing on safety, traffic efficiency and fuel efficiency. It is also clear that the functional descriptions which also represent an input to any socio-economic assessment are not subject to repetition and discussion in this deliverable. We refer to other euroFOT deliverables such as D6.4.

In terms of VMC data, the socio-economic assessment presented in this deliverable does not rely on separate data analysis or different impact appraisal. According to the FESTA-V, this analysis only uses results of D6.4 and D6.5/D6.6, since its goal is no parallel analysis, but an economic assessment from an additional research angle.

In order to use the assessment framework of ex-ante assessments, the analysis starts with scope definition. It is crucial to differentiate between goal (general focus on input or output of assessment) and direction of scope (ex-ante vs. ex-post) of the impact assessment:

- Theoretical studies like eIMPACT are ex-ante assessments of future assistance systems and intended to provide a socio-economic overview on what could change because of these functions. The safety impact methodology distinguished between risk, exposure and consequence, intended to capture a wide range of potential mechanisms, but without actually empirically proving them. The methodology development rather looked at comprehensively defining and quantifying all possible mechanisms by which systems can influence risk, exposure and consequence both directly and indirectly. Hence as a necessary output, this framework could be used to estimate all potential reductions in fatalities and injuries for the considered future systems.
- In field tests, significant changes in crash-related indicators are the key outcome in terms of safety. Inputs for the assessment necessarily are real-world effects of real systems. The indicators allow observing effects how systems could on a larger scale help lowering accident risk in specific constellations. To be methodologically consistent, making a link and up-scale from FOT to accident data level already would be outside the scope of the experimental setup of a field test, if no reduction of real accidents is observed. But being this strict, the results of euroFOT could not be used to estimate any expectable impacts on accidents or injuries at all - since the results do not directly allow predicting any changes in terms of road safety improvement.

In order to be in line with FESTA methodology, WP6400 only linked significant and unequivocal changes in events to addressable accidents that were - by using definitions according to system limitations - filtered to a level to limit the error. In future analysis, further research should aim at linking both scope and requirements of the two approaches, e.g., a detailed analysis of FOT data for effectiveness and case-by-case analysis from in-depth accident data could be used to review the full set of safety mechanisms for more functions that were intuitively assumed in eIMPACT.

3.2 Results from impact assessment (WP 6400)

3.2.1 Impact table

According to the FESTA handbook, an impact table can help to identify relevant impacts that should be taken into account when defining the scope. In order to limit the step of up-scaling effects to EU-level and monetising the effects in economic terms, this scope needs to consider results of comparable scale and quality [FESTA Consortium 2008].

The scope of the impact assessment in line with the FESTA methodology and linked to the objectives and key aspects of the analysis can be illustrated in an impact table to facilitate the scope definition (Table 9). It is obvious that only for systems (see individual rows) where results from impact assessment are available in quantitative terms and can be assumed to be valid, further progress towards a full-scale cost-benefit analysis is reasonable. E.g. FCW/ACC results from the impact assessment allow to include safety and fuel efficiency effects in the cost-benefit analysis. Most of the technologies assessed in euroFOT are already in the market as stand-alone assistance features. Hence, certain impacts (columns) were out of scope of the assessment as a whole.

Table 9: Impact table as summary of available input for the scope of socio-economic impact assessment (own figure according to FESTA)

Socio-economic impact assessment Impact table according to FESTA p. 99	Safety	Mobility	Efficiency & Productivity		Fuel & Emissions	User acceptance & human facors		Performance & Capability	Legal & implementation issues	Costs assessment		In CBA
euroF.O.T scope												
in WP6400 (impacts)	D6.4	D6.5 traffic eff.			D6.6	D6.3				(D6.7)		
euroF.O.T systems & considered impacts												
FCW/ACC cars	+	-			+	+				X		X
FCW/ACC trucks	+	-			+	+				X		X
LDW/IW cars	(+)					+				X		
LDW/IW trucks	(+)					+				X		
BLIS	(+)					+				X		
SRS (SL/CC combined)	(-)	(+)			(+)	+				/		
SafeHMI	(+)	+			(+)	+				/		

(grey) not covered by euroF.O.T WP6500 socio-economic impact assessment
(green) inputs (safety, traffic, environment) from SP6 impact assessment

+	positive	( )	no EU-wide assessment
-	negative	X	available
o	none	/	not available

Furthermore, the cost assessment as defined by studies such as eIMPACT should be consistent throughout all functions, which requires more modelling for some functions. In the following chapters, the results from WP6400 are discussed in detail in order to decide on the scope based on both methodology and findings of previous assessment steps. No additional data (e. g. directly provided by a VMC, bypassing WP6400) was included.

3.2.2 WP6400 results for ACC+FCW

The ACC+FCW function is intended to support the driver in selecting and maintaining an appropriate speed and time-headway depending on his/her preferences. Furthermore, ACC+FCW is intended to decrease driver response times in lead vehicle conflicts by issuing collision warnings, thus potentially reducing the risk of rear-end conflicts.

The impact of ACC/FCW was investigated using data collected by Ford, VW, MAN (all VMC German-1), Volvo Cars and Volvo (VMC Sweden). For detailed data analysis method (data filtering, incident detection) see D6.3.

Drivers experienced two conditions; 1) driving without the system (baseline condition) and 2) driving with the system available for use (treatment condition). The mileage covered in baseline and treatment is shown below in the attached table. It gives an overview over the number of kilometres of driving on which the analysis for ACC is based.

Table 10: Number of drivers available for the data analysis. The number of respondents varied somewhat for the different questions.

	Mileage		Number of drivers	
	Baseline	Treatment	$N_{passenger\ cars}$	N_{trucks}
Overall	727114 km	623615 km	174	53
Motorway	676924 km	602866 km	174	53
Rural	24983 km	12228 km	64	-
Urban	25207 km	8521 km	64	-

Overall, the bundle was expected to have a positive effect on both comfort and safety. The comfort side was mainly assessed subjectively with questionnaires in deliverable D6.3, while the potential safety benefits are addressed in D6.4. It should be noted that the following figures denote the changes in treatment in relative terms, i.e. the number of 0.16 represents an improvement of 16%.

Based on the overall results for ACC+FCW in cars, as displayed in Figure 10 to Figure 12, it can be concluded that when drivers use ACC+FCW, there is a positive effect on safety-related measures.

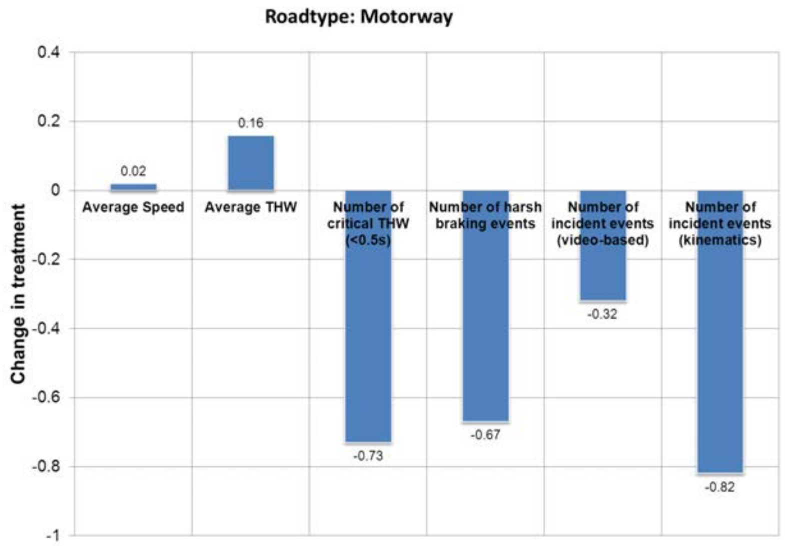

Figure 10: Overall benefit of ACC+FCW on motorways (passenger cars).

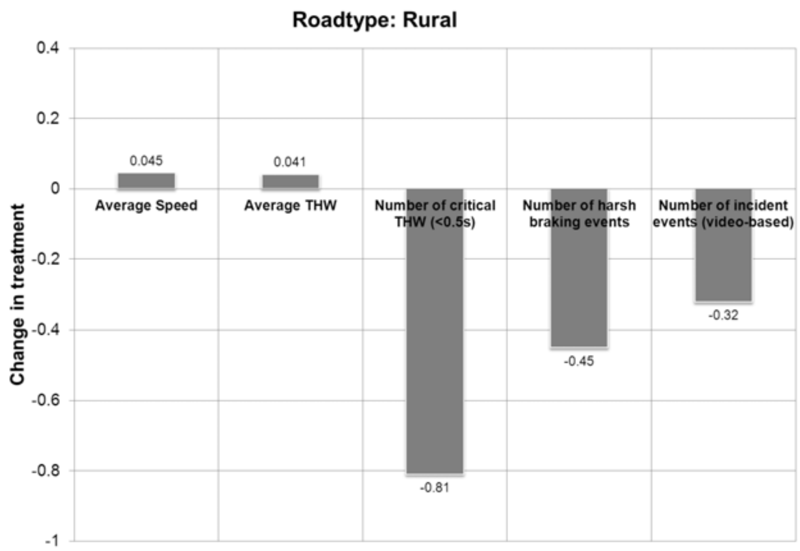

Figure 11: Overall benefit of ACC+FCW on rural roads (passenger cars).

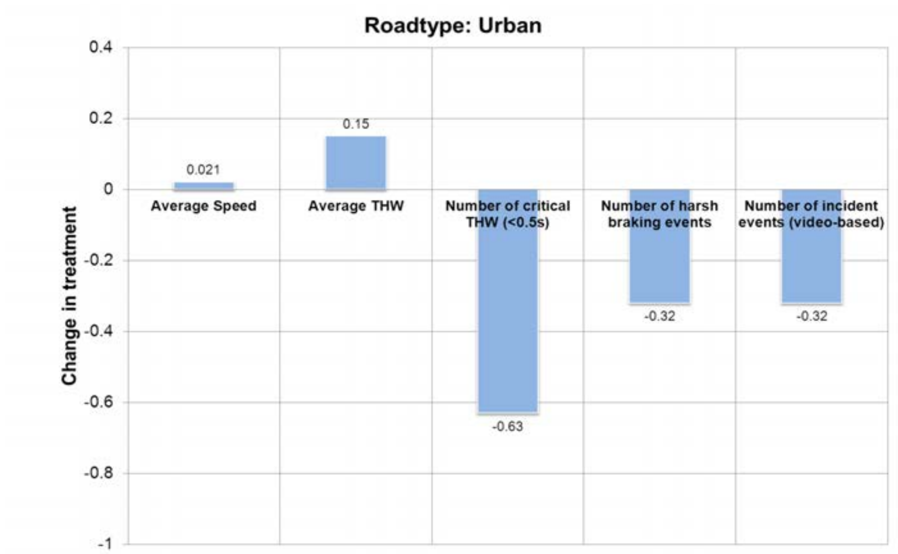

Figure 12: Overall benefit of ACC+FCW on urban roads (passenger cars).

There was no decrease in average speed (an indicator previously linked to increase in safety by Nilson, 1981), but the safety margins to the lead vehicle increased significantly when ACC+FCW was being used. Average time headway (THW) showed an overall increase of about 15%, and the frequency of critical THW's was reduced by 63% in urban areas, 81% on rural roads, and 73% on motorways. One possible contributing factor to the average THW increase is the fact that the selectable ACC time-headway settings can never be lower than the legally prescribed value, a limit that is not always respected in baseline driving.

Another way of assessing whether the safety margins actually increase in treatment is to look at braking behaviour. Essentially, if margins are greater, the need for more extreme braking manoeuvres should decrease. In principle, when drivers have more time to respond, the need for harsh braking is decreased. Following this, the evaluation of the number of harsh braking manoeuvres is also considered relevant to assess the safety benefit of the ACC+FCW. Results conform to this line of reasoning. For example, for motorway the reduction of these events is not quite as high as the one of critical time-headways, but one can say that two out of three harsh braking events occurring in the baseline were avoided by the use of the ACC+FCW bundle.

To make a prediction on an estimated benefit range for ACC+FCW, expert judgment was employed, based on a combination of the overall FOT results and previous knowledge from each VMC on the studied systems. The following procedure was adopted: as a low benefit boundary, the reduction in video-review based incidents (32%) was used for all road types. Although the hypothesis testing for these incidents was not statistically significant and as such only indicates a trend, we believe it serves as the best guideline we have for predicting a reduction of extremely risky situations, as it is the only indicator in the study where the full driving context can be taken into account when judging how serious, or near a crash, any particular situation is. For the upper bound, the reduction in the number of kinematic incidents was adopted where available, i.e., for motorways (81%). This incident type addresses a broader range of situations with where the precise level of risk involved is harder to assess, and thus leads to a less conservative reduction estimate. For urban and rural roads, the reduction in harsh braking events was used (rural: 45%, urban: 32%), since this indicator is the closest we have for these road types to the extreme kinematic conditions detected by the kinematic incident trigger.

In summary, it can be said that the combination of ACC and FCW can have a positive effect on safety-related measures based on the data gathered in the FOT. This positive effect can be attributed to changes in the distance behaviour while driving with active ACC and FCW. Due to the predefined settings of the ACC time-headway the number of (intended or unintended) close approaching manoeuvres is highly reduced and prevents therefore critical driving situations. If in addition the driving situation exceeds the braking capacities of the ACC because of a highly decelerating vehicle in front the presented warnings (by the ACC and the FCW) give the driver appropriate time to react on the driving situation.

In addition to safety impacts, WP6400 determined based on comparing directly measured fuel consumption and average speed in comparable baseline and treatment conditions changes in travel time and fuel savings. The implications made by selecting applicable mileage and the detailed methodology (e. g. difference between having and using ACC) are described in detail in D6.5. The results were taken into account for the cost-benefit analysis in chapter 4.

3.2.3 WP6400 results for LDW+IW & BLIS

The **LDW+IW** function was expected to support the driver in avoiding unintended lane departures, either due to distraction (LDW) or drowsiness (IW). Overall, the bundle was expected to have a positive effect on both comfort and safety. The comfort side was mainly assessed subjectively with questionnaires in D6.3, while the safety benefits are addressed here.

Based on the overall results for LDW+IW it can be concluded that some of the indicators point toward a potential increase in safety when drivers use LDW+IW. The mean steering wheel angle was slightly reduced and use of turn indicators increased, both of which may indicate improved lateral control. This concerns an interaction with other traffic participants. The interaction has positive implications for the other traffic participants, but no data was collected from unequipped vehicles. Also, results show that LDW issues warnings mainly when drivers are not looking at the road ahead. Hence, it may address potentially unsafe situations. The likelihood of experiencing a lateral crash relevant event also decreased when drivers used LDW+IW. However, that decrease was not statistically significant, mainly because the number of annotated events judged as relevant for LDW+IW was small. Crash relevant events and near crashes are rare events. A total of 5.5 MM was spent on reviewing over 1200 potential conflicts based on video and kinematic data. From this dataset, only 133 were judged to be truly relevant lateral events, and hence retained for the analysis.

We also investigated possible negative side effects of LDW+IW in terms of secondary task engagement, attention to forward roadway and drowsy trip frequency. Results showed some interesting effects related to LDW+IW in the first two measures. First, during normal driving, the likelihood of the driver using a nomadic device increased when drivers were using LDW+IW. However, during crash relevant events, no such increase was found. Many potential explanations for this exist and further investigation would be necessary to settle on anyone of those. However, at face value these results indicate that drivers seem capable of self-regulating nomadic device usage to situations that do not involve a potential increase in risk. This line of reasoning is supported by the fact that there was no difference in visual attention to the forward roadway during critical events in baseline and treatment.

Unfortunately, there is insufficient evidence to enable up-scaling of the safety impact of LDW+IW to EU-27 level. Since the difference in crash relevant events is not significant, there are only two indicators that show a significant difference between baseline and treatment (Mean Steering Wheel Angle and Turn Indicator Usage). Neither of these have a sufficiently strong connection to crash causation to suffice as a basis for up-scaling on their own. For example, lane keeping is not something that drivers optimize, i.e. they may "bounce" between lane markers rather than try to stay exactly in the center of the lane all the time. This makes the coupling between the average Mean Steering Wheel Angle and the risk of a lane departure (and hence a crash) weak. Furthermore, the decrease is small, i.e. it's approximately a tenth of a degree, where the typical range on all road types for this PI is 4-5 degrees.

The **BLIS** function was expected to support the driver in avoiding initiating lane changes when there is a vehicle in the adjacent lane, in particular when that vehicle cannot be seen through the regular rear view mirrors. Overall, the function was expected to have a positive effect on both comfort and safety. The comfort side was mainly assessed subjectively with the questionnaire data (see D6.3), while the safety benefits are addressed here.

In terms of the relative frequency of crash relevant events, very few BLIS relevant incidents could be identified in the data (< 10 events). Hence no significant differences between baseline and treatment could be identified.

The use of turn indicator decreased by, approximately, 10% when BLIS was in use. This is an interesting contrast to the LDW+IW findings, which indicate the opposite, i.e. a 10 % increase in turn indicator use when LDW+IW is in use. These results are not contradicting however, since the BLIS data studied was selected from the portions of treatment driving when LDW+IW was switched off. Rather, they seem to reflect a clear case of driver adaptation. When LDW+IW are active, drivers use the indicators more to avoid the warning sound that they otherwise get if they change lanes without signaling. When BLIS is active, the questionnaire data confirms that drivers trust the system not to give false negatives (i.e. not warn even though there is a vehicle in the blind spot). Hence the need to use the turn indicator is reduced, because drivers perceive that the really know that there is no other vehicle in the lane they are changing into.

In terms of predicting a safety impact of BLIS to a the regional/national or EU-27 level, there is unfortunately simply not enough solid results in the empirical data to base such an up-scaling on. No difference in crash relevant events could be identified, and the decrease in turn indicator usage alone is not a sufficient ground to base a prediction on crash involvement and injury outcome on.

3.2.4 WP6400 results for SRS (SL+CC)

SRS systems refer to two different systems with different purposes: SL is used to limit the vehicle speed on a voluntary basis, while CC is used to maintain a constant speed when driving conditions allow. Both SL and CC are mainly expected to have an effect on speed; therefore, models which attempt to quantify the relationship between instances of over speeding and accidents (Taylor et. al. 2000) were explored. The idea was to use these models as transfer functions when up scaling the potential benefit of SL and CC using speed-related indicators. However, we found that these models, which are based on measurements taken from select road locations rather than from continuous vehicle data, fail to capture several important aspects of the underlying safety mechanism. Among other things, they do not include traffic environment variables such as traffic density. Because of these limitations, a straightforward application of the models on the FOT data would lead to erratic results. For example, if a function mainly is used in low traffic densities—which is expected for CC— then an increase in average speed would not necessarily lead to an increase in average risk (which the models would predict), since risk is moderated also by traffic density.

Also, when it comes to over speeding events, the current dataset shows that the frequency of over speeding events goes down when drivers use SL (compared to baseline), but goes up when drivers use CC (compared to baseline). These opposite effects illustrate that drivers choose to use SL and CC under different traffic conditions, and also make it very difficult to interpret the effect of SRS as a whole.

Given these results and the limitations of the investigated models, our conclusion is that a trustworthy up scaling of SL/CC is not feasible; there are too many uncertainties for results of such an up scaling to be viewed as reliable. Different approaches for understanding the impact of SL/CC on accidents need to be further investigated in future work.

3.2.5 WP6400 results for Navigation systems

For the **navigation system**, it was observed that on urban roads driving is potentially safer if the system is activated. The positive effect on safe driving is reflected in positive changes in lane keeping behaviour, distance to the lead vehicle and hard braking events. Nevertheless, since safety benefits of navigation systems are not reported in the literature and also because no experiment is known that investigates possible mechanisms by which a navigation system might support safe driving, it is difficult to judge whether and under which assumptions the measured effects can be generalized. Because the safety mechanism for the navigation systems is not known, any potential safety benefit caused by navigation systems need further investigation. As a consequence, up-scaling of the measured effects to EU27 is not applicable.

Regarding traffic efficiency (D6.5), the FOT showed that there are large differences between the two tested navigations systems. Predicting the effect of other navigation systems available on EU level would introduce a great deal of uncertainty because of assumptions to be introduced. A second reason that makes it difficult to scale to an EU level effect is that there are differences between the FOT network (Germany) and the total European network, such as differences in density and differences in possibilities for route change. Finally, the scaling up to EU level requires that the current market penetration and usage rate is known. For navigation systems this is information is not available on EU level. For these reasons, the effects found in the FOT are not scaled to EU level.

Finally, scaling up to EU level requires that the current market penetration and usage rate is known to single out additional impacts in order to compare with and without cases (see SRS). For navigation systems this information is not available on EU level and developing models to solve this issue are not within the scope of euroFOT. For these reasons, the effects found in the FOT are not scaled up to EU level.

3.3 Scope selection for euroFOT

As a result from chapter 3, which is dedicated to impact analysis and scope definition, the following conclusions regarding the scope of the analysis can be summarised:

- The socio-economic benefit analysis of driver assistance system as in eIMPACT was intended to analyse functions which can be seen as independently equipped to vehicles ("optional features") with additional functionality benefits.
- Since during the trial no functional de-bundling was carried out, ACC+FCW and LDW+IW were treated as bundles in terms of treating them as one system with shared benefits and costs.
- For navigation systems (Safe HMI) and simple control functions (SRS) which impacts depend on the selection of driving periods for which the system is used, determining the baseline – in terms of comparable mileage – is more complex. In addition to monetising the impacts, re-modelling a virtual "without state" of already deployed systems based on the results would be necessary.
- Hence, the most applicable scope for an FOT-based assessment covers driver assistance systems which consist of additional components, offer additional functionality that is a technological add-on to what the driver is capable of, and are marketed as optional features. Thereby, the CBA models on a large scale the meaning of FOT systems and identified impacts for society. The difference between baseline and treatment on FOT level matches for these systems with the socioeconomic state without and with the system.
- The initial assessment framework (EU-27 up scaling, market model, define links to impact assessment) according to FESTA and eIMPACT was set up for functional bundles ACC+FCW and LDW+IW, and for the functions CSW and BLIS, since these features match the scope. LDW+IW, BLIS and CSW did not provide the required results in terms of EU-wide impacts that would allow a cost-benefit assessment.
- Due to the limited availability of results, no cost-benefit assessment based only on direct fuel or time savings was conducted for SRS and SafeHMI, since up-scaling these results would require excessive knowledge on EU-wide driver behaviour and network characteristics.

Finally, ACC+FCW for both cars and trucks results from WP6400 may be taken into account to determine the socio-economic impacts of these systems on European level in a cost-benefit analysis.

4 Cost-benefit analysis of selected functions

The socioeconomic cost-benefit analysis as developed in FESTA and described in detail in chapter 2 is carried out for ACC+FCW, separated for cars and trucks. In eIMPACT, there was one integrated assessment for the functions in both vehicle types, but given the experimental setup (e. g. different fleets, different assessment approaches based on the same tool set), the character of euroFOT is reflected best by treating them separately.

Table 11 shows in summary the key outcomes in terms of safety from D6.4 which are used for determining the benefits of these systems. Positive numbers indicate an estimated decrease in risk when ACC+ FCW is in use.

Table 11: Summary of the impact of ACC+FCW, based on the assumption that the selected safety-related measures are good indicators of how the accident population would change if all vehicles were equipped with ACC+FCW (euroFOT D6.4)

Vehicle type	Road type	Usage (portion of the total driving in treatment)	Changes between baseline and treatment in safety related measures in the FOT data.	Potential reduction in the target crash population (rear end crashes)	Potential reduction in the injury accident population per road type in EU-27
Passenger Cars	Motorway	51%	32 - 82%	16 - 42%	2.2 - 5.8%
Passenger Cars	Rural	31%	32 - 45%	10 - 14%	0.47 - 0.65%
Passenger Cars	Urban	19%	32%	6%	0.14%
Trucks	Motorway	42%	14 - 36%	6 - 15%	0.2 - 0.6%

As described in chapter 3, there are various kinds of scope of assessment, each valid within its assessment framework. Nevertheless, the amount of addressable benefits (and hence, the cost-benefit-ratio) highly relies on how to determine the safety impact. Table 12 (sources described in more detail in D6.4) shows that the results of the euroF.O.T functions are in line with comparable assessment studies.

Table 12: Impact of different functions in the literature (euroFOT D6.4)

Source	Vehicle type	Reduction in crashes (unless otherwise specified, reduction applies to target crash population)
	FCW	
NHTSA, 2001, cited in Bayly M. et al., 2007	Passenger cars	48%
Regan, et al., 2002, cited in Bayly M. et al., 2007	Passenger cars	7%
Kullgren, et al. 2005, cited in Bayly M. et al., 2007	Heavy vehicles	57%
Fitch G. et a., 2008	Heavy vehicles	21%
	ACC	
Elvik, **et al., 1997, cited in OECD, 2003**	Motorized vehicles	5.9% (reduction in total number of all crash types)
Abele, et al., 2005, cited in Bayly M. et al., 2007	Passenger cars	25%
	ACC+FCW	
Najm W. Ference, 2006	Passenger cars	3% – 26%
	ACC+FCW+ESP	
Hautzinger et. al., 2012	Heavy vehicles	34% (reduction of general accident risk measured in accidents per 1 million kilometres)

4.1 Cost-benefit analysis for ACC+FCW in cars

4.1.1 Benefits

The following restrictions that would need actually to be taken into account to get to the "true" benefits are not covered by the applied filtering and modeling of target groups and not considered when determining safety impacts with this approach.

- The assumption that all vehicles were equipped implies that all relevant accidents could be addressed by the system. For penetration rates less than 100% it is assumed that the same proportion of relevant accidents and casualties can be addressed (e.g. 50% of the relevant accidents in case of 50% share of fleet mileage of cars equipped with the system).
- The relevant shares of involved individuals and accidents were estimated based national data from a limited set of countries, which may not be necessarily reflecting the real accident situation in the other EU countries (see chapter 2.6).
- There was no effectiveness of the functions observed or proven in euroFOT in terms of the system leading to any direct avoidance of accidents or injuries.

- When a function addresses accidents in which it is designed to be active, it remains subject to further advanced modelling or simulation whether injury avoidance or mitigation effects can be derived in that accident target group.
- Usage of the system as it is intended to assist the driver is not necessarily reflected by the usage rate in terms of kilometres driven with the system on. On European level, customer needs might show different usage/user behaviour with the functions. This can also be subject to changes or behavioural adaptation over time.

In the context of the straightforward approach for calculating the safety impacts multiplying of the safety benefit in terms of a percentage change of injuries and fatalities respectively accidents (see Table 13) with the EU-27 target group numbers for cars (see Table 6) lead to the reduced total number of casualties and accidents as shown in Table 14). For further explanations on the safety impact calculation see chapter 5 of deliverable D6.4.

Table 13: The estimated safety impact of ACC+FCW for cars based on EU-27 accident data. The percentages represent the proportion of the total crash population that ACC+FCW in cars might address, given 100% deployment in the vehicle fleet

	Motorway		Rural		Urban	
EU-27 target group	low	high	low	high	low	high
Fatally inj. car occ.	1.68%	4.25%	0.09%	0.13%	0.10%	0.10%
Injured car occ	2.54%	6.42%	0.52%	0.73%	0.36%	0.36%
Fatalities (all)	1.16%	2.95%	0.06%	0.08%	0.02%	0.02%
Injuries (all)	2.24%	5.66%	0.42%	0.59%	0.16%	0.16%
Injury accidents (all)	2.24%	5.68%	0.47%	0.65%	0.14%	0.14%

Table 14: EU-27 benefit of ACC+FCW if all cars equipped & used as in euroFOT.

Lower Bound Safety Impacts of FCW/ACC (Cars)

	Motorway	Rural	Urban	all
Fatalities	26	12	4	42
Injured	2029	1904	1677	5610
Acc. Fat.	26	12	4	42
Acc. Inj.	1334	1500	1146	3981

Upper Bound Safety Impacts of FCW/ACC (cars)

	Motorway	Rural	Urban	all
Fatalities	67	17	4	88
Injured	5200	2678	1677	9555
Acc. Fat.	67	17	4	88
Acc. Inj.	3419	2110	1146	6675

***Note: No crash reduction or injury mitigation observed in euroFOT; estimated values according to methodology provided by FESTA and D6.2 in line with literature**

The **safety impacts** of ACC+FCW for cars were estimated in WP6400 in terms of various parameters, both with lower and upper bound of the FOT-level based "benefit range":

- Number of addressed road fatalities in EU-27
- Number of addressed injured road user in EU-27
- Number of addressed injury accidents in EU-27.

The relevant impact in terms of numbers is displayed in Table 14. The safety impacts range between 42 and 88 fatalities per annum on EU-27 level. In terms of avoided injuries the impact approximately ranges between 4,000 and 10,000 injuries. It should be recalled that these numbers are valid for a 100% penetration rate, i.e. every car would be equipped with ACC+FCW. Taking a lower, more realistic penetration rate for the near future into account (10%) the number of avoided fatalities and injuries ranges between 6 and 12 respectively 762 and 1,290. The number of avoidable accidents with a given severity equals or is somewhat lower than the corresponding number of casualties because in one accident multiple occupants can be involved.

In addition to safety, ACC+FCW was analysed in euroFOT in order to determine the impact on traffic efficiency **fuel efficiency benefits** or **time savings**. Related to the safety impacts, indirect traffic impacts were also considered.

- In D6.5, based on the evaluation of the results on FOT level, the impact on fuel consumption on EU-27 level was estimated. To see the potential of the ACC in saving fuel it is assumed for scaling up that all vehicles in the European fleet are equipped with ACC. Since no data on kilometres driven with active ACC is available on EU-27 level the km-based usage rate is deduced from the FOT data. The effects are calculated for driving on motorways based on statistical data on mileage in the EU-27 in 2010. In the EU-27 countries 694.34 billion kilometres per year were driven on motorway with passenger cars and 40.26 billion kilometres with trucks.
- Since the cost-benefit analysis also assumes different penetration rates of the systems ranging from 5% to 100% (5%, 10%, 25%, 50%, 100%). This also implies a non-linear relationship between market penetration and the share of driven fleet mileage. Usually, new cars have a higher mileage than their respective share of the fleet penetration rate. For instance, a fleet penetration rate of 10% equipped cars equals a driven mileage share of approximately 14%.
- As mentioned before the system was evaluated in different geographic regions which cause the results to vary within a certain range. The usage rate was defined by the ratio of the sum of kilometres driven with active ACC in both geographic regions and the sum of all kilometres driving within the treatment phase. In sum, about 50% of the kilometres driven with passenger cars on the motorway were covered with active ACC (during the FOT). In combination of the usage rate and the reduction in fuel consumption when driving with ACC fuel savings of 1.05% could be achieved in the European passenger car fleet. Assuming an average fuel consumption of 7.26 l/100km (as found in the FOT data) this would sum up to absolute savings of 488 million litres fuel per year for a full penetration scenario and 66 million for a 10% equipment rate.

From the fuel saving potential it is also possible to derive the **savings in CO_2 emissions**. The CO_2 emissions are calculated based on the average conversion factor for petrol and diesel engines (petrol: 2.32 kg CO_2/l, diesel: 2.62 kg CO_2/l). Assuming 61.8% petrol- and 35.3% diesel-powered passenger cars in the European vehicle fleet the found fuel savings represent savings in CO_2 emissions of about 1.2 million tons (100% penetration rate) respectively 160 thousand tons (10% penetration rate) for passenger cars.

Regarding the **time savings**, the slight reduction of average speed would lead on a larger scale (considering the millions of hours spent in traffic) to additional time loss, since trips get longer. WP6500 calculated based on the euroFOT values regarding speed, usage, trip length and mileage shares the economic value of these changes to get to an estimate of the amount of these changes. Assuming a 0.2% increase of travel time for all trips equally, overall economic effects sum up to 5 million hours more spent in traffic and its economic equivalent is estimated to 100 million Euro for the full penetration scenario. Since effects on the traffic efficiency occur only if a certain share of cars is equipped with the system it is assumed that changes of the travel time will result from a penetration rate of 25% and higher.

Table 15 shows the impacts for a full penetration rate scenario which will be used for the cost-benefit analysis. The impacts for safety (reduced fatalities and injuries, accidents) are displayed for two different scenarios (lower and upper bound).

Table 15: Impacts introduced to CBA (Cars) assuming full penetration (own calculations).

Impacts introduced to CBA			
		lower bound (impacts)	**upper bound (impacts)**
Safety impact EU-27	fatalities	42	88
	injured	5,610	9,555
Reduced number of accidents	fatal accidents	42	88
	injury accidents	3,981	6,675
Time (mio hours)	working	-1.50	-1.50
	non-working	-3.50	-3.50
	commercial		
Fuel reduction (mio l)	mio liter fuel	488	488
Emissions reduction	mio tons CO_2	1.20	1.20

Taking into account a more realistic penetration rate which can be reached in the near future the above displayed values have been adjusted to a basic penetration rate of 10% equipped cars accordingly:

Table 16: Impacts introduced to CBA (Cars) assuming 10% penetration (own calculations).

Impacts introduced to CBA			
		lower bound (impacts)	**upper bound (impacts)**
Safety impact EU-27	fatalities	6	12
	injured	762	1,290
Reduced number of accidents	fatal accidents	6	12
	injury accidents	541	901
Time (mio hours)	working	-	-
	non-working	-	-
	commercial	-	-
Fuel reduction (mio l)	mio liter fuel	66	66
Emissions reduction	mio tons CO_2	0.16	0.16

For the calculation of the socio-economic benefit the total impact numbers in terms of safety, traffic and environmental effects have to be monetised. The monetary values used for the impact appraisal are displayed in Table 17 and will be used for both scenarios and penetration rates.

Table 17: Cost unit rates or the impact appraisal

Cost unit rates for the impact appraisal	
€/fatality	1,600,000
€/injured	70,000
€/fatal accident	15,500
€/injury accident	5,000
€/h working	20
€/h non-working	20
€/h commercial	30
€/liter fuel	0.75
€/tons CO_2	70

The benefits of ACC+FCW for cars lead to accident cost savings of nearly 460 million Euro in the lower bound scenario and of 810 million Euro in the upper bound scenario respectively (100% penetration rate). For the 10% penetration rate the accident cost savings range between 62 million Euro and 109 million Euro. Additionally, a decrease in accident related congestions due to lower accident numbers result in a benefit of 20.5/34.5 million Euro (100%) respectively 2.8/4.7 million Euro (10%). Due to longer trips in the full penetration scenario the time savings are negative and sum up to nearly 100 million Euro. A more economically driving performance of cars equipped with ACC+FCW results in a total monetary benefit of 450 million Euro (100%) respectively 61 million Euro (10%) for fuel and emission savings. In total the use of ACC+FCW in cars can save nearly 830/1,194 million Euro (100%) respectively 138/187 million Euro (10%) on EU-27 level. Table 18 and Table 19 give an overview of the different benefit categories.

Table 18: Benefit synopsis in Euro for ACC+FCW in cars for full penetration (own calculation)

Benefit synopsis in €			
		lower bound (impacts)	**upper bound (impacts)**
Safety benefit	fatal	67,200,000	140,800,000
	injury	392,700,000	668,850,000
Indirect traffic effects	fatal	651,000	1,364,000
	injury	19,905,000	33,375,000
Traffic efficiency benefit		-29,991,515 -69,980,202	-29,991,515 -69,980,202
Fuel savings benefit		366,000,000	366,000,000
Emission savings benefit		84,000,000	84,000,000
Benefit of ACC+FCW		**830,484,283**	**1,194,417,283**

Table 19: Benefit synopsis in Euro for ACC+FCW in cars for 10% penetration (own calculation)

Benefit synopsis in €			
		lower bound (impacts)	**upper bound (impacts)**
Safety benefit	fatal	9,131,195	19,132,027
	injury	53,360,420	90,275,177
Indirect traffic effects	fatal	88,458	185,342
	injury	2,704,709	4,507,169
Traffic efficiency benefit		-	-
		-	-
		-	-
Fuel savings benefit		49,732,400	49,732,400
Emission savings benefit		11,413,994	11,413,994
Benefit of ACC+FCW		**126,431,176**	**175,246,108**

4.1.2 Costs of ACC+FCW in cars

For ACC+FCW in cars, the FESTA rule was used to come from market prices to system cost. ACC market prices range from 560 to 1.980 Euro, including VAT. For the base case the most cost-efficient system will be taken into account. Using the eIMPACT/FESTA approach of applying the Factor 3 rule a system cost price of 190 Euro will be assumed. This cost price has to be further adjusted by taking into account economies of scale (see chapter 2.5) for the different penetration rate scenarios (medium scenario). Finally, the benefit-cost-ratios can be modelled with cost of 112 € per unit (100%) respectively 166 € per unit (10%).

In line with ACEA statistics for the years 2005 - 2011, the EU-27 number of new passenger car registrations was averaged to 14.5 million. A linear regression based on the recently low figures would lead to lower estimates – but taking into account the average car age [ACEA 2011], assuming a lower figure would lead to a smaller fleet and hence, to lower mileage and accidents.

In total the costs for the equipment of the whole car fleet in the EU sum up to nearly 1.6 billion Euro (full penetration) respectively 241 million Euro (10% penetration).

Table 20: Costs of ACC+FCW for cars for full penetration

Costs of ACC+FCW		
Vehicles to be equipped	mio new reg/year	14.50
Single unit cost	€/per system	112
Total costs of ACC+FCW	in €	**1,624,000,000**

Table 21: Costs of ACC+FCW for cars for 10% penetration

Costs of ACC+FCW		
Vehicles to be equipped	mio new reg/year	1.45
Single unit cost	€/per system	166
Total costs of ACC+FCW	in €	**240,700,000**

4.1.3 Benefit-cost ratio of ACC+FCW

In a final step, the benefits have to be confronted with the costs. The results are presented in the following tables. To obtain the possible range of benefit-cost ratios, the benefits from the lower bound scenario respectively upper bound scenario are compared to the total equipment costs of the whole car fleet in EU-27. The optimistic view leads to a benefit-cost-ratio in the full penetration scenario of nearly 0.74, which means that every spent Euro for ACC+FCW results in a benefit of 0.74 Euro for society. The lower bound scenario shows an even lesser profitability in the base case from a society point of view with a BCR of 0.51. For the 10% penetration scenario the BCR ranges between 0.53 and 0.73.

Table 22: Benefit-cost ratios of ACC+FCW for cars for full penetration

	lower bound (impacts)	upper bound (impacts)
Benefit of ACC+FCW	830,484,283	1,194,417,283
System cost (FESTA rule)	1,624,000,000	1,624,000,000
Benefit cost ratio	**0.51**	**0.74**

Table 23: Benefit-cost ratios of ACC+FCW for cars for 10% penetration

	lower bound (impacts)	upper bound (impacts)
Benefit of ACC+FCW	126,431,176	175,246,108
System cost (FESTA rule)	240,700,000	240,700,000
Benefit cost ratio	**0.53**	**0.73**

It can be concluded that the system is either too expensive or users on average drive too less km for pay off of the “investment”. Nevertheless, changing of some input values such as including underreporting of injuries and the use of higher cost unit rates can triple the benefit-cost-ratios (see sensitivity analysis in chapter 5).

4.1.4 Benefit-cost ratio matrix of ACC+FCW

The following matrix shows the results of the variation of two key calculation parameters. Table 24 displays BCRs for different levels of economies of scale (limited, medium, large, see chapter 2.5) as well as for various equipment rates of vehicles. Thereby, also the optimistic and pessimistic safety effects are taken into account.

As the matrix shows, a beneficial BCR (>1) is only reached if large economies of scale and a penetration rate of at least 50% as well as a high safety potential are assumed. The decreasing BCRs for the limited economies of scale scenario result from the effect that the lower percentage of cars has a higher share of mileage in comparison to the average value in a full penetration scenario. Very new cars drive more than their corresponding share of fleet. The difference between share of mileage and the share of fleet decreases for penetration rate scenarios higher than 10%. Therefore until a 10% penetration rate the benefits increase more than the equipment cost of the corresponding cars.

Table 24: Benefit-cost ratios of ACC+FCW for different levels of economies of scale and penetration rates

Penetration rate (in%)	BCR Low Limited economies of scale (5%)	BCR Low Medium economies of scale (10%)	BCR Low Large economies of scale (20%)
5	0.48	0.48	0.48
10	0.50	0.53	0.59
25	0.46	0.51	0.66
50	0.45	0.53	0.78
75	0.42	0.53	0.86
100	0.39	0.51	0.92
Penetration rate (in%)	**BCR High Limited economies of scale (5%)**	**BCR High Medium economies of scale (10%)**	**BCR High Large economies of scale (20%)**
5	0.67	0.67	0.67
10	0.69	0.73	0.82
25	0.66	0.74	0.95
50	0.64	0.76	1.11
75	0.60	0.75	1.23
100	0.56	0.74	1.32

4.2 Cost-benefit analysis for ACC+FCW in trucks

4.2.1 Benefits

The following restrictions that would need actually to be t aken into account to get to the "true" benefits are not covered by the applied filtering and modeling of target groups and not considered when determining safety impacts with this approach.

- The assumption that all vehicles were equipped implies that all relevant accidents could be addressed by the system.
- The relevant shares of involved individuals and accidents were estimated based national data from a limited set of countries, which may not be necessarily reflecting the real accident situation in the other EU countries (see chapter 2.6).
- There was no effectiveness of the functions observed or proven in euroFOT in terms of the system leading to any direct avoidance of accidents or injuries.
- When a function addresses accidents in which it is designed to be active, it remains subject to further advanced modelling or simulation whether injury avoidance or mitigation effects can be derived in that accident target group.
- Usage of the system as it is intended to assist the driver is not necessarily reflected by the usage rate in terms of kilometres driven with the system on. On European level, customer needs might show different usage/user behaviour with the functions. This can also be subject to changes or behavioural adaptation over time.

In the context of the straightforward approach for calculating the safety impacts multiplying of the safety benefit in terms of a percentage change of injuries and fatalities respectively accidents (see Table 25) with the EU-27 target group numbers for trucks (see Table 8) lead to the reduced total number of casualties and accidents as shown in Table 26). For further explanations on the safety impact calculation see chapter 5 of deliverable D6.4. Since the equipment of trucks with an automatic emergency braking system will be mandatory for every truck over 3.5 t from 2015 on in the EU, the calculation for trucks was conducted only for a full penetration scenario (EC 2009).

Table 25: The estimated safety impact of ACC+FCW for trucks based on EU-27 accident data. The percentages represent the proportion of the total crash population that ACC+FCW in trucks might positively address, given 100% deployment in the vehicle fleet

EU-27 target group	Motorway low	Motorway high
Fatalities (all)	0.79%	2.02%
Injuries (all)	0.42%	1.08%
Injury accidents (all)	0.51%	1.31%

Table 26: EU-27 benefit of ACC+FCW if all trucks equipped & used as in euroFOT.

Lower Bound Safety Impacts of ACC+FCW (trucks)

	Motorway
Fatalities	7
Injured	160
Acc. Fat.	7
Acc. Inj.	123

Upper Bound Safety Impacts of ACC+FCW (trucks)

	Motorway
Fatalities	19
Injured	410
Acc. Fat.	19
Acc. Inj.	316

***Note: No crash reduction or injury mitigation observed in euroFOT; estimated values according to methodology provided by FESTA and D6.2 in line with literature**

The **safety impacts** of ACC+FCW for trucks were estimated in WP6400 [D6.4] in terms of various parameters, both for the lower and upper bound of the FOT-level based “benefit range”:

- Number of addressed road fatalities in EU-27
- Number of addressed injured road user in EU-27
- Number of addressed injury accidents in EU-27.

The relevant impact in terms of numbers is displayed in Table 26. The safety impacts range between 7 and 19 fatalities per annum on EU-27 level. In terms of avoided injuries the impact approximately ranges between 160 and 410 injuries. It should be recalled that these numbers are valid for a 100% penetration rate, i.e. every truck would be equipped with ACC+FCW. The number of avoidable accidents with a given severity equals or is somewhat lower than the corresponding number of casualties because in one accident multiple occupants can be involved.

In addition to safety, ACC+FCW was analysed in euroFOT in order to determine the impact on traffic efficiency **fuel efficiency benefits** or **time savings**. Related to the safety impacts, indirect traffic impacts were also considered.

- In D6.5, based on the evaluation of the results on FOT level, the impact on fuel consumption on EU-27 level was estimated. To see the potential of the ACC in saving fuel it is assumed for scaling up that all vehicles in the European fleet are equipped with ACC. Since no data on kilometres driven with active ACC is available on EU-27 level the km-based usage rate is deduced from the FOT data. The effects are calculated for driving on motorways based on statistical data on mileage in the EU-27 in 2010. In the EU-27 countries 694.34 billion kilometres per year were driven on motorways with passenger cars and 40.26 billion kilometres with trucks.
- As mentioned before the system was evaluated in different geographic regions which cause the results to vary within a certain range. The usage rate was defined by the ratio of the sum of kilometres driven with active ACC in both geographic regions and the sum of all kilometres driving within the treatment phase. For trucks a usage rate of 57% was recorded during the FOT. This results together with a fuel reduction of 1.85% in phases of active ACC in an overall benefit of 1.05%. Assuming an average fuel consumption of 24.65 l/100km (as found in the FOT) one can calculate the total annual fuel savings for driving on motorways with ACC equipped trucks to be 95.8 million litres.

From the fuel saving potential it is also possible to derive the **savings in CO_2 emission**s. The CO_2 emissions are calculated based on the average conversion factor for petrol and diesel engines (petrol: 2.32 kg CO_2/l, diesel: 2.62 kg CO_2/l). With about 98% diesel-powered trucks in the European fleet [ACEA 2011] the fuel savings represent 220 thousand tons less CO_2 per year for trucks.

Regarding the **time savings**, the slight reduction of average speed would lead on a larger scale (considering the millions of hours spent in traffic) to an additional time loss, since trips get longer. WP6500 calculated based on the euroFOT values regarding speed, usage, trip length and mileage shares the economic value of these changes to get to an estimate of the amount of these changes. Overall economic effects sum up to 70 Thousand hours more spent in traffic and its economic equivalent is estimated to 2 million Euro.

Table 27 shows the impacts which will be used for the cost-benefit analysis. The impacts for safety (reduced fatalities and injuries, accidents) are displayed for two different scenarios (lower and upper bound).

Table 27: Impacts introduced to CBA (Trucks) for full penetration (own calculations).

Impacts introduced to CBA			
		lower bound (impacts)	**upper bound (impacts)**
Safety impact EU-27	fatalities	7	19
	injured	160	410
Reduced number of accidents	fatal accidents	7	19
	injury accidents	123	316
Time (mio hours)	working		
	non-working		
	commercial	-0.07	-0.07
Fuel reduction (mio l)	mio liter fuel	95.8	95.8
Emissions reduction	mio tons CO_2	0.22	0.22

For calculation of the socio-economic benefit the total impact numbers in terms of safety, traffic and environmental effects have to be monetised. The monetary values used for the impact appraisal are displayed in Table 28 and will be used for both scenarios.

Table 28: Cost unit rates or the impact appraisal

Cost unit rates for the impact appraisal	
€/fatality	1,600,000
€/injured	70,000
€/fatal accident	15,500
€/injury accident	5,000
€/h working	20
€/h non-working	20
€/h commercial	30
€/liter fuel	0.75
€/tons CO_2	70

The benefits of ACC+FCW for trucks lead to accident cost savings of nearly 22 million Euro in the lower bound scenario and of 59 million Euro in the upper bound scenario respectively. Additionally, a decrease in accident related congestions due to lower accident numbers result in a benefit of 720 Thousand respectively 1.9 million Euro. Due to longer trips the time savings are negative and sum up to nearly 2 million Euro for both scenarios. A more economically driving performance of cars equipped with ACC+FCW results in a total monetary benefit of 87.5 million Euro for fuel and emission savings. In total the use of ACC+FCW in trucks can save nearly 108 respectively 146 million Euro on EU-27 level. Table 29 gives an overview of the different benefit categories.

Table 29: Benefit synopsis in Euro for ACC+FCW in trucks for full penetration (own calculation)

Benefit synopsis in €			
		lower bound (impacts)	upper bound (impacts)
Safety benefit	fatal	11,200,000	30,400,000
	injury	11,200,000	28,700,000
Indirect traffic effects	fatal	108,500	294,500
	injury	615,000	1,580,000
Traffic efficiency benefit		0	0
		0	0
		-1,960,557	-1,960,557
Fuel savings benefit		71,850,000	71,850,000
Emission savings benefit		15,540,000	15,540,000
Benefit of ACC+FCW		**108,552,943**	**146,403,943**

4.2.2 Cost for ACC+FCW in trucks

It was defined in chapter 2.5 that the estimation of the manufacturing costs / cost price for an ACC+FCW system for cars will also be used for the cost-benefit analyses of trucks. Therefore, the FESTA rule was used to come from market prices to system cost. ACC market prices range from 560 to 1.980 Euro, including VAT. For the base case the most cost-efficient system will be taken into account. Using the eIMPACT/FESTA approach of applying the Factor 3 rule a system cost price of approximately 190 Euro will be assumed. This cost price has to be further adjusted by taking economies of scale (medium case) into account. Finally, the benefit-cost-ratios can be modelled with net cost of 112 € per unit for a full penetration scenario.

In line with ACEA statistics for the years 2005 - 2011, the EU-27 number of new truck registrations was averaged to 250 Thousand vehicles. In total the costs for the equipment of the whole truck fleet in the EU sum up to nearly 28 million Euro.

Table 30: Costs of ACC+FCW for trucks for full penetration

Costs of ACC+FCW			
Vehicles to be equipped	mio new reg/year		0.25
Single unit cost	€/per system		112
Total costs of ACC+FCW	in €		**28,000,000**

4.2.3 Benefit-cost ratio of ACC+FCW trucks

Finally, the benefits of trucks with ACC+FCW have to be confronted with the equipment costs. The results are presented in the following table. To obtain the possible range of benefit-cost ratios, the benefits from the lower bound scenario respectively upper bound scenario are compared to the total equipment costs of the whole truck fleet in EU-27. The optimistic view leads to a benefit-cost-ratio of nearly 5.23, which means that every spent Euro for ACC+FCW results in a benefit of 5.23 Euro for society. The lower bound scenario shows a lesser profitability in the base case from a society point of view with a BCR of 3.88. Nevertheless, the equipment and use of ACC+FCW in trucks is justified, because the resource savings exceed the cost. This means that ACC+FCW would even under pessimistic assumptions and hypotheses contribute to the welfare of EU-27.

Table 31: Benefit-cost ratios of ACC+FCW for trucks for full penetration

	lower bound (impacts)	**upper bound (impacts)**
Benefit of ACC+FCW	108,552,943	146,403,943
System cost (FESTA rule)	28,000,000	28,000,000
Benefit cost ratio	**3.88**	**5.23**

5 Sensitivity Analysis

This chapter intends to provide a broader picture and interpretation of the benefit-cost results as displayed in chapter 4. The sensitivity of results is addressed at three different levels, starting from parameter changes of the calculation model, then enlarging the model to incorporate further impacts such as property damage only (PDO) costs and finally broaden the perspective to wider economic impacts such as growth and employment. In doing so, it becomes obvious that at later stages of this chapter, only references to the nature of potential impacts can be provided and the statements do not longer base on findings and measurements from the field test itself. It should be noted that these sections are embedding euroFOT in a more general and broader context.

5.1 Sensitivity of results to parameter changes

The sensitivity of the results (benefits, costs, benefit-cost ratio) is tested for several changes of parameters which serve as input to the calculation. The general underlying question is hence: "What happens to the results if parameter "xy" is changed"? The assumptions for parameter variation are "borrowed" from database reports [Derriks, Mak 2007] and impact assessment studies such as eIMPACT, HEATCO and the AEBS study [Baum et al. 2008, Bickel et al. 2005, Grover et al. 2008].

The sensitivity tests comprise the following set of parameter variations (see Figure 13):

- What if the safety impact will be higher because of underreporting of injury numbers?
- What if the safety impact will be appraised with different, i.e. higher, cost-unit rates?
- What if the minor change in traffic conditions is not taken into account?
- What if all variations are considered together?

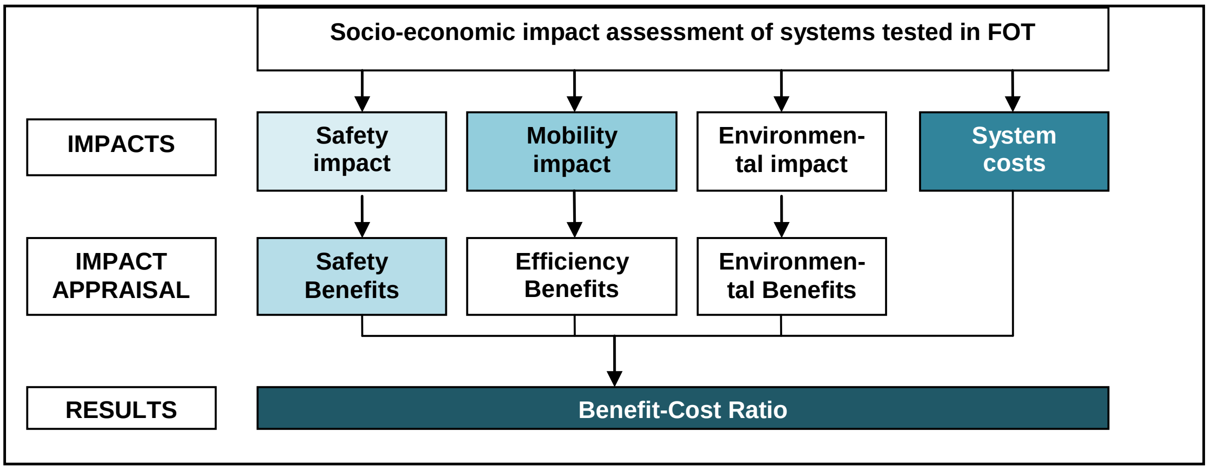

Figure 13: Parameter changes introduced to sensitivity tests

The impact of the parameter variations is later displayed graphically for each test. The impact on the benefit-cost ratio is finally displayed for all cases in a summary table.

It should be further noted that the sensitivity test are performed for the benefits and costs of ACC+FCW for cars. The results for Heavy Goods Vehicles have already indicated a high profitability from society point of view so that there is no further need for sensitivity analysis in this area. Furthermore, only the "full penetration case" is tested on sensitivity to parameter changes regarding impact appraisal. This scenario is in line with the WP6400 reports, which did not identify considerable sensitivity to parameter changes on physical impact level.

5.1.1 Underreporting of injuries

The first sensitivity test assumes that accident numbers and related casualties are too low due to underreporting:

- The problem of underreporting may have various sources in the process chain how accidents are commonly registered [Derriks Mak 2007, Figure 14].
- Recent German research [Kranz 2010] has revealed that approximately 20% of the accidents with slight injuries registered in insurance files are not recorded by the police whereas for fatalities and severe injuries the figures match almost exactly. The corresponding rate for Property Damage Only (PDO) accidents amounts to nearly 100%.
- HEATCO [Bickel et al. 2005] recommends EU-level correction factors of 1.02 for fatalities, 1.50 for severe injuries, 3.00 for slight injuries and 6.00 for Property Damage Only (PDO) accidents.

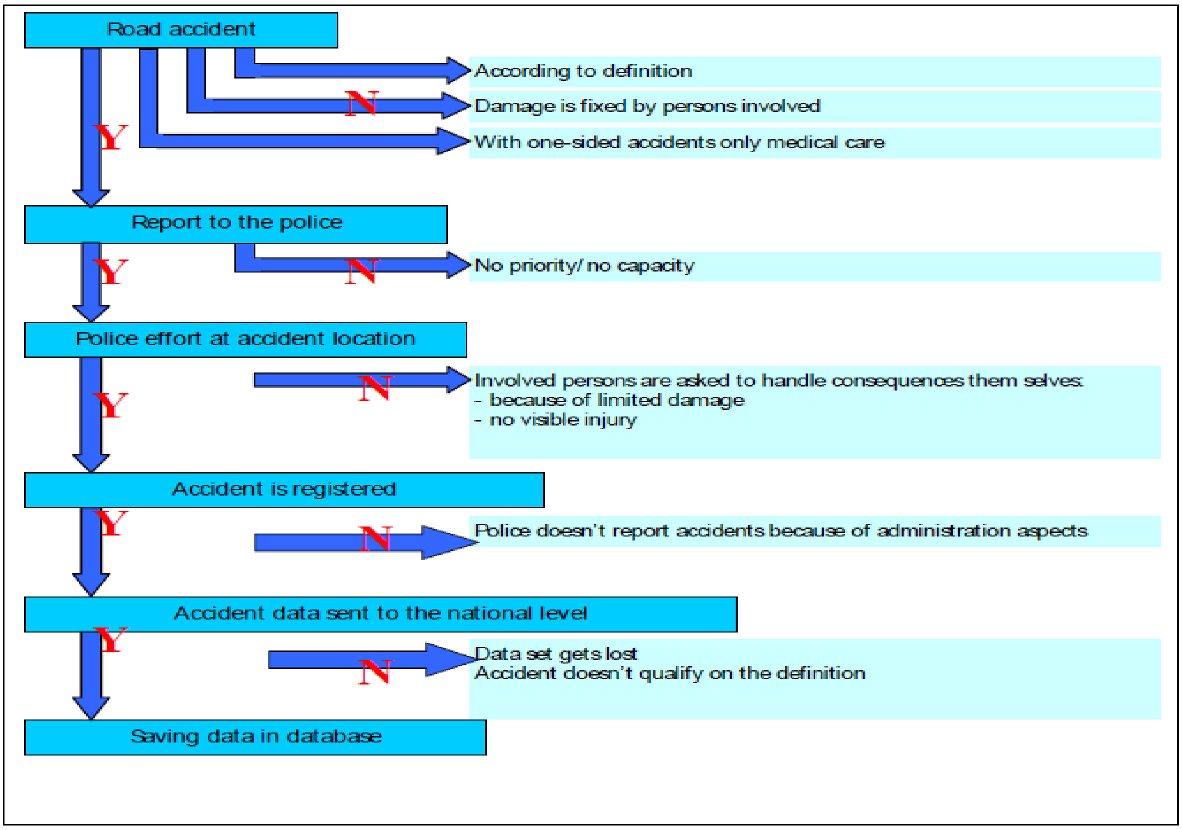

Figure 14: Registration process of accidents and possible sources of underreporting

Based on these empirical findings [Derriks Mak 2007, Kranz 2010, Bickel et al. 2005] we assume that injury numbers are 80% higher than reported. As a consequence, this would affect the safety impact via the size of the Likely Target Group. Because every avoided accident and injury is also accompanied with avoided accident caused congestion there is also a minor impact on indirect traffic impacts.

The impact of this parametric change is displayed in Figure 15. The safety benefits (lower bound – upper bound) would grow by the amount of 315 to 530 Million EUR. The total safety benefits would then sum up to a range (lower bound – upper bound) between 775 and 1,340 Million EUR. As argued above there is also a small add-on to traffic efficiency benefits in the magnitude of 16 to 27 Million EUR.

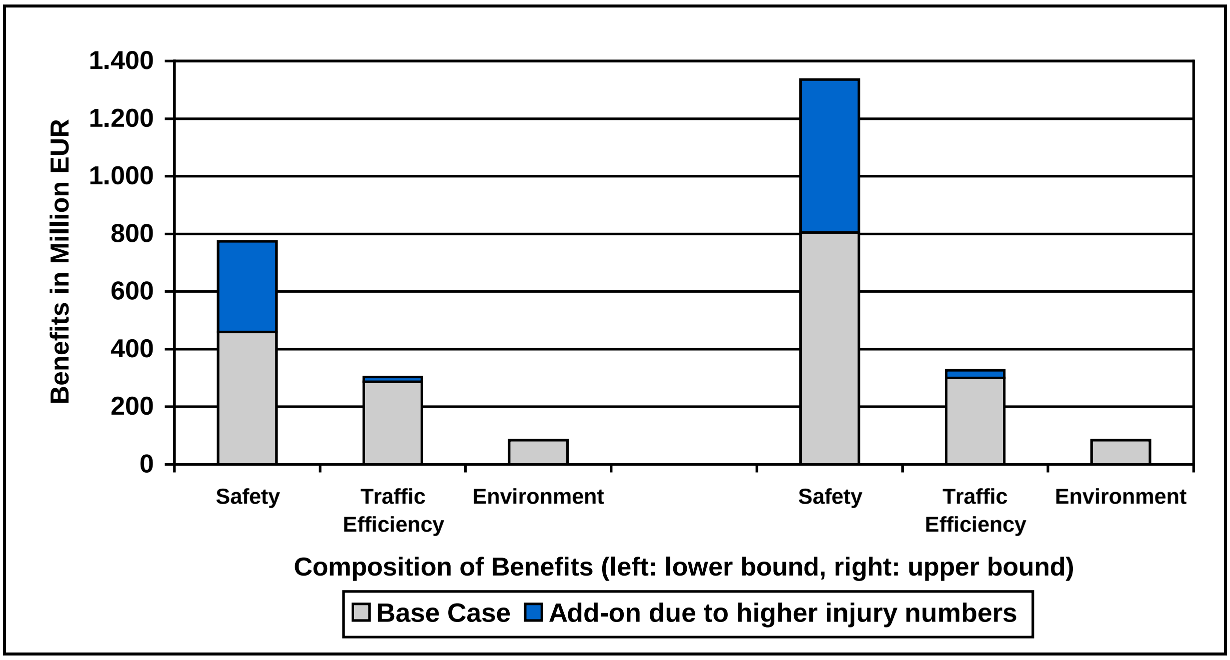

Figure 15: Changes of benefits when underreporting is considered

5.1.2 Higher cost-unit rates for impact appraisal

In the methodology chapter of this Deliverable (see chapter 2.4) it was already argued that national practice in impact appraisal does involve in some cases substantial differences. This can be largely attributed by different methods of appraisal (e.g. damage costs versus willingness to pay). In the following we show exemplarily the impact of a higher cost unit rate for fatalities as applied in the TRL AEBS study [Grover et al. 2008]. As Figure 4 has already demonstrated this U.K. cost unit rate for fatalities is 32% higher than the cost unit rate applied in this study.

The impact of this parametric change is displayed in Figure 16. The safety benefits (lower bound – upper bound) would grow by the amount of 21 to 45 Million EUR. The total safety benefits would then sum up to a range (lower bound – upper bound) between 485 and 850 Million EUR. The impact of this parametric change is rather small because the higher cost-unit rate is only applied to fatalities (which are only a small part of all casualties).

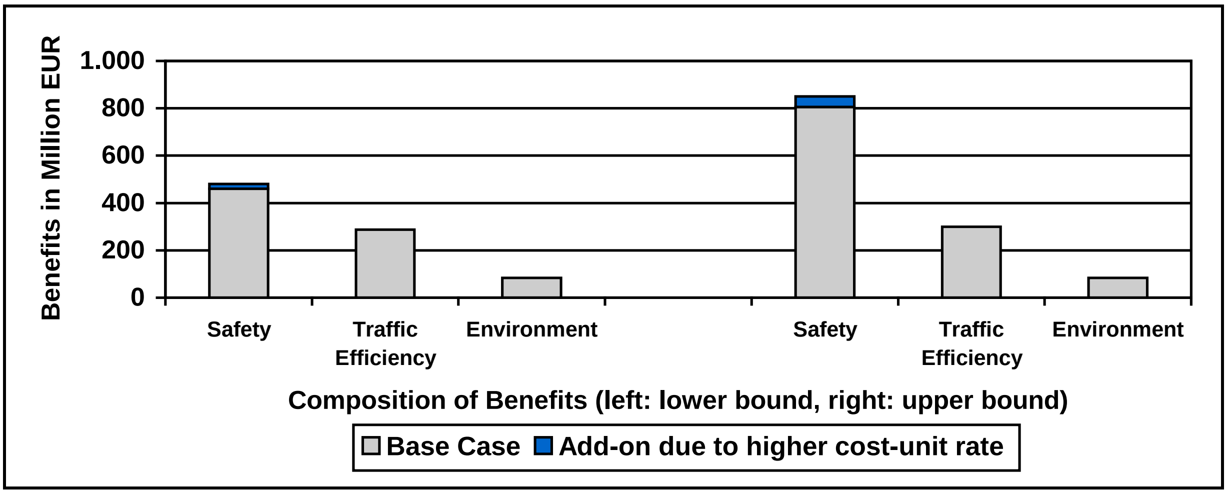

Figure 16: Changes of benefits due to higher cost-unit rate for fatalities

5.1.3 Disregarding direct traffic impacts

The results of the cost-benefit analysis contain a minor negative traffic impact of 0.2 % increase of travel time for all trips (Output of traffic impact assessment, input to CBA). In an aggregated view this leads to a substantial disbenefit, i.e. higher time costs, in the order of 5 Million hours or its equivalent of 100 Million EUR (see chapter 4.1.1).

This brings up the question the question of accountability of these individual time losses. Most of the economic micro systems (private consume, working schedules) do not suffer losses when some minutes are lost in traffic [RAS-W 1986, EWS 1997]. It is only justified to allocate an economic value to time losses or savings when the time is re-used for productive work. When one considers a weighting boundary of 5 minutes (time changes greater than 5 minutes are taken as 100 %), the average trip length would need to be 40 hours, if a 0.2 % change could be taken as full (100%) impact. The average trip length in euroFOT with ACC can be calculated as about 21 minutes. In conclusion, it is justifiable to disregard the negative traffic impact when determining the benefits of ACC+FCW. Even though the EU-27 distribution of trip lengths is unknown – it is highly unlikely that a relevant share of trips exceeds the limits which would lead to substantial travel time changes.

The impact of this parametric change is displayed in Figure 17. Since no difference was made between lower and upper bound traffic impacts the add-on benefits amount to 100 Million EUR for both cases.

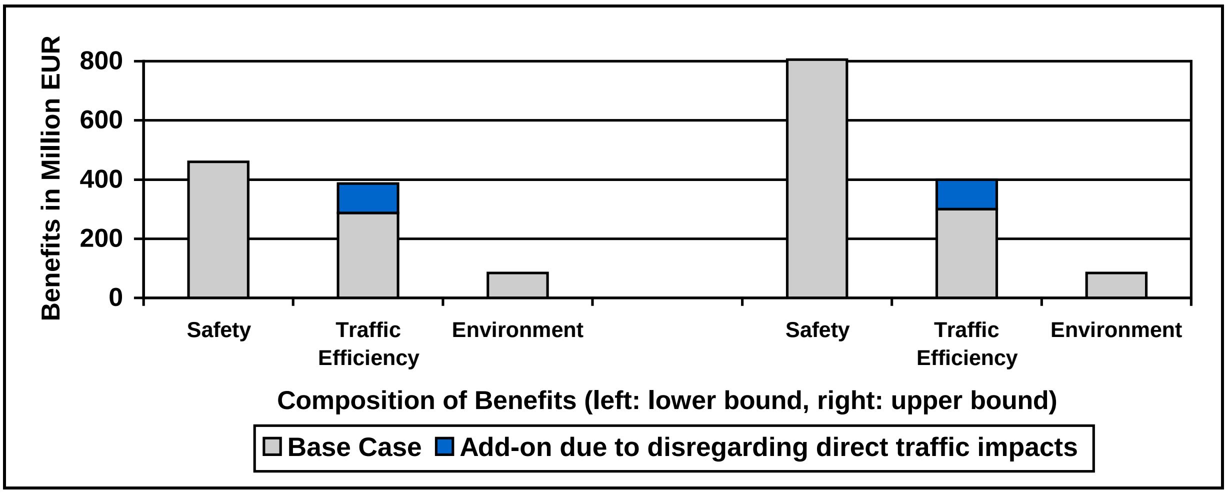

Figure 17: Changes of benefits due to disregarding direct traffic impacts

5.1.4 Combined parametric changes

This section will show the impact on the benefit-cost ratio of all parametric changes. Table 32 displays this result. It becomes obvious that all combined changes on the benefit side improve the benefit-cost ratio significantly by more than fifty percent. When all parametric changes are considered in combination, the benefit-cost ratio for ACC+FCW comes close to 1.

Table 32: Impact of parametric changes on the benefit-cost ratio

Parametric change	Affected element of the calculation model	Change in parameter	Benefit-cost ratio	
			lower bound (impacts)	upper bound (impacts)
Base case	---	---	0,51	0,74
Underreporting of injuries	Safety impact injuries, Indirect traffic impact	80%	0,70	1,06
Higher cost unit rates	Cost unit rate for fatalities	32%	0,52	0,76
Disregarding direct traffic impacts	Travel time savings	100 mn EUR	0,57	0,80
Combined changes in impact appraisal	All benefit changes		0,78	1,15

Referring to the overall calculation model for the cost-benefit analysis it is also possible to derive elasticities as an indicator of sensitivity. Elasticities are dimensionless figures which indicate how strong (in relative terms, in %) the benefit-cost ratio reacts to relative changes (in %) of input parameters. The benefit-cost ratio is composed of the numerator and the denominator. In our analysis, the unit costs are the only parameter in the denominator. The numerator is made of the safety, traffic efficiency and environmental benefits.

In conclusion, the CBA results are considerably sensitive to parameter changes, since the key statement ("BCR above or below 1?") is not stable throughout the analysed cases. Different cost-unit rates or disregarding minimal traffic impacts do not have large effects, but only lead to marginal changes of the overall result. This shows an overall consistency between socioeconomic assessment frameworks (e. g. UK national vs. EU harmonised), hence CBA as a tool leads to generally similar results.

However, changes to safety impacts lead to higher benefits exceeding the costs. This is particularly interesting since due to conservative filtering in WP6400, all accidents other than a limited share of addressable rear-end collisions are not considered to be affected by ACC/FCW. It is questionable that this very strict assumption stands if the system was deployed to all vehicles. This assessment is limited to the results of the VMC data analysis, hence additional safety impacts (further than correcting for underreporting) cannot be considered. Still, the improvement of the results due to the analysed changes indicates that a final judgment on ACC/FCW cannot be made solely on the euroFOT impact assessment results.

5.1.5 Comparison of results with former socio-economic impact assessment studies

In the previous chapter it was shown that the benefit-cost ratio for ACC+FCW for cars is unexpectedly low in comparison to former socio-economic impact assessment studies [Baum et al. 2008, Grover et al. 2008, Robinson et al. 2011]. Even though a comparison of results from other studies is strongly influenced by its assumptions introduced into the assessment (geographical scope, accident target group, relevant system costs etc.) in the following it is analysed exemplary for the results from the eIMPACT [Baum et al. 2008] study which sources of discrepancies do exist.

The differences arising from safety impact assessment can be summarised as follows:

- This euroFOT study has used recent fatality and injury numbers for EU-27 (2008, see Table 2) of approximately 38,500 fatalities and 1.6 Million injuries. The use of in-depth accident databases such as GIDAS has led to a conservative estimation of the likely target group. The target population accounts for approximately 350 fatalities and 60,000 injuries per year. Factors such as the usage rate and the effectiveness of the system (Table 25) scale the safety impact down to 42-88 fatalities and 5,600-9,500 injuries. Central values, although not calculated in euroFOT, would point towards 65 fatalities and 7,500 injuries, each of them valid for full penetration.
- Key figures for the safety impact assessment in eIMPACT are the forecasted casualty numbers for 2020 (approx. 21,000 fatalities, 900,000 injuries for EU-25), mostly addressable by IVSS considered in eIMPACT. The effectiveness of the Full Speed Range ACC (here used as proxy for comparison) was estimated to 1.4 % decrease of fatalities (most probable estimate) and 3.9 % decrease of injuries (most probable estimate). When the potential safety impact for 100% penetration is calculated from these base figures, it results in an avoidance potential of approx. 300 fatalities and 35,000 injuries per year. It should be noted that this calculation process lacks two elements
    - the involvement of in-depth accident databases which reveal additional information about addressable accidents and therefore narrow down the target group of fatalities and injuries and
    - the usage rate which is in ex-ante assessment studies typically excluded or set to 100% as a proxy in absence of more detailed information.
- In summary, there is roughly factor 4 to 5 between the safety impact of eIMPACT and euroFOT. The differences can be identified in the usage rate (where FOT can produce valuable information) and the more conservative information of the addressable fatalities and injuries.

Safety impact appraisal as the next step for deriving safety benefit was not found to be a significant source of differences. Both studies make use of similar cost unit rates, namely 1.6 million EUR per fatality and roughly 70,000 EUR per injury.

The differences arising from system cost estimation can be summarised as follows:

- The relevant system cost for ACC+FCW were calculated backwards from recent market prices in applying the rule of thumb advised by eIMPACT (cost price = 1/3 of market price). This approach has led to system cost of 190 EUR per unit, reflecting current market penetration. Including economies of scale for large-scale deployment, the unit costs are estimated to 112 EUR.
- In eIMPACT the cost-price of Full Speed Range ACC was estimated to 143 EUR for the year 2020 based on expert workshop opinion.
- In summary there is factor 0.8 between the cost estimations of the different projects.

Taking all mentioned factors into account, there is factor 3 difference between the benefit-cost ratios of ACC+FCW in euroFOT and Full Speed Range ACC in eIMPACT. This can comprehensively explain the discrepancy between the BCR of 0.5-0.7 for the base case in euroFOT and the BCR of 1.6-1.8 from eIMPACT.

In addition, it has to be regarded that ACC represents foremost a comfort system. There are several implications resulting from this statement:

- The improvement of road safety and other measurable impacts (e.g. fuel consumption) represent hence only parts of the user benefits which determine the willingness to pay for the system.
- Research originating in the German INVENT project has revealed that the comfort effects of ACC-like systems can be substantial [Grawenhoff 2006]. The underlying stated preferences analyses have shown that the comfort benefits are estimated by users to approx. 30% of the total benefits (composed of safety benefits, fuel consumption savings and comfort aspects).
- However, it has to be clear that comfort effects are not relevant for a cost-benefit analysis from society point of view but for the analysis of user benefits and costs. Nota bene that it is the other way round for environmental effects which are relevant to include on societal level but will not be reflected in user related cost-benefit considerations.

5.2 Potential add-on benefits due to avoiding property damages

The cost-benefit analysis for ACC+FCW has considered the costs and the potential savings of productive resources (time, capital, energy, environment) in road transport. This boundary of analysis is fully in line with mainstream CBA performance. However, there are also impacts beyond the boundary, even in road transport.

ACC+FCW as well as other euroFOT functionalities can contribute to lower property damages. In most studies, this effect is not considered in the analysis because of missing reliable data about the size of the impact. The involvement of the insurance industry (Allianz) in the euroFOT consortium makes it however possible to shed some light on the potential magnitude of impacts. In doing so, we investigated three In-depth databases from Allianz Center for Technology relating the PDO reduction potential of ACC+FCW.

5.2.1 Overview of the PDO databases

The first database contains collision accidents with minor property damage only, which are not reported to insurance nor the police, in the following shortened Minor PDO. The second one comprises third party liability (TPL) accidents with property damage only, with the difference that these accidents have been reported to Allianz Insurance in Germany. The third database contains motor own damage (MoD) claims with collision (collision with vehicles or objects only; partly cover claims like hail, theft are not included). All these accidents are shortened PDO. Table 33 displays the basic parameters of these databases.

Table 33: Basic information on the PDO databases

Database	Minor Property Damage (**Minor PDO**)	Third Party Liabilty – Property Damage only (**TPL-PDO**)	Motor Own Damage - Collision only (**MoD-PDO**)
Number of fields	81	127	135
Number of claims	181	2,000	2,000

All three databases are organized the same way, consisting of five blocks, which are:

- General information on the accident,
- Information on the driver and passengers of the insurance holder vehicle,
- Information on the insurance holder vehicle,
- Information on the driver and passengers of the claimant vehicle,
- Information on the claimant vehicle.

The general information block contains data on when, where and under which circumstances, such as time of the day, street and visibility conditions, the accident happened. Furthermore, it includes data on the road type, the accident type and many more. The blocks on the car occupants deal with age, sex and injuries of the passengers. Information on the manufacturer, age, type and damage of the involved vehicles can be found in the vehicle blocks. In addition to that, these blocks provide facts on the collision direction, speed and installed driver assistance systems.

The fields relevant for the analysis can be described as follows:

- **Type of accident (= Unfalltyp)**: The accident type cell, named UTYP in the databases, sorts the accidents according to the classification of the German Insurance Association (GDV). For the determination of the accident type, only the conflict situation that led to it, is of importance. Any collision or guilt circumstances are not significant. The type of accident consists of a three-digit number, whereas the first one indicates the main type of the accident. The second and third digits classify the accident type exactly [GDV, 1998]. All the accident types can be found in Annex 2.
- **Initial speed (= Ausgangsgeschwindigkeit):** The initial speed of both vehicles involved is documented in the cells VNULL for the insurance holder and VNULL2 for the claimant. It is divided into 20 km/h steps. The initial speed cell reports the speed of the vehicle before something happened, speaking no braking, accelerating or collision. It is not the collision speed or any speed difference.
- **Characteristic of street at accident place (= Charakteristik der Unfallstelle):** Information on the characteristics of the carriageway at the accident place is listed in the cell STFUHO. This column categorizes the accident place according to its rough characteristic, e.g. straight, curve, crossing or parking lot.
- **Road surface condition (= Straßenoberfläche):** The cell STROB is dedicated to the road surface conditions at the accident site. Possible conditions are dry, wet, icy or snowy and slippery for different reasons, for example mud or oil.

5.2.2 Estimation of the target group for generic ACC+FCW and ACC+FCW (generation 2008)

ACC+FCW are systems which are already more than 10 years on the market. Since that time different generations are available. Newer generations cover more critical situations than older ones. Therefore the system generation which were tested in euroFOT (generation 2008) and further generations as generic systems (optimal system) are taken into account to show the real effect which can be covered and the potential which could be mined in the future:

Generic ACC+FCW (optimal system)

The accidents, which are considered relevant for the generic ACC+FCW, are selected by accident type. For a generic system the accident type has to be a frontal crash situation with a vehicle driving the same direction or standing in front of a vehicle. All the accident types, used in the following, can be found in Annex 2. In specific the selected types were 201, 231, 541, 542, 500 - 509, 551, 552, 741, 742 and 600 - 649. 201 and 231 address rear end collisions involving vehicles intending to turn left and right. The types 500 to 509 are accidents with parking vehicles that were rear-ended, complemented by 741 and 742, which stands for crashes with broken down vehicles on the road. 541 and 542 stands for rear-ending a vehicle, which intended to park or stop. The types 551 and 552 stand for conflicts with vehicles leaving a lateral parking space on the driveway. The group 600 - 649 includes all rear end collisions that can be addressed by a generic FCW+ACC.

euroFOT ACC+FCW (generation 2008)

The accidents that are considered relevant for ACC+FCW which are tested within euroFOT are also sorted by type of accident, using the specific system limitations described in Annex 2. According to a necessary minimum speed of the vehicle in front, all accidents with standing or parking vehicles have been excluded. The striking vehicle has to drive faster than the speed threshold of the system, which was averaged to 20 km/h. Furthermore, ACC+FCW function was assumed to be limited on slippery surfaces. Consequently, the road surface condition STROB was taken into account by only selecting accidents, which happened on a dry or wet road, excluding icy, snowy and slippery road conditions. This leaves us for the euroFOT system (generation 2008) with the accident types 201, 231, 541, 542 and 600 – 649 and the restrictions on speed and road conditions. The restrictions are summarized in Table 34.

Table 34: Restrictions for the generic ACC+FCW and euroFOT ACC+FCW (generation 2008)

System	Restrictions
Generic ACC+FCW (optimal system)	UTYP (Type of accident): 201, 231, 500 – 509, 541, 542, 551, 552, 600 – 649, 741, 742
ACC+FCW used in euroFOT (generation 2008)	UTYP: 201, 231, 541, 542, 600 – 649 / VNULL > 20km/h / STROB (Street condition): not slippery

Results for generic ACC+FCW and euroFOT ACC+FCW

In Table 35 for each PDO database the total number of claims and the percentage of the target group for the generic ACC+FCW and euroFOT ACC+FCW (generation 2008) are depicted.

Table 35: Results of the target group analysis by number in the different PDO databases

DB / DAS	Minor PDO		Third Party Liability PDO		Motor Own Damage PDO	
	n	**%**	**n**	**%**	**n_I**	**%**
ACC+FCW generic system	23	12.7	576	28.8	343	19.2
ACC+FCW euroFOT system	4	2.2	252	12.6	63	3.2
DB Size:	n = 181		n = 2,000		n = 2,000	

It can be seen that the target group for ACC+FCW used in euroFOT (generation 2008) is limited particularly for minor PDO (2.2%) and motor own damage PDO (3.2%). The reason for this is that approximately 70% of minor PDO and up to 50% of motor own damage PDO occur during parking, ranging manoeuvres and low speed rear end collisions below 20 km/h. On the other hand, the target group of third party liability PDO claims for generation 2008 systems is relatively high (12.6%).

Furthermore, the data for the target group of the generic ACC+FCW system give an outlook how effective already today available systems (generation 2012) and future generations of ACC+FCW (e.g. with stop&go function, full speed range, emergency brake, advanced brake assist) could be. Up to nearly 20% of motor own damage collisions and 30% of the third party liability PDO could be reduced.

5.2.3 PDO claim avoiding potential in Germany

One prerequisite for the estimation of the PDO claim avoiding potential in Germany is the knowledge of the total number of the different kind of claims. Table 36 shows the number of PDO claims (minor, TPL andMoD), with the data derived from [Holland, 2010], [GDV, 2010] and the number of accidents with casualties [DESTATIS, 2010].

Table 36: Number of PDO claims (minor, TPL, MoD) and number of accidents with casualties in Germany in 2009 (numbers are rounded)

Kind of accident/claim	Number
Minor PDO [Holland, 2010]	4,830,000
Third party liability PDO [GDV, 2010]	2,380,000
Motor own damage PDO collisions only [GDV, 2010]	1,410,000
Accident with casualties [DESTATIS, 2010]	250,000

Obviously, the numbers of PDO claims are far higher than the number offer accidents with casualties. To arrive at some high level numbers, there is:

- approximately factor 10 between accidents with casualties and third party liability PDO accidents,
- approximately factor 20 between accidents with casualties and minor PDO accidents,
- approximately factor 6 between accidents with casualties and motor own damage collisions.

A second prerequisite for the estimation of the total PDO damage on a monetary basis are the average costs for minor, TPL and MoD PDO. Data for TPL and MoD are available from the German Insurance Association (GDV). The annual Minor PDO average costs, were ascertained by a AZT study [Holland, 2010]. The average costs of PDO claims in Germany for 2009 are as follows (values are rounded):

Minor PDO for cars	600 €
TPL PDO for cars	2,300 €
MoD PDO for cars (only collisions)	2,600 €

The maximal number of claims avoidable and the monetary damage avoidable with euroFOT ACC+FCW (generation 2008) for third party liability PDO, motor own damage and minor PDO claims for Germany can be estimated by multiplying the percentage of relevant accidents (target group) with the number of claims and the average costs of a PDO claims (minor, TPL and MoD), as exemplified in Table 37.

Table 37: Calculation procedure for euroFOT ACC+FCW (generation 2008) – 100 % penetration rate and ideal usage

	ACC+FCW (generation 2008) target group in [%]	Number of PDO claims	Maximum number of PDO claims avoidable	Maximum monetary damage avoidable
Minor PDO	2.2	4,830,000	106,260	63,756,000 €
PDO-TPL	12.6	2,380,000	299,880	689,724,000 €
PDO-MoD	3.2	1,410,000	45,120	117,312,000 €

The number of avoidable accidents and the related monetary damage as calculated in Table 37 is certainly only true if the penetration rate is 100 % and if

1. the usage rate of euroFOT ACC+FCW is 100%
2. and the system is in each relevant critical traffic situation effective.

However, from FOT data it was derived that – depending on the road type - the usage rate ranges between 19% and 51%. Furthermore, the changes between baseline and treatment in safety related measures in the FOT data ranges from 32% to 82% (see Table 11, chapter 4). Hence, in Table 38 the avoidable number of claims and monetary damage are corrected by taking into account an average usage rate of 35% and an average change between baseline and treatment in safety related measures of 57% by using the correction factor 0.35*0.57=0.2.

Finally, with a simple projection method using the car stock ratio from EU-27 and Germany (229,767,000/41,184,000 = 5.6) we are able to get a best estimate for the number of avoidable PDO claims in EU-27 with the euroFOT ACC+FCW. In this regard, it have to be emphasized that this projection method is not reasonable for the projection of monetary avoidable damage as – for example - the average PDO costs for TPL and MoD are highly different between EU member states.

Table 38: Best estimate for euroFOT ACC+FCW (generation 2008) avoidance in Germany and EU-27 taking into account 100 % penetration rate and the real usage data from FOT

	Correction factor (for real usage relating FOT data)	Number of claims avoidable in Germany	Monetary damage avoidable in Germany	Number of claims avoidable in EU-27
Minor PDO	0,35*0,57	21,199	12,719,322 €	118,714
PDO-TPL	0,35*0,57	59,826	137,599,938 €	335,026
PDO-MoD	0,35*0,57	9,001	23,403,744 €	50.408

Limitation of the PDO claim estimation

Despite the fact of the limited effectiveness of ACC+FCW (generation 2008) it can be stated that in the whole EU-27 each year approximately 500,000 PDO claims could be avoided or at least mitigated if all vehicles would be equipped with the system. The data used for this very first best estimate study on PDO can be – naturally - questioned. Especially, the results for Minor PDO have to be handled with care, following the small sample size of only 181 valid data sets, as well as the high number of projected cases based on these.

In addition, the monetary damage avoidable in Germany has to be seen differentiated, due to the different basis of cost calculation.

- The Minor PDO costs base on the costs occasioned for the holder of the vehicle (mostly the owner),
- The PDO TPL and MoD costs are the claims expenditure for the insurance company paying it,
- The cost rates for casualties are the economic costs of an accident (see previous chapter).

Conclusively there is to say that one has to distinguish between the **different origins of the costs** whilst comparing the costs.

5.2.4 Insurance Perspective on the euroFOT data

Certainly, Table 38 shows a limited reduction potential for ACC+FCW (generation 2008) on PDO claims. Nevertheless, the euroFOT results on the different systems tested are very valuable for Allianz Insurance, as in the past, any evaluation of these systems had to rely on forecasts and a large number of assumptions.

For the first time this large-scale field test now provides genuine scientific data on acceptance, use and efficiency that clearly demonstrate the increased safety provided by systems that are already available. Furthermore, the development and optimisation of driver assistance systems is progressing very rapidly. For example ACC+FCW is currently already available on the market with additional functions like emergency brake assist, advanced brake assist and stop&go function. These functions address far more accident types and critical situations then the generation 2008.

The importance of the euroFOT results for the insurance industry was recently stated in a press release https://www.allianz.com/en/press/news/studies/news_2012-08-24.html of Allianz Insurance. There it is written: *"The data that were gathered in real-life traffic are particularly important to Allianz", explains Karsten Crede, CEO of Allianz Global Automotive. "They enable us to even better evaluate the impact of driver assistance systems on insurance claims and to develop insurance products for the international market with our partners in the automotive industry that take account of the accident reduction potential."*

For the development of insurance products taking into account driver assistance systems following euroFOT research results on traffic safety are particularly important for the insurance industry:

Adaptive cruise control (ACC) and forward collision warning system (FCW)

- The number of sharp braking manoeuvres is reduced significantly (highway: -67%, rural roads: -45%, in towns: -32%)
- The number of critical distances to the vehicle in front is reduced significantly (highway: -73%, rural roads: -81%, urban roads: -63%)
- The number of near misses is reduced significantly (highway: -32%, rural roads: -45%, urban roads: -2%)
- High degree of use of ACC on highways (switched on 52% of the time)
- 31% of drivers make use of ACC on rural roads
- The prevention potential of forward collisions on the highway is 42% (on rural roads up to 14%)

- The drivers participating in the survey emphasized that ACC and FCW are functions that are greatly appreciated and much used, given that they increase both driving comfort and safety.

Lane departure warning (LDW)

- Improved lane adherence, as well as reduction of the average turning angle
- Improved use of indicators

Navigation systems

- High degree of acceptance, in particular during long journeys and on unfamiliar routes
- Driver behaviour is significantly improved, in particular as regards changing lanes, keeping an appropriate distance to vehicles in front and reducing the need for sharp braking manoeuvres

Blind spot information system (BLIS)

- 80% of drivers were of the view that BLIS improves safety (particularly useful in heavy inner-city traffic, no additional burden)
- Important supplement to visual checks (looking over one's shoulder)

Speed limiter (SL) + cruise control (CC)

- Reduction of journeys at excessive speeds
- Fewer abrupt braking manoeuvres
- Fewer critical distances

Curve speed warning (CSW)

- 75% of drivers were of the view that CSW increases safety (particularly useful on rural roads).
- CSW supports defensive driver behaviour.

This quantitative and qualitative euroFOT results bring the insurance industry into the position to adapt the gathered data to new generations of driver assistance systems. Conclusively, there is to say that already some insurance products on the basis of euroFOT data on the market granting incentives for driver assistance systems.

5.3 Wider economic Impacts

Cost-benefit analysis is, as already argued (see chapter 5.2), traditionally focused on potential savings of productive resources. It is therefore a tool which focuses on supply side optimisation of the economy. What lies beyond the scope of traditional CBA are demand side effects, i.e. what individuals, companies really do with the saved time and resources. Modern and enlarged concepts [Banister Berechman 2003] include these effects in terms of income, growth and employment, e.g. corresponding to the EC Lisbon goals, as wider economic impacts. The cost-benefit analysis becomes then embedded in a “twin approach”, consisting of the assessment of resource savings and wider economic impacts. Both can justify the implementation of a given measure.

Keeping in mind the research focus of euroFOT on measured data and impacts, this section does not intend to quantify wider economic impacts itself. It is more intended to serve as food for thought and it makes use of existing pieces of research, in particular resulting from the eIMPACT assessment project [Baum et al. 2008, Geißler 2008].

With growing maturity of the systems wider economic impacts (income, growth, employment, also fiscal revenues) can become substantial. Figure 18 displays conceptually the process chain how demand for any given system, rising the value of the vehicle, stimulates the production value and the employment in automotive sector and its supplier industries. The generated income will be spend to a large extent for consumption which then leads to second round effects in other industries such as consumers goods production and services.

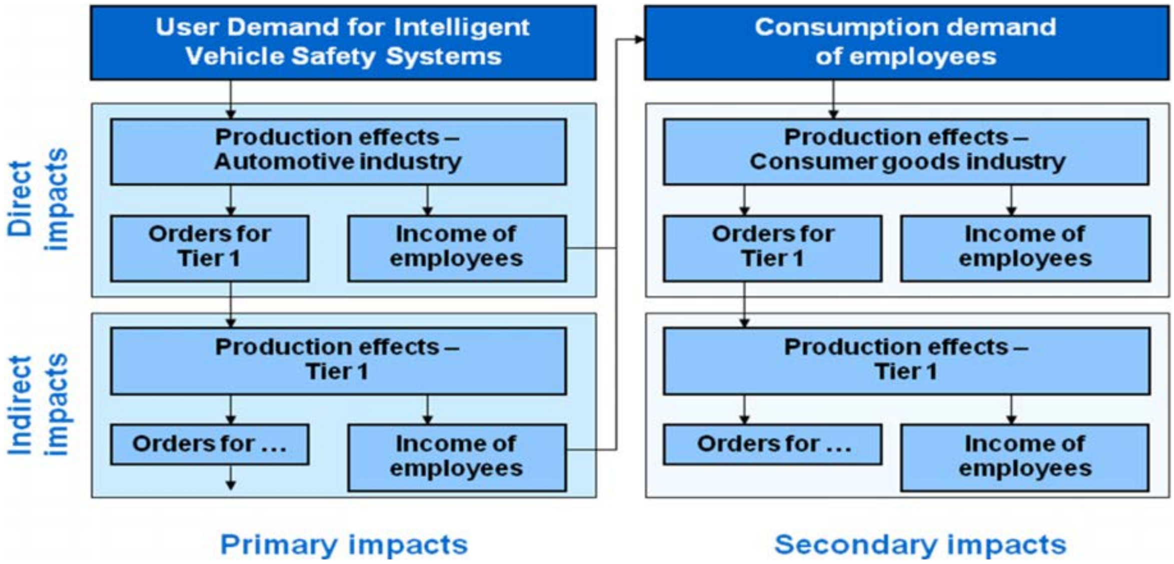

Figure 18: Conceptual process to assess wider economic impacts

In order to illustrate the argumentation above, Figure 19 displays (on the basis of eIMPACT results) some wider economic impacts, exemplified for Electronic Stability Control. According to that, direct and indirect effects on employment that result from production and implementation of ESC amount to about 10,000 employees in Germany. Scaling up the results to EU level it would imply employment effects of approximately 40,000 employees. Nearly half of the effects can be attributed to the automotive industry. But also other industries such as trade and financial services benefit from the employment stimulation.

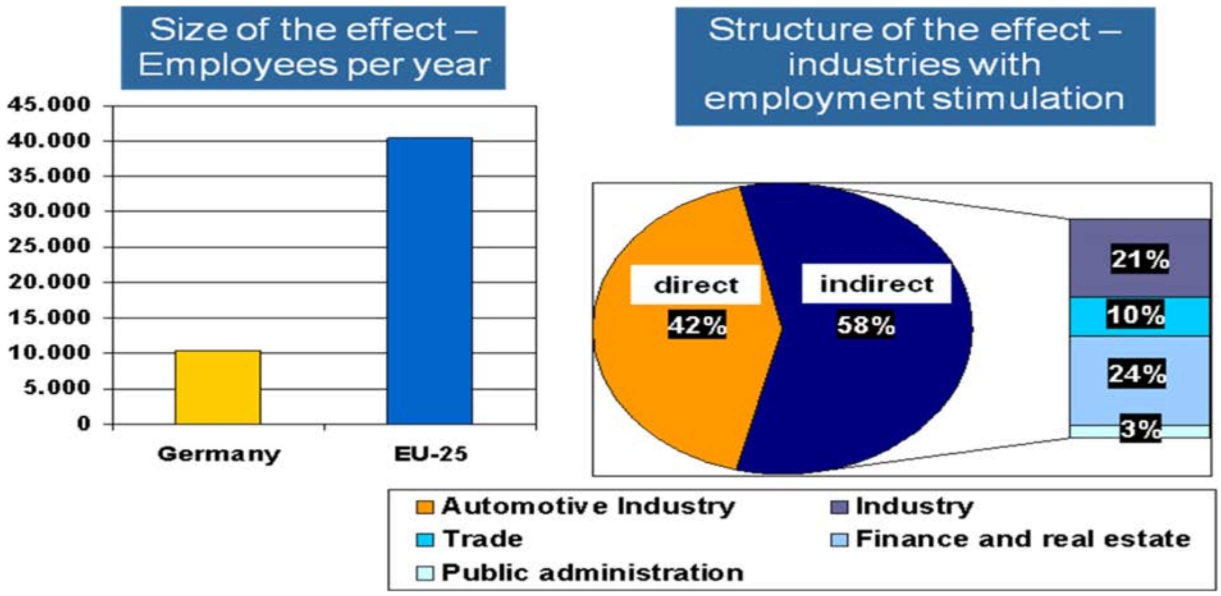

Figure 19: Wider economic impacts of Intelligent Vehicle Safety Systems

6 Conclusions

The main results of the cost-benefit assessment can be summarized as follows:

- The costs of equipping the entire fleet of passenger cars and heavy trucks with the combined system ACC+FCW lead to annually approx. 1.6 Bn EUR (passenger cars) and approx. 28 Mn EUR for heavy trucks (because of the smaller fleet). When only parts of the fleet will be equipped (e.g. 10% of the car fleet), the costs amount to 240 Mn EUR.
- Annual benefits for cars add up to 0.8 to 1.2 Bn EUR (full penetration) respectively 126 to 175 Mn Euro (10% penetration rate), depending on the magnitude of safety impact. The result is dominated by the safety impact which accounts for approximately half of the benefits in the lower bound scenario and two thirds in the upper bound scenario. However, also traffic impacts and environmental effects provide substantial contributions to the benefits.
- Annual benefits for trucks amount to approximately 108 and 146 Mn EUR. The same pattern of results as for cars appears also here. Safety is dominant in the upper bound scenario whereas traffic represents the biggest impact in lower bound scenario
- For trucks, the ACC+FCW bundle is clearly profitable from society point of view. The benefit-cost ratio is between 3.9 and 5.2.
- For cars, the attainable benefits (based on the assumptions introduced to the assessment) are not sufficient to outweigh the costs. The benefit-cost ratio ranges between 0.5 and 0.7. The system is either too expensive or users on average drive too less km for pay off of the “investment”. It has to be kept in mind that the tested system ACC+FCW represents foremost a comfort system. These effects are however not subject of monetisation in a transport-focused cost-benefit analysis.
- Sensitivity of the results was tested for the cars scenario. The overall result was that modifying input parameters (such as higher cost-unit rates for impact appraisal, considering potential underreporting of injury accidents) would bring the benefit-cost ratio close to or even above 1. Changing of the penetration rate and taking different levels of economies of scale into account provides a BCR above 1 for a scenario assuming large economies of scale and a penetration rate of at least 50%.
- Former ex-ante impact assessment studies have indicated more favourable benefit-cost results (e.g. eIMPACT). The differences for euroFOT can be explained by making use of in-depth databases for modelling the accident target group, considering empirical evidence of usage rates and the estimation of system cost (expert estimations vs. market price based assessment).
- For passing the profitability threshold it would require to widen the scope of the assessment by including also benefits from avoiding property damages. In this context, a first best estimate study on the basis of Allianz insurance databases with PDO claims (minor, TPL and MoD) using euroFOT results revealed, that in EU-27 each year approximately 500,000 PDO claims could be avoided or at least mitigated if all passenger cars would be equipped with ACC+FCW (generation 2008). This is particularly remarkable as for newer generations of ACC+FCW even higher accident avoidance is probable. Further benefits are expected if wider economic impacts in terms of growth and employment will be considered.

The cost-benefit analysis has also led to a number of lessons learned in the fields of process as well as conceptual framework. These experiences are relevant for reviewing and updating the FESTA handbook:

- It can be stated that this study carried out – for the very first time – a cost-benefit analysis which is not based on ex-ante expert assessment of impacts but on results proven in the field.
- The FESTA methodology has proven its applicability to this type of research question. Unfortunately, performance restrictions of the impact assessment (no measured or insignificant effects, up-scaling to EU-27) have limited the applicability of CBA to systems tested in euroFOT.
- Hence, socio-economic assessment as final assessment step of FESTA-V must lead to limited results, since only the most trustable and verifiable results can be used in quantitative terms for CBA. But for other functions, it could be possible to make further use of the FOT data, e .g. to test assumptions from ex-ante assessments or to improve simulation models. Without the need for statistical proof from previous stages (which is anyway out of scope for safety impacts in terms of real-world accident avoidance), simulation models could transfer intermediate results into benefit estimations which would reflect the real world impact on a larger scale. If this is not considered, the benefits and hence, the overall BCR results suffer from a “pessimism bias”. This must be considered in early phases of future projects e.g. by providing a contingency plan to make use of simulation or further expert assessments.
- It can be also discussed whether to use other evaluation methods than cost-benefit analysis, e.g. cost effectiveness analysis, multi criteria analysis etc. would be more appropriate. This would lead to different output figures, e.g. when impacts are not transformed to units of money. It would however not avoid or help out of interpreting measured data for deriving impacts (e.g. the crucial “bridge” from incidents to accidents).
- Upscaling from micro level (FOT) to macro level (EU-27 databases for accidents etc.) provides still considerable challenges, especially concerning the granularity of information. CBA makes typically use of averages of variables whereas distributions of variables would be valuable to keep the value added of FOT data. Research in this direction would help to solidify the derivation of socio-economic impacts from Field Test data.
- Generally, it can be recommended that the socio-economic impact assessment should allow for a wider scope of impacts, including those beyond transport, i.e. for the overall economy. Such impacts for productivity, growth and employment represent important results for policy making (e.g. Lisbon agenda, CARS 2020). There are concepts available to broaden the scope of CBA and to include macroeconomic / wider economic impacts in a “twin approach” [Banister Berechman 2002]. Obviously, this class of impacts can be assessed based on models. On the other hand, these figures have a different quality or nature than measured effects within a Field Operational Test. To summarise this, it should be preferred to assess impacts in a wider scope than to stick to a too narrow set of effects derived from measured data.

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Annex 1 Glossary

In this Annex the reader will find a selection of words coming from the official euroFOT glossary which is particularly important for the understanding of this deliverable.

The euroFOT glossary started inside euroFOT SP2 and is based on the FESTA glossary. Every time the glossary is updated, the parallel European supporting initiative FOT-NET[1] is notified; the glossary is then updated on the FOT-NET website and other FOT projects such as Tele-FOT are notified of the new available version of this glossary. For this reason we invite the readers of this report to also consult the euroFOT glossary on http://www.fot-net.eu/.

ACEA	The European Automobile Manufacturers Association (French: Association des Constructeurs Européens d'Automobiles; abbreviated ACEA) is the main lobbying and standards group of the automobile industry in the European Union.
AEBS	An Advanced Emergency Braking System (AEBS) is an autonomous road vehicle safety system which employ sensors to monitor the proximity of vehicles in front and detect situations where the relative speed and distance between the host and target vehicles suggest that a collision is imminent. In such a situation, emergency braking can be automatically applied to avoid the collision or at least to mitigate its effects.
Baseline period/phase	The part of the data collection during which the **function(s)** operate in "silent mode", that is, they collect data, but do not give any signals to the driver. From the viewpoint of the driver the **function(s)** is/are off.
Baseline within comparison situation	**Scenario** with **system** under evaluation "turned off"
BCR	Benefit-cost ratio is an indicator, used in the formal discipline of cost-benefit analysis, that attempts to summarize the overall value for money of a project or proposal. A BCR is the ratio of the benefits of a project or proposal, expressed in monetary terms, relative to its costs, also expressed in monetary terms.
CBA	Cost-benefit analysis is a systematic process for calculating and comparing benefits and costs of a project, decision or government policy.
Controlled factors	Are those factors that are kept constant within one **analysis.** The data are filtered such that only occurrences in which the controlled factors assume the intended values are selected.
EWS	EWS are technical rules and standards for the economic feasibility of road infrastructure projects in Germany.
FOT aka Field Operational Test	A study undertaken to evaluate a function, or functions, under normal operating conditions in environments typically encountered by the host vehicle(s) using quasi-experimental methods.
Function	Implementation of a set of rules to achieve a specified goal
GIDAS	GIDAS (German In-Depth Accident Study) is a German in-depth accident database for the comprehensive documentation of road accidents with casualties in two investigation areas in Germany.

Hypothesis	A specific statement linking a cause to an effect and based on a mechanism linking the two. It is applied to one or more **functions** and can be tested with statistical means by analysing specific **performance indicators** in specific **scenarios**. A hypothesis is expected to predict the direction of the expected change.
IVSS	Intelligent Vehicle Safety Systems represent a summary term for advanced driver assistance systems aiming at primarily safety benefits such as Electronic stability control, Forward collision warning etc.
ITS	Intelligent Transport Systems (ITS) are advanced applications which, without embodying intelligence as such, aim to provide innovative services relating to different modes of transport and traffic management and enable various users to be better informed and make safer, more coordinated, and 'smarter' use of transport networks
PDO	PDO (Property Damage Only) is a police term for property damage traffic accidents.
Performance indicator	Quantitative or qualitative indicator, derived from one or several **measures,** agreed on beforehand, expressed as a percentage, index, rate or other value, which is monitored at regular or irregular intervals and can be compared to one or more criteria.
RAS-W	RAS-W are guidelines for economic feasibility studies of road infrastructure in Germany.
Research question	General question to be answered by compiling and testing related specific **hypotheses**
Scenario	A **use case** in a specific **situation.**
Situation	One specific level or a combination of more specific levels of **situational variables**.
Situational variable	An aspect of the surroundings made up of distinguishable levels. At any point in time at least one of these levels must be valid.
STATS 19	STATS 19 is an accident data collection system used by the police in UK.
STRADA	STRADA (Swedish Traffic Accident Data Acquisition) is a national information system collecting data of injuries and accidents in the entire road transport system. STRADA is based on information from the police as well as the hospitals.
System	A combination of hardware and software enabling one or more **functions**
System state	The current setting of a **system**.
Treatment period/phase	The part of the data collection during which the **function(s)** are switched on by the experimental leader, such that they are either active all the time, or can be switched on or off by the driver.
Treatment within comparison situation	**Scenario** with **system** under evaluation "turned on"
Use case	A specific **event** in which a **system** is expected to behave according to a specified **function**
Variable factors	Are covariates, they are not kept constant within one analysis, but their values are logged and their influence on the results is considered.

[1] – FOT-NET: the FOT-Net project aims to create a networking platform for anyone interested in Field Operational Tests, their set-up and their results. More information on this project can be found at http://www.fot-net.eu/.

Annex 2 Accident classification

Accident Type according to [GDV, 1998]

Accident Classification System (GDV)

5.2 Type 1: Driving Accident

Definition: A driving accident occurred when the driver loses control over his vehicle because he chose the wrong speed according to the run of the road, the road profile, the road gradient or because he realised the run of the road or a change in profile too late.
Driving accidents are not always single vehicle accidents where the vehicle leaves the road. A driving accident can also lead to a collision with other road users.

Type 10
In a curve

Type 11
In a curve with turning priority

Type 12
Turning in or off to another road

Type 13
At a swaying road

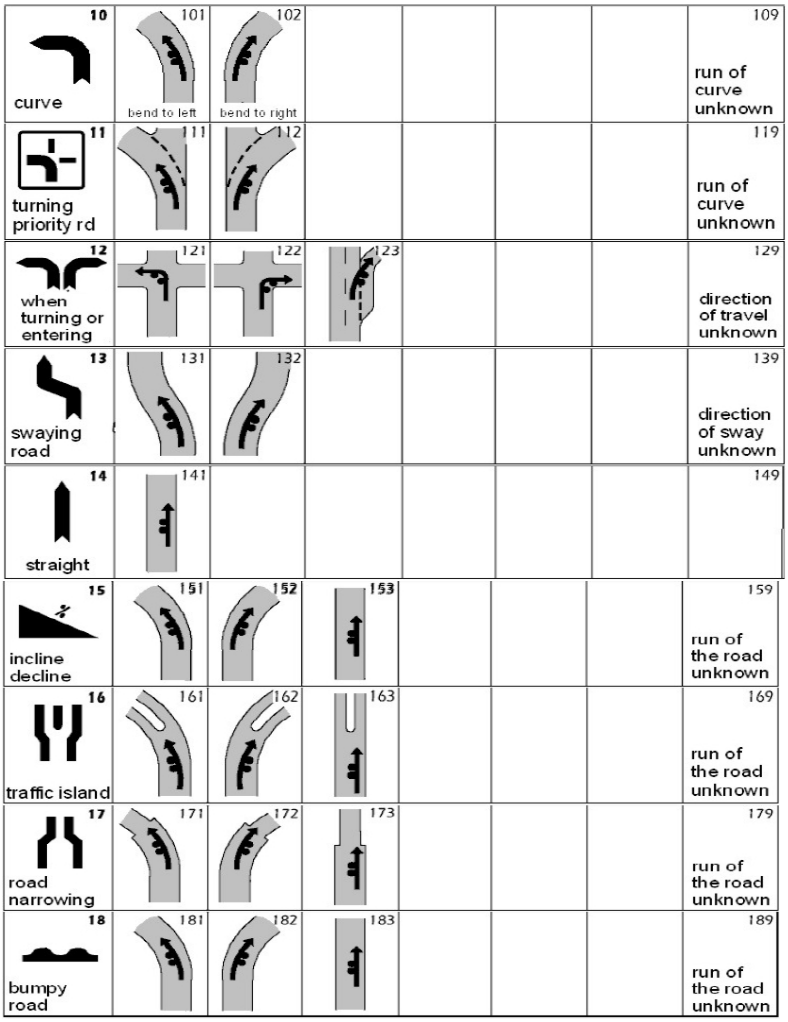
Type 14
On a straight road

Type 15
…gradient

Type 16
…traffic island

Type 17
… road narrowing

Type 18
… uneven road



Type 19
… other driving accidents

Other driving accidents 199

Accident Classification System (GDV)

5.3 Type 2: Turning off Accident

Definition: A turning accident occurred when there was a conflict between a turning road user and a road user coming from the same direction or the opposite direction (pedestrians included!). This applies at crossings, junctions of roads and farm tracks as well as access to properties or parking lots.

Type 20
Conflict between a vehicle turning off to the left and following traffic

Type 21
Conflict between a vehicle turning off to the left and oncoming traffic

Type 22
Conflict between a vehicle turning off to the left and a vehicle from a special path/track or a pedestrian going to the same or opposite direction

Type 23
Conflict between a vehicle turning off to the right and following traffic

Type 24
Conflict between a vehicle turning off to the right and a veh. from a special path/track or a pedestrian moving in to the same or opposite direction

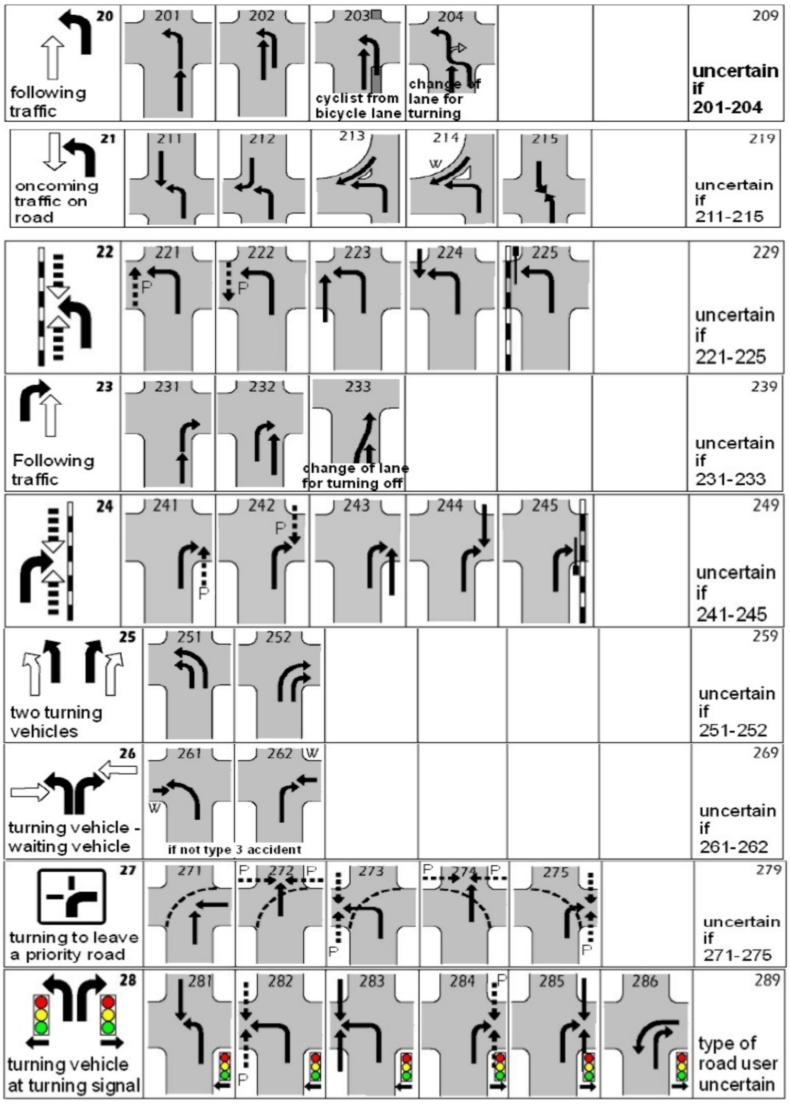
Type 25
Conflict between two turning off vehicles, moving along side in the same direction.

Type 26
Conflict between a turning off vehicle and a vehicle without priority, waiting at the headed road of the turning veh.

Type 27
Conflict between a turning off veh. from a priority rd and another road user at a traffic junct. with a turning priority road.

Type 28
Conflict between a turning off veh. and another rd user coming from the same or the opposite direction when the turning traffic is regul. by traffic lights.

Type 29
Other turning off accidents



Other turning off accidents 299

Accident Classification System (GDV)

5.4 Type 3: Turning in / crossing accident

Definition: A turning in / crossing accident occurred due to a conflict between a turning in or crossing road user without priority and a vehicle with priority. This applies at crossings, junctions of roads and farm tracks as well as access to properties or parking lots.

Type 30
Conflict between a non priority vehicle and a priority vehicle coming from the left, which is not overtaking.

Type 31
Conflict between a non priority vehicle and a priority vehicle coming from the left, which is overtaking.

Type 32
Conflict between a non priority vehicle and a priority vehicle coming from the right, which is not overtaking.

Type 33
Conflict between a non priority vehicle and a priority vehicle coming from the right, which is overtaking.

Type 34
Conflict between a non priority vehicle and a bicyclist with priority coming from a bicycle path.

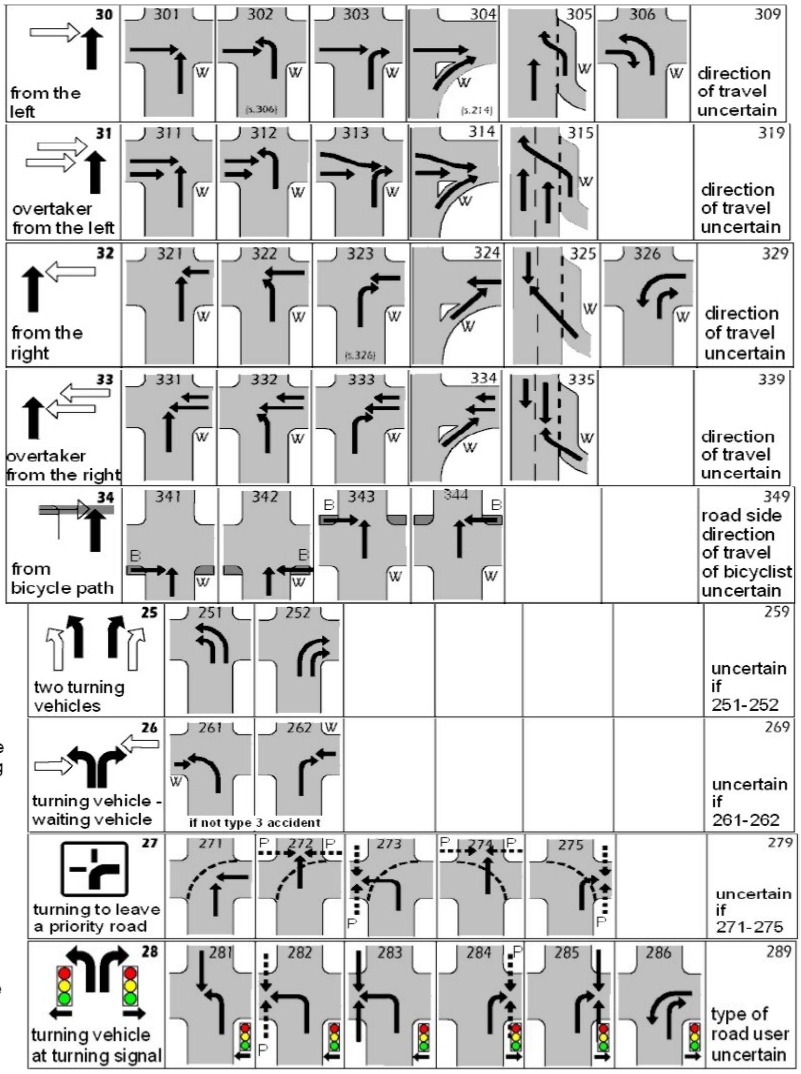
Type 25
Conflict between two turning off vehicles, moving along side in the same direction.

Type 26
Conflict between a turning off vehicle and a vehicle without priority, waiting at the headed road of the turning veh.

Type 27
Conflict between a turning off veh. from a priority rd and another road user at a traffic junct. with a turning priority road.

Type 28
Conflict between a turning off veh. and another rd user coming from the same or the opposite direction when the turning traffic is regul. by traffic lights.

Type 29
Other turning off accidents



Other turning off accidents 299

Accident Classification System (GDV)

5.5 Type 4: Pedestrian Accident

Definition: A pedestrian accident has occurred due to a conflict between a pedestrian crossing the road and a vehicle unless the vehicle was turning off. This is independent of whether the accident occurred at a place without special pedestrian crossing facilities or at a zebra crossing or similar.

Type 40
Conflict between a pedestrian coming from the left and a vehicle.
(Unless type 41)

Type 41
Conflict between a pedestrian coming from the left and a vehicle which had an obstructed line of sight by parking vehicle, tree, fence ….

Type 42
Conflict between a pedestrian coming from the right and a vehicle.

Type 43
Conflict between a pedestrian coming from the left and a vehicle.
(Unless type 44)

Type 44
Conflict between a pedestrian coming from the left and a vehicle which had an obstructed line of sight by parking vehicle, tree, fence ….

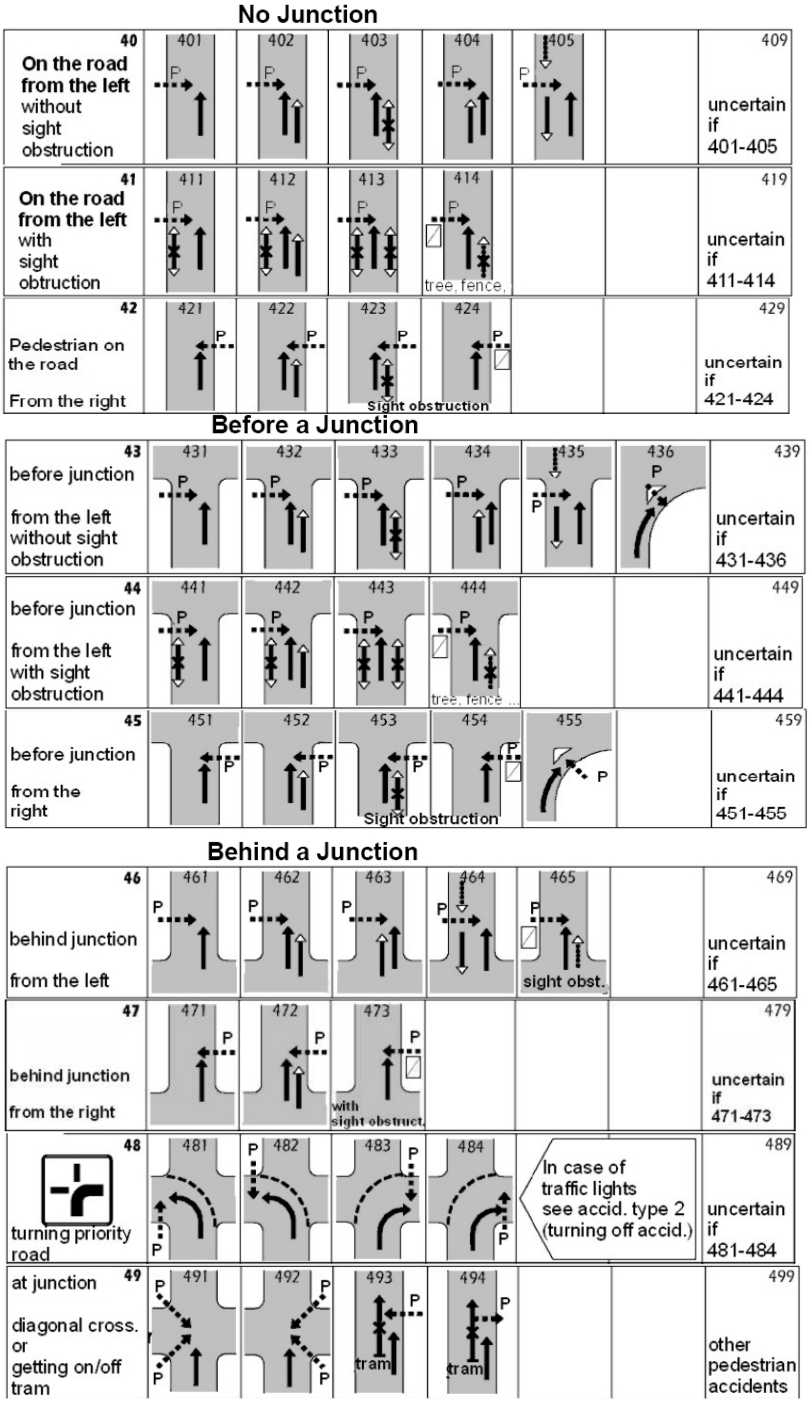
Type 45
Conflict between a pedestrian coming from the right and a vehicle.

Type 46
Conflict between a pedestrian coming from the left and a vehicle.

Type 47
Conflict between a pedestrian coming from the right and a vehicle

Type 48
Conflict between a pedestrian and a vehicle following a turning priority road.

Type 49
Conflict between a vehicle and a pedestrian crossing a junction diagonally, or getting on/off a tram.
As well as other pedestrian accidents



Accident Classification System (GDV)

5.6 Type 5: Accident with parking traffic

Definition: An accident with standing traffic occurred due to a conflict between a vehicle from moving traffic and a vehicle which is parking, has stopped or is manoeuvring to park or stop. This is independent of whether stopping/parking was permitted or not.

Type 50
Conflict between a vehicle and a parking vehicle in front.

Type 51
Conflict between a vehicle swinging out to avoid a parking vehicle and a following vehicle.

Type 52
Conflict between a vehicle swinging out to avoid a parking vehicle and an oncoming vehicle.

Type 53
Conflict between a vehicle swinging out to avoid a parking vehicle and a pedestrian.

Type 54
Conflict between a vehicle which is stopping to park or entering a parking space and a vehicle of the moving traffic.

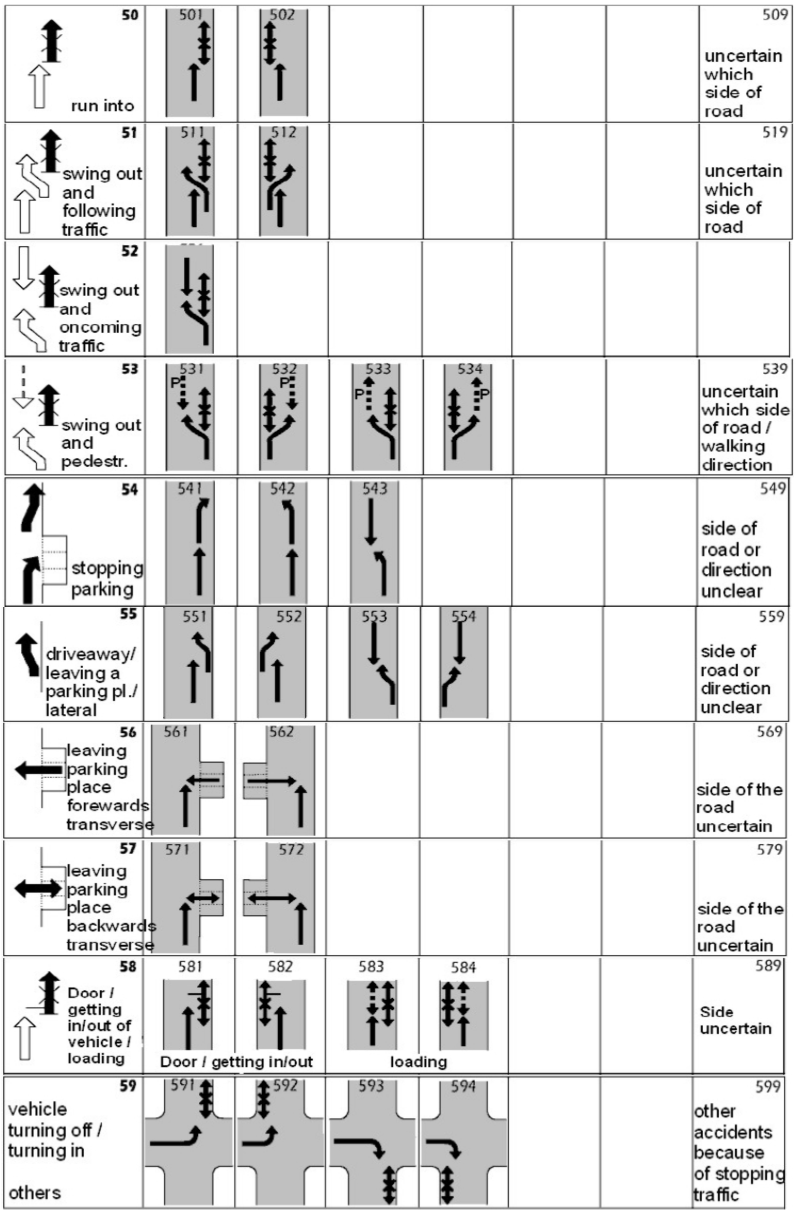
Type 55
Conflict between a vehicle driving away or leaving a lateral parking space and a vehicle of the moving traffic.

Type 56
Conflict between vehicle leaving a transverse parking space forewards and a vehicle of the moving traffic.

Type 57
Conflict between vehicle leaving a transverse parking space backwards and a vehicle of the moving traffic.

Type 58
Conflict because of opening a vehicle door, getting into /out of the vehicle or loading.

Type 59
Conflict between a turning vehicle and a parking vehicle which is located at the headed path – as well as other accidents with parking vehicles.



Accident Classification System (GDV)

5.7 Type 6: Accident in lateral traffic

Definition: The accident in lateral traffic occurred due to a conflict between road users moving in the same or in the opposite direction. This applies unless the conflict is the result of a conflict corresponding to another accident type.

Type 60
Conflict between a vehicle and another vehicle driving in front on the same lane.

Type 61
Conflict between a vehicle which is braking, standing or going slow due to a traffic jam and a following vehicle.

Type 62
Conflict between a veh. wh. is braking, standing or going slow due to traffic or non priority and a following vehicle.

Type 63
Conflict between a vehicle which is changing lanes to the left and a following vehicle on the lane alongside.

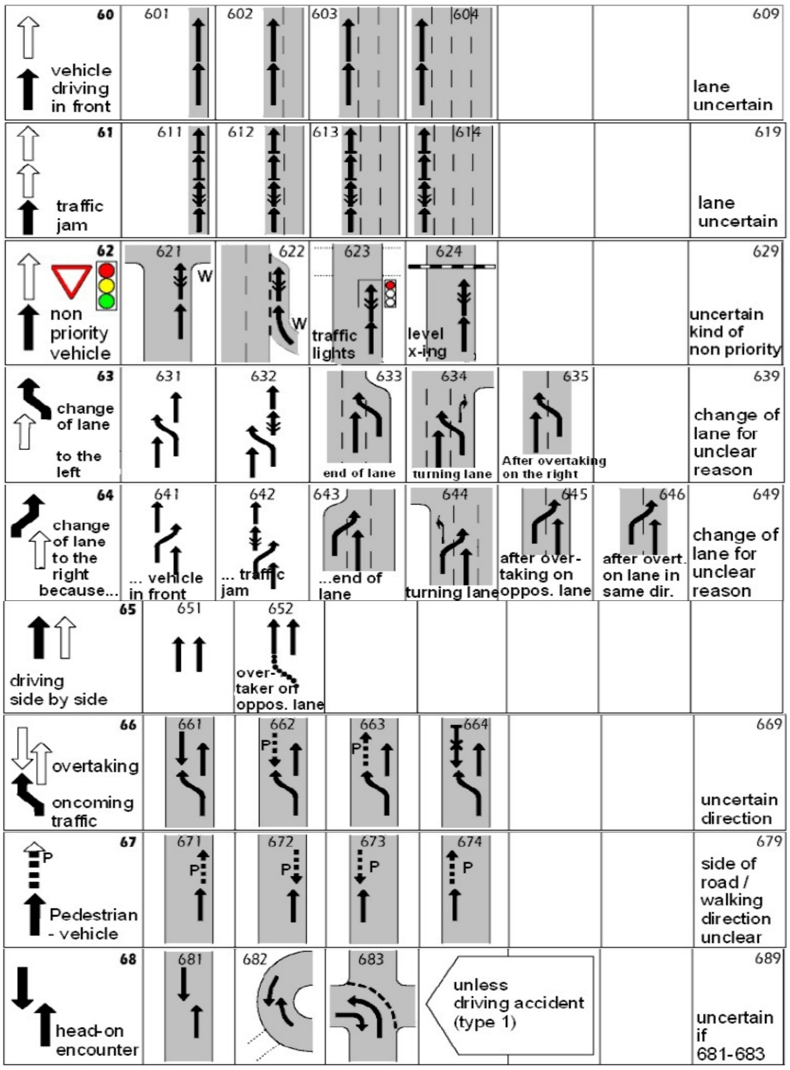
Type 64
Conflict between a vehicle which is changing lanes to the right and a following vehicle on the lane alongside.

Type 65
Conflict between two vehicles, side by side, going in the same direction.

Type 66
Conflict between an overtaking vehicle and a vehicle from oncoming traffic, a pedestrian or a parking vehicle.

Type 67
Conflict between vehicle which is not overtaking and a pedestrian on the same lane.

Type 68
Conflict between two head-on encountering vehicles.



Type 69
Other accidents in lateral traffic.

Other accidents in lateral traffic 699

Accident Classification System (GDV)

5.8 Type 7: Other Accident Type

Definition: Other accidents are accidents that cannot be assigned to the accident types 1-6. Examples: Turning around, backing up, accidents between two parking vehicles, objects or animals on the road, sudden vehicle defects.

Type 70
Accident with two parking vehicles.

Type 71
Accident while backing up or rolling back. Unless manoeuvring to park

Type 72
Accident due to a u-turn.

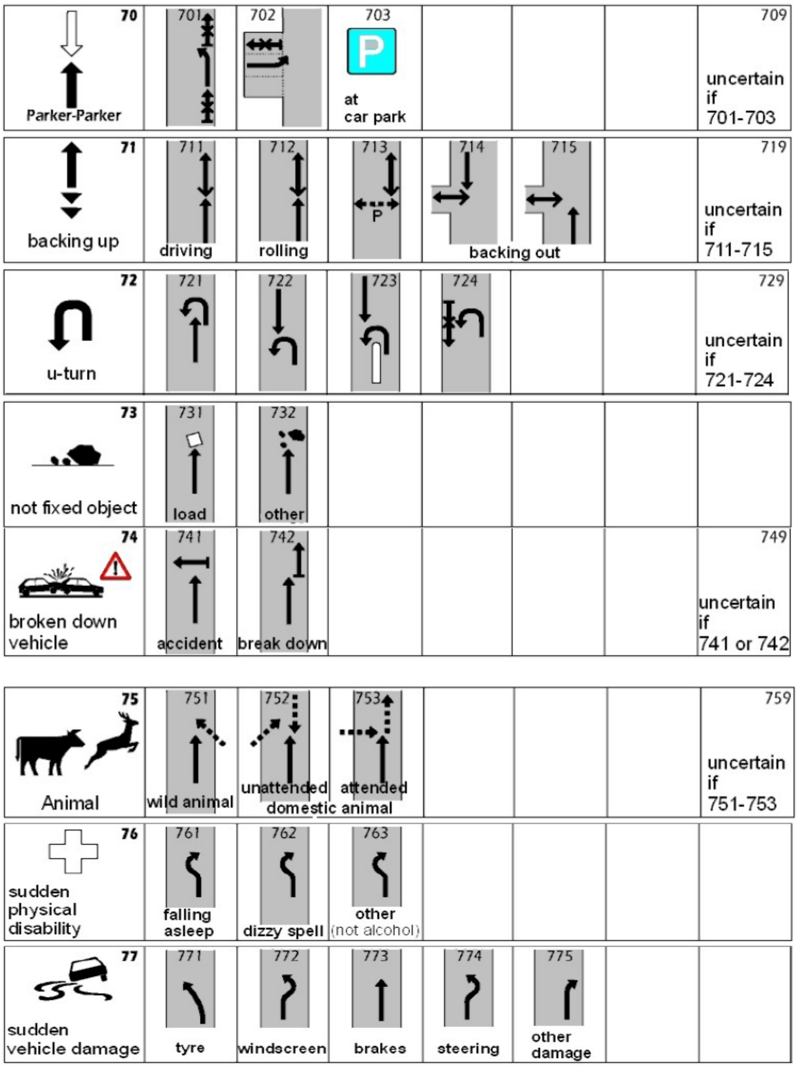
Type 73
Accident due to a not fixed object.

Type 74
Accident due to a broken down vehicle.

Type 75
Accident due to an animal on the road.

Type 76
Accident due to a sudden physical disability of a road user.

Type 77
Accident due to a sudden technical defect on the vehicle.



Type 79
All other accidents

Other accidents 799

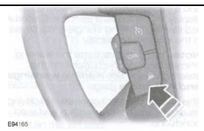
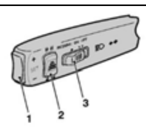
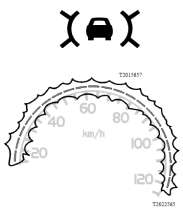
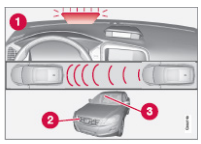
Annex 3 System specifications

Forward collision warning (FCW)

A forward collision warning system provides alerts to assist drivers in avoiding or reducing the severity of crashes involving the equipped vehicle striking the rear of another vehicle.

This function detects and tracks obstacles in front of the vehicle using radar. It calculates and evaluates the trajectories and relative speed of the subject vehicle in front. If the obstacle in front shows a high probability of a collision, the system provides a warning to the driver. Thus it is intended to decrease driver's reaction time in case of potential rear-end accidents. Table 39 contains the specifications of the euroFOT FCW versions.

Table 39: FCW specifications - differences among the systems implementing the FCW function at different OEMs [Dozza et al. 2009].

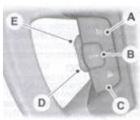
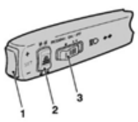
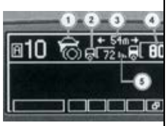
Specs	Ford	MAN	VOLVO	VCC
Speed threshold	15 km/h	15 km/h	30 km/h	7 km/h
Combination with other functions?	No	No	Yes: with ACC (same system)	No
Specific situations where the system is not intended to work (i.e. automatically disengaged or the driver is instructed to not use the system)	The system will only react to vehicles travelling in the same direction The system will not react to slow or stationary vehicles	The system will only react to vehicles travelling in the same direction The system will not react to slow or stationary vehicles	The system will only react to vehicles travelling in the same direction The system will not react to slow or stationary vehicles	The system will only react to vehicles travelling in the same direction
Active braking?	No	No	No	Yes
HMI system activation and control	 Activation buttons on the steering wheel	No activation by the driver is needed – the system is always engaged	 Activation and controls on the left stalk	Vehicle settings
HMI visualization of system status and settings	Red flashing warning triangle in the information display	Boxed pop up message in the primary display combined with acoustic warning	 Acoustic and visual warning	 Acoustic and visual warning
Settings	ON/OFF Sensitivity	ON/OFF	ON/OFF	ON/OFF Sensitivity

Adaptive cruise control (ACC)

The ACC function supports the driver in selecting and then automatically maintaining an appropriate speed and distance to the vehicle in front depending on his/her preferences and the current traffic situation.

The ACC function actively controls the vehicle speed to adapt to the driver's selected speed and following distance. This function detects and tracks, by using radar, if a vehicle is in front and adjusts the speed accordingly. If the leading vehicle accelerates, the function accelerates up to the target speed and keeps the pre-selected following distance, which is expressed in a time gap. The system is disengaged when the driver acts on the brake or when the driver pushes the related disengage button. If the car was built with manual gear, changing gear would also disable ACC. The function is neither active below a certain speed nor when the vehicle is being started. It needs to be resumed in order to work after the vehicle experienced a speed below a certain threshold, which is listed in the table below. When activating the function for the first time after the engine was shut down, the settings for following distance and speed are reset.

Table 40: ACC specifications - differences among the systems implementing the ACC function at different OEMs [Dozza et al. 2009].

Specs	Ford	MAN	VOLVO	VCC	VW
Speed threshold	30 km/h	25 km/h	18 km/h	30 km/h	0/30 km/h
Combination with other functions?	No	No	Yes: with forward collision warning (same system)	No	Yes: with FCW*
Specific situations where the system is not intended to work (i.e. automatically disengaged or the driver is instructed to not use the system) *Ford and VCC use the same system but instructions to the drivers are different.	heavy traffic; slippery surfaces; twisty roads; Heavy rain, spray, or snow; Entering or leaving motorways; Engine speed very slow	ABS system in the trailer is not working Trailer ABS is not operational fog slippery road	ABS system in the trailer is not working hilly terrains heavy traffic slippery surfaces overtaking manoeuvres	Accelerator pressed for a long period. Wheels lose traction Brake temperature high	slippery surfaces entering/ exiting lanes, constructions sites Resting foot on accelerator low visibility winding roads tunnels
Active braking?	Yes (30%)	No	Yes	Yes (30%)	Yes (30%)
HMI system activation & system control	 Left buttons on the steering wheel	 Right buttons on the steering wheel	 Left stalk control	 Left buttons on the steering wheel	 Left buttons on the steering wheel
Specific HMI visualization: System status and settings					

For some vehicles of the Volkswagen group (Audi A4, A5, Q5, Q7) ACC includes FCW (acoustic/visual warning + brake-jerk). FCW is active, even if ACC is switched off, but can be switched off by the driver over the MMI (Multi Media Interface).

To sum this up ACC will be tested by five different OEMs and will be implemented in four different systems: Volvo, VCC/Ford, VW, and MAN. These different systems differ from each other in terms of handling, instructions and thresholds. Furthermore, Volvo's ACC and FCW are not possible to separate. In fact, FCW is marketed by Volvo as a feature of ACC and not as a different system or function.

The main expected benefits from the ACC function are:

- to reduce exposure time to under-running critical headways
- to increase driving comfort by automatic adjustment of distance and speed
- to lower driver stress by decreasing drivers' workload especially on long trips
- to prevent speeding by setting a speed limit
- to reduce time gaps to the leading vehicle