Road Safety Data, Collection, Transfer and Analysis

D5.7: Real World and procedures

Please refer to this report as follows: Kohsiek, A., Achmus, S, Evgenikos, P., Papantoniou, P., Yannis, G., (2012), Real World and procedures, Deliverable 5.7 of the EC FP7 project DaCoTA.

Grant agreement No TREN / FP7 / TR / 233659 /"DaCoTA"
Theme: Sustainable Surface Transport: Collaborative project
Project Coordinator:
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Project Start date: 01/01/2010 **Duration 30 months**

Organisation name of lead contractor for this deliverable: Volkswagen AG – VW			
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Due date of deliverable	**31/10/2012**	**Submission date:**	**31/10/2012**

Project co-funded by the European Commission within the Seventh Framework Programme	
Dissemination Level (delete as appropriate)	
PU	**Public**

Project co-financed by the European Commission, Directorate-General Transport and Energy

TABLE OF CONTENTS

INTRODUCTION

The European Union has set the aim of cutting the 2010 figure for road fatalities by half within 10 years. The number of road fatalities has already been reduced considerably in the past decades. There is no obvious single cause for this reduction in traffic fatalities. More likely it is the combined effect resulting from the efforts of many active partners (e.g. road planers, road and infrastructure construction, emergency medical services, lawmakers, vehicle manufacturers). Currently a technical revolution is taking place in vehicle safety as electronic systems for active safety are incorporated into the vehicles: The prime aim of active safety systems is accident avoidance. Thus, in addition to the passive safety—the reduction of the accident severity for the occupants—accidents will be avoided or at least reduced in their severity. ESC (Electronic Stability Control) is the active system whose effectiveness was predicted early in the product cycle and is validated by accident data by now. Similar leaps in vehicle safety with accident avoidance and consecutive reduction in accident victims will be expected from new active systems.

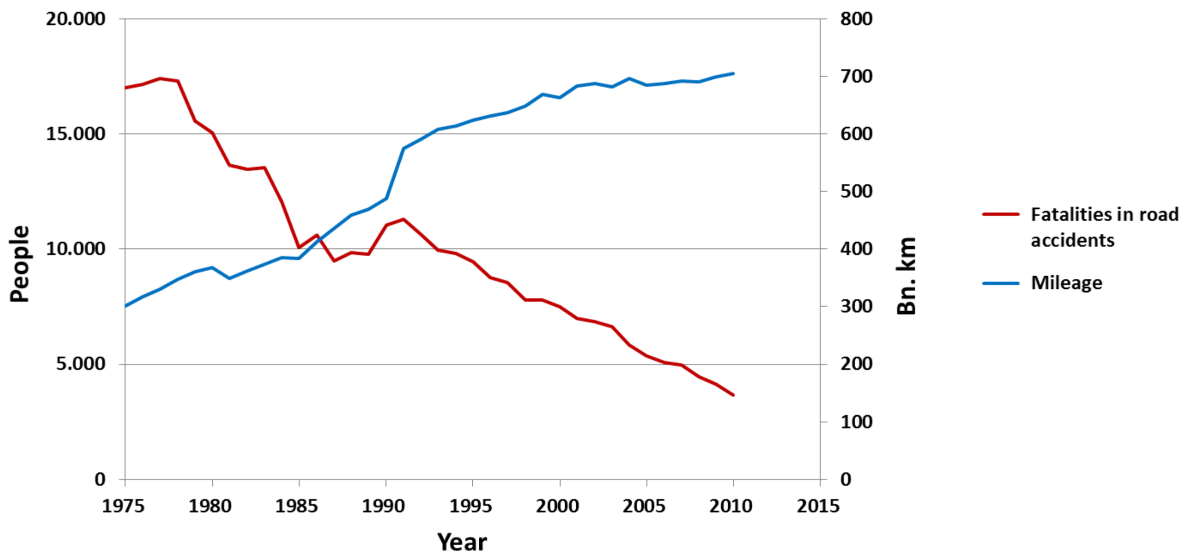

Figure 1 Road traffic fatalities, Germany 1975-2010,

Data source: Federal Statistical Office, Germany

This deliverable 5.7 from the DaCoTa project should provide information and guidelines for development of new test procedures. There exist three categories of “test procedures”:

a) Tests for checking the function of the system. These Tests cover the validation, if the system does what it has to do, and how effective it works. For this reason tests have to represent the accidents which the system addresses.

b) Tests for checking of the functional safety of the system e.g. as demanded by ISO 26262.

c) A specific driver assistance systems (ADAS) should be the response on a given road safety problem. Usually there are several technological possibilities for solving a given problem and hence different implementations of systems addressing the same functionality will be found in the market. Consequently it is of some interest to rank these different solutions.

In this document guidelines for test procedures of category (a) are in the primary focus and first hints to (c) are given. It is not the purpose of this deliverable to define the test procedures themself. For test procedure development many facts have to be collected and analysis have to be done depending on the functionality of the ADAS tested. In particular, test procedures for advanced driver assistance systems (ADAS) should be developed that appraise their effectiveness in addition to the functional tests of the systems. There also several points of regarding the aspect of the test procedure like accidentology, regulations, consumer organisations, financial constraints, lobby groups, etc. The decision was to focus on accident research point of view in this deliverable.

1 GUIDELINES FOR THE ASSESSMENT OF ADVANCED DRIVER SYSTEMS

1.1 The road from passive to active safety

The reduction of serious injuries and deaths on roads during the last couple of decades was, at least in part, a result of the improvements in passive safety. These improvements took place in restrain system design for occupants as well as in structural vehicle design. Since introduction of driver airbags in 1980, passenger airbags followed in 1988, side airbags in 1995, curtain or window airbags in 1997 and knee airbags in 2003. The penetrations rate of these features in new vehicles licenced 2010 in Germany illustrated in table 1. Besides the proliferation of airbag systems, several improvements to seatbelt systems were introduced: seat belt pre-tensioner in 1984 and seat belt load limiter in 1995. On the side of structure integrity of the passenger compartment, the introduction of high tensile strength steel to chassis design in the late 1990s is most notable. The use of high tensile strength steel in automotive design is ever increasing, as is the tensile strength of the steel itself. Furthermore modern steel remodelling techniques like usage of 3D-blanks and selective heating of blanks prior to remodelling are current innovations for an increased stiffness of the passenger compartment, Additionally improvements both at bumper and bonnet design were introduced during the last decade.

Since 1998 each new passenger car registered in one of EU countries have to be conform at the same frontal crash with 56 km/h, 40% offset into a deformable barrier (OBD) (EU regulation 96/27EG respectively ECE-R94) and at the same side impact crash with 50 km/h (EU regulation 96/27/EG respectively ECE-R95).

In 1997 an EU cross national consumer test was introduced for the rating of vehicle passive safety. (EuroNCAP). Actually in November 2012 latest test results are published for 15 new models. Except of one all reach the maximum assessment category of 5 stars.

	KBA	Driver airbag		Passenger airbag		Side airbag		Curtain airbag		Knee airbag	
Market Segment	**cases**	**Verbau %**	**Serie %**	**Verbau %**	**Serie %**	**Verbau %**	**Serie %**	**Verbau %**	**Serie %**	**Verbau %**	**Serie %**
Upper class	22.825	*100 %*	*100 %*	*100 %*	*100 %*	*100 %*	*100 %*	*100 %*	*97 %*	*34 %*	*34 %*
Upper middle class	140.748	*100 %*	*100 %*	*100 %*	*100 %*	*100 %*	*100 %*	*100 %*	*100 %*	*45 %*	*39 %*
SUV	295.254	*100 %*	*100 %*	*100 %*	*100 %*	*97 %*	*97 %*	*97 %*	*97 %*	*21 %*	*21 %*
Vans	119.420	*100 %*	*100 %*	*100 %*	*100 %*	*96 %*	*96 %*	*96 %*	*90 %*	*19 %*	*19 %*
Middle class	417.637	*100 %*	*100 %*	*100 %*	*100 %*	*100 %*	*100 %*	*99 %*	*99 %*	*31 %*	*31 %*
Compact	790.386	*100 %*	*100 %*	*100 %*	*100 %*	*100 %*	*100 %*	*92 %*	*89 %*	*37 %*	*37 %*
Sport cars	46.305	*100 %*	*100 %*	*100 %*	*100 %*	*100 %*	*100 %*	*78 %*	*54 %*	*33 %*	*33 %*
Subcompact	550.256	*100 %*	*100 %*	*100 %*	*100 %*	*100 %*	*97 %*	*52 %*	*34 %*	*25 %*	*25 %*
Micro-Vans	177.324	*100 %*	*100 %*	*100 %*	*100 %*	*100 %*	*100 %*	*90 %*	*90 %*	*20 %*	*20 %*
Minis	202.918	*100 %*	*100 %*	*100 %*	*100 %*	*75 %*	*51 %*	*26 %*	*17 %*	*16 %*	*16 %*
SUV	126.919	*100 %*	*100 %*	*96 %*	*86 %*	*88 %*	*30 %*	*30 %*	*4 %*	*6 %*	*0 %*
Motor Caravan	18.139	*100 %*	*98 %*	*95 %*	*69 %*	*57 %*	*0 %*	*57 %*	*0 %*	*0 %*	*0 %*
total	**2.916.260**	***100 %***	***100 %***	***100 %***	***99 %***	***97 %***	***92 %***	***79 %***	***72 %***	***28 %***	***27 %***

Berechnungen der FSD Fahrzeugsystemdaten GmbH, Dresden.

Table 1: Rate of restrain system equipment in new passenger cars licenced 2010, also with the information of the rate of standard equipment, and vehicle classes. [Unfallverhütungsbericht Straßenverkehr 2010]

It can thus be said that passive safety measures have reached a high degree of maturity. It is a widely held believe, that further substantive improvements in passive safety seem to carry an overburdening weight penalty. Thus further reductions in road casualty rates are more easily obtainable using active systems, like e.g. implementing an automatic emergency brake. These active safety systems are playing an increasingly important role in the further reduction of serious injuries and fatalities on the road towards the goal of “Vision Zero”, i.e. road traffic without fatal accidents [OECD 2008]. In the future the complementary use of both active and passive safety systems will be important for reaching the ‘projected’ accident reductions set by the EU as well as “Vision Zero” as the ultimate goal.

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The effectiveness of passive safety measures is tested in standardized crash tests and proven in retrospective analysis based on accident data. These crash tests give an answer to the overall protection of the tested vehicle; it’s a result of the adjustment of airbags, seatbelts, structure, etc. looking at criteria from biomechanics and deformations outside and inside of the vehicle. These criteria are the result of the work of scientific researchers, experts, lawyers over many decades. Though most of the biomechanical injury criteria are in flux, like the new thorax injury criteria or a still not agreed upon biomechanical sound brain injury criterion, even unsound criteria like e.g. HIC have standardized injury measurement and made different systems comparable. One could speak of an injury severity rate reduction by proxy.

For advanced driver assistance systems (ADAS) new approaches are required to prove the benefits of such systems because of two reasons:

a) As in passive safety the benefit of ADAS should be the result of the overall level of protection provided by of the vehicle, regardless whether the protection is provided by passive safety systems or active safety systems.

Particularly in injury protection, one could be tempted to offset effectiveness of active and passive measures against each other. Along the lines: If the accident is avoided the occupant does not sustain any injuries and thus does not need any measures of injury severity reduction. This concept can be taken further by looking at systems for accident mitigation. Taking an ideal automatic emergency braking system that always manages to break before an impact and say thus reduces all impact speeds of 64km/h to 40km/h. Generally speaking an impact at 40km/h will always be less severe than one at 64km/h, providing the target is hit in the same way. This argument is flawed by two problems: First of all the assumption of ‘hitting [the target] in the same way’ whether an active system intervened or not, is overly optimistic, even for stationary targets, as the intervention usually increases the time to impact and thus leaves room for additional breaking and steering manoeuvres by the driver as well as such manoeuvers by the target, if it is moveable. This directly leads to the second problem, the possible change in impact configuration by the active system. The classic example of such a change in impact configuration is ESC: Though ESC roughly eliminates 70% of all skidding accidents the remaining 30% of skidding accidents are transformed by the ‘unsuccessful’—at least unsuccessful at accident avoidance—ESC intervention from a side impact to a small offset frontal collision. Though this transformation was not obvious at the time of introduction of ESC, it has since been shown to occur regularly. In-depth evaluation of ESC accidents showed that the injury severity of the small overlap frontal collision is of a lesser injury severity for all occupants than the corresponding side impact without ESC intervention. This statement holds even for the cars on the road in 1995, the year of ESC introduction as was shown using published British accident data as well as German GIDAS evaluations of that time.

Thus statements like “reducing the speed in a collision by X km/h is more effective than any passive measure” are missing the point: The aim of a perfect active system is to avoid all accidents were as the aim of a perfect passive system would be to avoid all injuries vehicles having an accident. We do not live in a perfect world and therefore we have to combine active and passive safety systems in order to obtain the best possible result for each traffic participant. Some experts tend to call this merger of active and passive safety systems integrated safety, even though this single term blurs the two distinct ways of looking at traffic injury mitigation. More simply put: Everybody wants to drive in a car that cannot be involved in an accident, but if it is everybody wants to be uninjured.

It is also not constructive to test and assess individual active safety systems independently of each other.

b) ADAS are aimed at preventing accidents or at least mitigating accident severity.

An accident that does not occur due to the intervention of an active system should always be assessed more positively than the equivalent reduction in injury severity brought about by passive measures. In other words, accident avoidance should be seen a more worthy goal than injury severity reduction.

The following points should be answered in the investigation of ADAS:

- Which ADAS should be given priority in development and deployment in order to maximise the benefit in real world accidents?
- How effective is a specific ADAS in the real world? How many deaths or severely injured persons can a system prevent?
- How should an ADAS system be configured / parameterized to maximise its benefit in real accidents?

1.2 From the idea to the requirements for test procedures

At the beginning normally there is the request to have a service supplied with the aim of answering a problem of general order of insecurity. This insecurity may be an improvement of the visibility, the improvement of the road holding in emergency situations, a detection of the collision, etc. Such a service is called 'safety function'.

A safety system is a component of a safety function, an application that allows to answer a specific problem, e.g. 'blind spot detection' is a safety system helping the driver to improve his field of vision. A safety system can also be a part of several safety functions, e.g. an Automatic Emergency Braking System (AEBS): The safety function of collision detection 'assists' the driver of the vehicle in an emergency situation by automatically applying the brakes and thus reduced the energy in the actual crash and consecutively reducing the injury severity.

A technology is a component of the safety system which assures a very precise functionality (acquisition, processing, and execution). It refers to the technical aspect. The same technology can be used by various systems. Otherwise, it's also possible that different technologies can be used for one safety system.

Keeping these three definitions in mind the general process developing a test procedure for a safety system can be described on 6 phases:

a) The safety system itself

   The starting point is a real object, a safety system, provided by an engineer, like a car manufacturer or a supplier. In order to derive at a system which is the best one for every vehicle, the first step is to 'translate' the system into a safety function or service. Meaning the fields of insecurity of road traffic this system address has to be identified. For this first mapping normally a simple description of the system is sufficient.

b) Documentation phase

   In this sequence, the relevance of this function from an accidentology point of view is checked. During this phase main questions have to be answered to define the limit of the system:

   - stake of the problem

- target population
- risk analysis
- a priori evaluation of the effectiveness

These main questions can be answered in several ways. For example to determine the effectiveness of a system a case by case analysis made by experts is possible or the application of simulation tools or accident replay with the new function (see chaper 1.7) or real tests. Real tests could be static tests, on simulator, on track, on opened road). Each method has advantages and disadvantages. This will be discussed in chapter 1.3.

The critical points in this phase are the used database, the representativeness of the results and the applied methodologies. Also important in this phase is the description of the system.

The results of this phase are essential if a developing test procedures for the system regarded should continue from the accidentology point of view.

c) Confrontation phase

This is a period of discussion / exchange with others. Developing test procedures as optimal as possible the knowledge of several disciplines is necessary—from car industry, research, insurance, public authorities, etc. Here the discussion is opened, ideas have to confront the others. Mostly additional studies are necessary. This phase normally takes a long time.

d) Convergence phase

The initial idea seems to be good. The objective is to find a common position, a consensus between main actors. At this stage the general functional requirements of the safety function have to carve out. According to these functional requirements the complexity and variance found in real life accidents / situations have to be abstracted into real life scenarios. Suitable types of test have to be chosen. Crucial points are repeatability and independency of the technologies.

e) Validation Phase

It is very important to check if the consensus solution is in line with the starting definition (idea) and the previous accidents analysis.

f) Transfer phase

Topic of this phase is the preparation of the specifications / requirements for the performance tests. Recommendation such as repeatable tests, real life scenario tests, type of tests, assessment etc. should be included.

1.3 Different approaches for assessing active safety systems (aka ADAS)

Three different methods for the assessment of ADAS spring to mind:

- Corresponding to the assessment of passive safety systems, a representative number of test scenarios could be defined. Using these scenarios, the effectiveness of the ADAS systems is validated in real world tests. These test scenarios could be used to demonstrate that the ADAS functions perform in the intended fashion. Furthermore the test scenarios could be used to assess the effectiveness of the ADAS, at least to some degree (e.g. the collision speed reduction of an AEBS).

- Retrospective assessment of the ADAS effectiveness using accident data. This can only be done with accident data of a very high granularity as the ADAS to be validated are usually not known at the time of accident acquisition: The accident database has to be detailed enough to cover for assessment of the ADAS target population and efficiency. Some of the ADAS assessment can also be done indirectly, as will be shown later.

- Using statistically representative, high granular accident data, the impact of an ADAS system on the accident situation can be assessed for a wide range of different scenarios by using simulations. Here the level between a disclosure of the way the system works and a black box has to be defined so that the results of the simulation are transparent—at least to a certain limit. The effect of an ADAS on the actual accident situation can be estimated using, for example, the reduction of fatally or severely injured persons as a measure of effectiveness.

Real world tests are difficult to conduct, due to the complexity of ADAS as well as their situation specific responses. Both factors hamper the reproducibility of the tests. The test scenarios not only need to check if the system works correctly but also have to assess the quality of performance in terms of the effectiveness of the ADAS. Therefore the expected improvement of the system on the accident situation has to be considered. A measure of the effectiveness of an AEBS could be the reduction of the collision speed, the time interval between activation of the system and the collision, the degree of improvement from speed reduction to accident avoidance etc.

Also retrospective assessment using accident databases is not free of difficulties: The current market penetration of ADAS is low since on the one hand the systems are only installed in new vehicles and thus depend on the turnover of the vehicle population and on the other hand the equipment rate of new vehicles with ADAS is well below 100%. Furthermore the ADAS are constantly refined, leading to an ever improved performance. E.g. the ESC of 1995 applied the brakes a single wheel only, the ESC of 2012 can apply different braking forces to all 4 wheels. For a statistically backed assessment of the field effectiveness, a large number of coded accidents are required. As larger accident databases tend to provide less detailed information on the accident situation, the vehicles, etc., they allow mainly for a generalised assessment of the potential of the ADAS. Furthermore accidents avoided by ADAS already in the market no longer happen and thus are not accounted for in the accident statistics. In order to estimate the number of accidents avoided by use of ADAS it can be attempted to compare the accident frequency distributions of vehicles with and without the ADAS. The objective assignment of differences in accident frequencies to individual ADAS ranges from difficult to impossible as current ADAS complement each other on their functionality. Furthermore several ADAS are offered as packages making ADAS impact assessments for individual active systems even more difficult.

For use of simulation in ADAS effectiveness assessment there are two main requirements: 1.) An accident database with detailed information on the precrash phase, e.g. GIDAS, CZIDAS, CCIS. Information on the precrash phase is vital as it is during this phase of the accident when the actuators of active systems, i.e. ADAS, try to intervene and modify the severity of the accident situation. 2.) Information on the functionality of the ADAS system like sensors, algorithm, and actuator. Thus a level of disclosure has to be defined, leaving the notion of the ADAS as a black box to make the assessment transparent and comprehensible, at least to a certain degree.

When assessing an active system the functional overlap of different ADAS has to be taken into account. Therefore, for each system being investigated one needs to establish the share of real world accidents which is addressed by the system as well as the share of the accidents addressed by other systems already in the market or in the vehicle. This analysis of functional overlap in the context of the overall accident situation is fundamental for any assessment of the effectiveness of an individual ADAS.

There are different advantages and disadvantages to each of the approaches of ADAS affectivity assessment:

1. Real (vehicle) tests

   Advantages:

   - The effect of the ADAS is tested in real world scenarios; weather influences etc. can be taken into consideration, though they are notoriously hard to reproduce.
   - Many solutions are available, on tracks, on simulator or on opened road.
   - Interaction with the real traffic is available on opened road

   Disadvantages:

   - The number of test scenarios: Which and how many test scenarios do you need to cover the complexity of an active system and what share of the real accident occurrence is really covered by it?
   - How many drivers and which profiles are useful to validate the test?
   - Are all results from the test scenarios reproducible?
   - Is the test scenario already addressed by another ADAS which is not under consideration now? Can those other ADAS systems really be switched for testing without compromising overall vehicle performance? Can they really be switched off? Do they automatically reactivate in the test condition?
   - High costs: there is a need for a detailed protocol, the correctly working function has to be supposed before any real test, no person may be exposed to dangerous situations; it has to be considered which mode of a system is tested: automatic ones like ESC, driver activated systems like ACC, or depending on the driver like a drowsiness warning.

2. Retrospective analysis

   Advantages:

   - Exact determination of effectiveness is possible if accident data is available in sufficient quantity, quality and depth. Sufficient depth and quality means that detailed data is available for specific analysis regarding the ADAS under consideration. The data must contain information on specific parameters in a high enough sampling and coding quality so that e.g. the analysis is not based on dummy variables which come close to the desired parameter but doesn't meet exactly. Sufficient quantity means that statistically reliable results can be worked out.

- Estimation methods are comprehensible and validated . Such methods and sample applications are given in deliverable 5.6 of DaCoTa ("Evaluation Tools")

Disadvantages:

- Field effectively assessment of a newly introduced ADAS system is not possible within a short period of time: The market penetration of the ADAS must be relevant for an assessment using accident data: No accidents, no assessment.
- Can the effectiveness of an advanced driver assistance system be assessed separately from other systems or do the functions of systems overlap so that separate assessment is difficult or nearly impossible on the basis of a limited database?
- If an ADAS is avoiding accidents these avoided accidents are no longer in any accident data base. Thus a direct analysis is impossible. An indirect analysis maybe imprecise as the separation of the influence of different ADAS is more difficult than in direct analysis.
- Details on the ADAS of each vehicle involved in a road accident are needed.

3. Simulation

Advantages:

- Real accidents can be depicted and the accident situation can be appraised with a safety system. The results are statistically representative for the effectiveness if representative accident data is available in sufficient quantity, quality and depth. Safety systems that are already on the market can be taken into consideration.
- The driver can be integrated into the loop if a model of driver behaviour is available (e.g. knowledge brought by naturalistic driving)
- Simulations are reproducible.
- Several technical solutions could be tested (e.g. for the development or to optimize the effectiveness)

Disadvantages:

- Some Information on the technical specification of the system to be simulated is needed. As most of time detailed information on the system is confidential a level of disclosure has to be defined.
- Accident data with detailed information on the precrash phase (e.g. speed, braking or steering manoeuvres) is needed. The data must be statistically representative or the data has to be weighted.
- What is the degree of abstraction in the simulation?
- How is the simulation validated?

- Changes in the traffic (e.g. driver adaptation) are not taken into account if they can't be modelled and integrated into the simulation.

An investigation into false positive deployments of the system is desirable. For real tests as well as simulations, further scenarios are conceivable that check the possibility of false positive deployment. In simulations, a rough estimate of the consequences of false positive deployment is also possible by parameter variation. In the retrospective analysis, this kind of assessment is also possible to a very limited extent since false positive deployment is only listed in accident data if it caused an accident.

Since the retrospective analysis cannot be used for an a priori assessment of an ADAS, this method will not be dealt with any further.

1.4 Requirements for assessment methods

Various requirements should be set for an assessment method to be developed that will be looked at more closely in the next section.

1. Specification of the share of the real accident occurrence that is addressed by the system being evaluated.
2. Identification of all accident scenarios in which the system should be activated (both for real tests and also for simulation).
3. Consideration of other systems that are already on the market (overlapping of target populations).
4. It should be avoided that an ADAS with a very limited operating rage—the worst case scenario would be a system singularly addressing the test condition—is positively assessed. These ADAS developed for the test conditions would exhibit a very restricted benefit to the overall real world accident situation.
5. The results must be transparent, comprehensible, deterministic, and thus reproducible.
6. The possible market penetration should be taken into account (ADAS as standard issue or as a luxury option).
7. For the assessment of the real world benefit, the warning strategy and the HMI concept has to be taken into account.

Identification of the share of accident situations addressed by an ADAS.

This target population of an ADAS can be identified by analysing accident data. First of all the number of addressed accidents has to be determined, taking the accident severity outcome (property damage, lightly injured persons, ..., fatalities) addressed by the system into account. The target population of an ADAS system is possibly limited by additional pieces of information (e.g. system only active in daylight, only in specific speed ranges, not under all weather conditions). The quality of the answer also depends on the depth and size of the database used. If the database is too small or parameters with sufficient detail depth are not included, only a rough estimate of the addressed share of accidents can be made.

Identification of all accident scenarios in which the ADAS should be activated (both for real tests and also for simulation).

Conversely one can use a set of questions to specify the target population: What does a typical accident addressed by the advanced driver assistance system look like? Does it occur more frequently in the dark, more frequently at junctions, more frequently outside built-up areas, on motorways or in built-up areas? At which speeds do these accidents occur? At which angle did the vehicles collide etc.? The more in-depth such questions are answered, the better the addressed accident scenarios can be identified. These results are thus essential for answering the question of how the typical accident addressed by the system can be described or whether it happens at all and in which accident situations the ADAS concerned would have been activated. This is essential for a good test set-up independent of the system or for an assessment based on a simulation. One suitable accident database is GIDAS (German In-depth Accident Study, [GIDAS 2003]),) which is representative for Germany (with weighting factors). Other accident databases (e.g. CCIS, etc.) may be used. For weighting GIDAS to Europe EuroNCAP has made a suggestion (Referenz). Currently the GIDAS consortium is looking into the weighting problem.

Consideration of other ADAS that are already on the market (overlapping of target populations).

If vehicles with other driver assistance systems are already on the market, it must be ensured that only the additional effectiveness in preventing an accident/reducing the consequences of the accident is assessed.

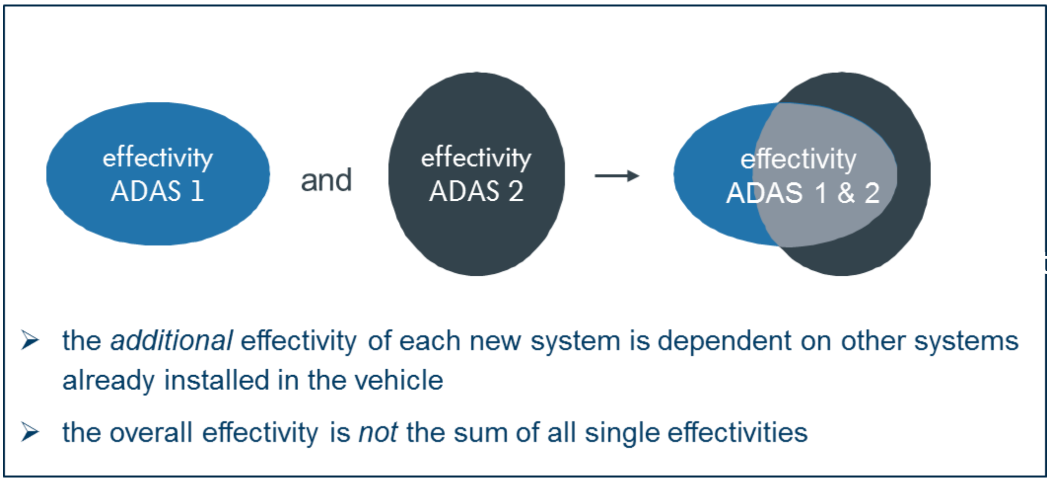

Figure 2: Overlapping target populations of driver assistance systems (ADAS)

Can the effectiveness of an ADAS be assessed independently from the vehicle it will be deployed in? Put in others words, can an ADAS be assessed independently of the passive safety level of the vehicle?

Obviously the passive safety level can be ignored in the evaluation of ADAS able to avoid accidents. In accident mitigation systems one focusses on injury severities or fatalities the passive safety level is important in assessing an ADAS. But under the premise that the passive safety level of the vehicle will not be changed by the incorporation of an additional ADAS into the vehicle the accident mitigating ADAS will result in an injury severity shift towards a lesser injury severity. The injury severity shift for vehicles with a lower level of passive safety should be higher than that for the ones with a higher level, as it is more likely that a passenger compartment failure can be averted. Furthermore the benefit of a set injury reduction is higher for more severely injured than for the less uninjured. Thus testing an ADAS in a vehicle with a high passive safety level will underestimate the injury severity reduction seen in vehicles with a lower passive safety level.

The problem of developing an active safety system just for a tightly defined test scenario and not for broader real world situations must be addressed. Otherwise a high score in the test will not lead to real world effectiveness.

By selecting suitable test scenarios and configuring the test environment, no sensor types, algorithms, driver models or also actuators should be preferred or placed at a disadvantage. The relevance of the assessment results must be ensured for the actual accident occurrence.

Examples:

1. When comparing the ADAS of different OEMs the same functionality can be achieved by use of different sensors and sometimes even different actors.

Sensors used are either passive, i.e. not emitting anything, or active, i.e. illuminating the targets. Typical passive systems are cameras in the visible range as well as IR-range and PMDs. Active systems include ultrasound detectors (PDC), RADAR, LINDAR, LASER-Scanners etc. The different properties of the waves detected as well as the different frequency range of those waves result in different kind of images. By combining sets of sensors the properties of the detected objects can be specified in greater detail. Sensor sets are also used to validate the signals of the individual sensors against each other, reducing false positive and false negative readings.

Taking the autonomous emergency braking system (AEBS) as an example, the object that should not be crashed into could be detected by either optical sensors, RADAR based sensors or even the ultrasonic detectors. Either sensor would be capable to do the job, within certain speed ranges. In a test system using real hardware for the objects to be detected, these hardware substitutes have to be detectable by the specific sensor used by an autonomous braking system. This is a minor problem for AEBS systems designed for car-to-car crashes, but in systems designed to mitigate pedestrian accidents, i.e. car-to-pedestrian crashes, the situation can become very complex.

2. ADAS system design is a trade of between goals: Taking the responsiveness of the brake as an example, a fast acting break will result in a shorter breaking distance at the cost of vehicle stability. When performing brake tests on a straight road, the reduction in vehicle stability is of minor importance. But real world emergency braking is rarely done on straight road sections but on bends, uneven road surfaces, under wet conditions etc. Thus the construction of a test scenario has to take the systems that are on the market as well as those close to introduction into account.

The possible market penetration should be taken into account (ADAS as standard issue vs. optional extra).

In the assessment, it should be taken into consideration whether the ADAS should be offered as standard equipment or an option.

The system design regarding warning to autonomous action has to be taken into account and also the driver / HMI concept has to be considered.

An ADAS can provide anything from a simple warning beep to a completely automatic driving maneuver or even an escalating cascade. The responsibility for the actions of the ADAS is firmly assigned to the driver. For most of the later ADAS like lane assist, lane departure warning, this is obvious as the driver can deactivate the functionality. For some of the more fundamental ADAS like ASR, ABS, or ESP the responsibility of the driver is not obvious on first sight, as these systems are neither deactivate able nor is the driver able to override the action of the ADAS. Therefore the extent of assistance or automation should be included in the assessment. As many systems are activated only if the driver activates them (e.g. autonomous emergency break, lane assist) an acceptance of the system is important. In as far as the acceptance can be measured and should influence the assessment should be discussed. A related aspect is the HMI concept and its effects on the ability of the driver to use the system in the intended as as well as changes in driver behavior by use of the system. A driver's trust in a specific ADAS can be the result of high reliability of the ADAS under standard conditions. The most striking example of this thrust and consequent overreliance on ADAS is the abuse of ACC in foggy conditions, the so called 'Nebelrasen' were the driver uses the radar beam of the ACC under conditions of low/no visibility to drive 'safely' at unreasonable speeds.

A subjective assessment of the system should not find its way into the assessment, as the expectations of a driver would influence this part of assessment and the expectations are dependent of the driver population which may be different for different cars.

1.5 Limitations in assessment of advanced driver assistance systems

In the development of realistic test scenarios or in the simulation of accident scenarios, the analysis of human factors should not be neglected. Today's and also future ADAS increasingly act with escalation stages like warnings, partial and full braking manoeuvres or also steering manoeuvres that are performed by the vehicle and can be suppressed by the driver. Therefore differentiated models for driver reactions to the different deployment stages should be examined in addition to the regular factors like reaction times, type and extent of reaction (e.g. braking / steering / no reaction). This must be taken into consideration in future both in simulation models and also in the test set-up.

Solely because of the fact that a real test or a series of tests represents an abstraction, concentration and selection of real accidents, support from computer-supported simulation is recommended as described in chapter 1.6. For an objective assessment of an ADAS, at least additionally a simulation based on a wide-ranging accident database is indispensable so that, for example, the reaction time of a test driver is not reflected or a positive assessment of a driver assistance system tailored exactly for the test situation which shows little benefit in real accidents cannot occur.

Simulating all relevant real accidents allows a good prediction of the impact of an ADAS on the whole accident occurrence. Conversely whether a test scenario is desirable in addition to a simulation depends greatly on the result of the target population analysis. If a few test scenarios cover a large and decisive proportion of the real accident occurrence, they can thus support the result of the simulation. If, however, each individual test scenario only represents a small share of the accident occurrence, it can contribute little to the assessment of the ADAS. Associated with the analysis of the target population as well as the simulation is the selection of the database. It must be ensured that the analysis based on any appropriate database lead to comparable results if the same methodology / simulation process is used. Maybe the solution will be a referenced database.

When the results of a simulation and / or test scenarios have been obtained the result have to be generalized to the accident occurrence in Europe or a specific country. The problem of weighting the singular results of each test in a test series can be avoided by using the proportion of the target population and thus of the effectiveness calculated by the simulation. If there is no estimation of the influence of an ADAS on the whole accident occurrence (as simulation offers) the problem of weighting the singular results of each test scenario arises. Afterwards a method for generalization of the results to Europe or a specific country can be done by a method of projection.

1.6 Assessment of effectiveness using software simulation

One possible assessment method for determining the effectiveness of an active safety system is software simulation. To obtain a statistically representative statement on the effectiveness, a multi-stage assessment process is necessary.

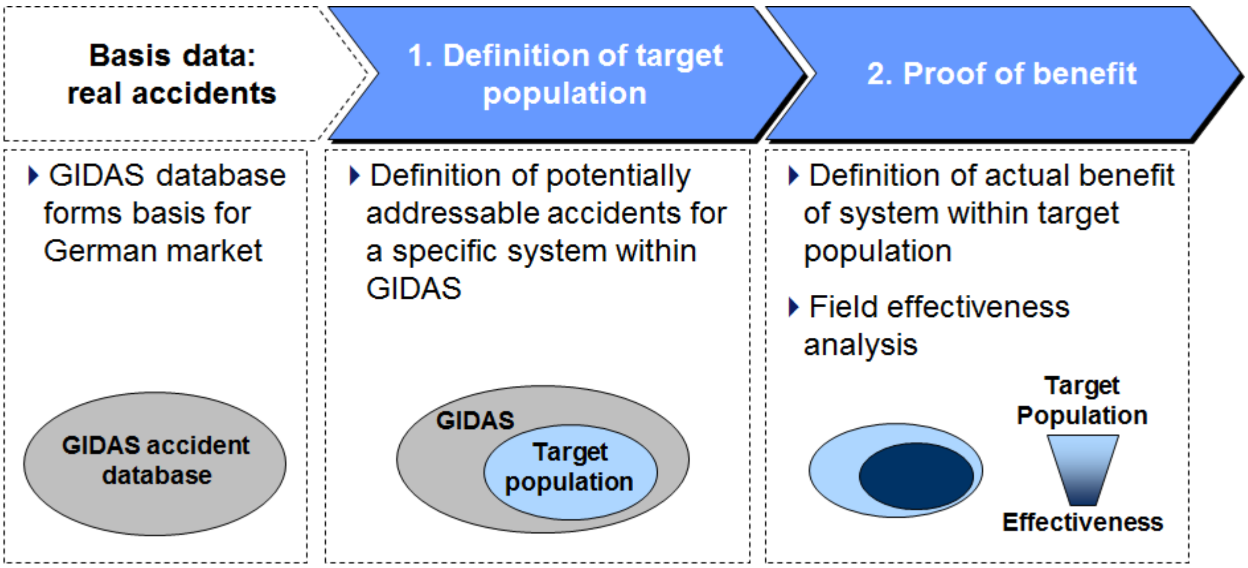

Figure 3: Two-stage approach for proving effectiveness

As shown in figure 3, this process is divided into two basic steps. At first, the effective area of the system is determined on the basis of the accident database, i.e. all potential addressable accidents. The requirement for this is detailed knowledge of these accidents. Here, it is not just the collision itself and its consequences that are decisive, but in particular also extensive knowledge of the pre-crash phase since the active safety systems act during this phase. The optimum basis for this is a numerical description of the pre-crash phase based on accident reconstructions.

For Germany, corresponding data is provided in the GIDAS database (German In-Depth Accident Study, [GIDAS 2003]), for which approx. 2000 road accidents in Hanover and Dresden have been recorded in detail each year since 1999. Beside GIDAS itself, the method of detailed accident reconstruction can also be adopted to other countries like e.g. the Czech Republic, where a GIDAS pendant named CZIDAS is in progress to be built up. Of course, any other accident database with an adequate level of detail can also be used.

The target population as a subset of all available accidents in the database simultaneously represents the upper limit for the effectiveness of the system and corresponds with the effectiveness of a perfect safety system that can prevent all accidents it addresses. In reality, the benefit of a system will always be smaller than its target population. While the target population can still be determined via a selective database query, an accident simulation with precise times and geometry is required to determine the benefit.

The complete procedure for an assessment is shown in figure 4. The starting point is the German accident occurrence that is available in a sample in the form of GIDAS PreCrash matrices (see [Erbsmehl 2009]), which can be simulated. The “reference accident occurrence”, for which the behaviour of the vehicles in the selected accidents is adapted to the current safety level, is looked at in particular. If not installed in the accident vehicles, e.g. ESP, brake assist, rigid passenger cell are included in the assessment procedure. Without this adaptation to the current safety level, the effectiveness of the safety systems would be overestimated since the risk of injury in newer vehicles is lower and, when the ADAS that is currently in development is introduced, the old vehicles will only be on the market in small numbers. If you define the risk of injury from the GIDAS basic data with 100% as the starting point, the modern vehicle fleet already reduces this by about 20%. Any benefit of a safety system may only be indicated starting from this value.

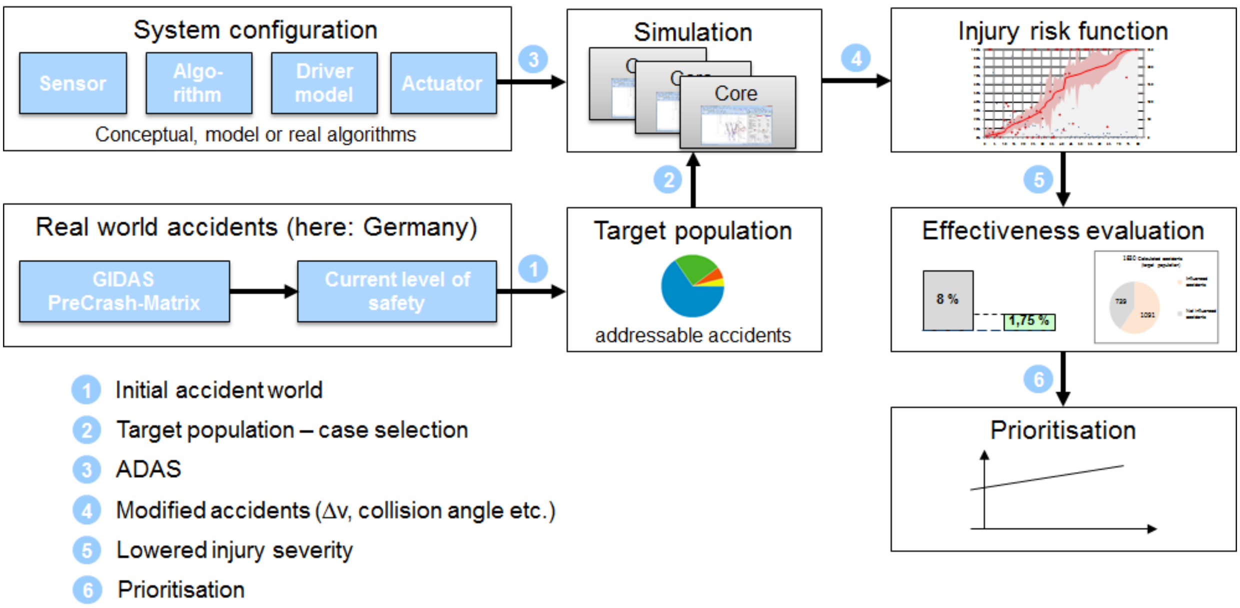

Figure 4: Effectiveness assessment process

In the next step, the target population of the system being assessed is defined. This simultaneously means a selection of cases for the accidents to be simulated. The cases selected in this way are simulated in the next step. The basis for the simulation is formed by a core that calculates the driving dynamics and considers the components of the system configuration. The result of this simulation is modified technical collision parameters like for instance Δv (value for change in speed during the collision), collision angle and point of contact for each individual accident.

On the basis of various injury risk functions according to collision type and type of road users the modified accidents are evaluated considering the original and the modified accident severity. That means, for every person involved in one of the addressed accidents the original injury risk and the injury risk for the modified accident is known and can be compared. For all other accidents (not within target population) the injury risk remains constant.

To assess the effectiveness of the ADAS, all persons involved in an accident are taken into consideration and the individual risk of injury for every person is added up for all calculated accidents. For the projection of the considered accidents of the accident database to the considered market (e.g. Europe) every accidents / person is provided with a weighting factor. The total effectiveness of the system is obtained as the quotient of the relative difference of the overall injury risk for vehicles with the considered ADAS and the overall injury risk for vehicles without the ADAS (original injury risk) and the original overall injury risk as denominator:

$$eff_{ADAS} = \frac{\sum_{i=1}^{N} [f(i) * \{IR]_{no\,ADAS}(i) - IR_{ADAS}(i)\}}{\sum_{i=1}^{N} f(i) * IR_{no\,ADAS}(i)}$$

with

$f(i)$ weighting factor for the person $i, i = 1, \ldots, N$

$IR_{ADAS}(i)$ injury risk of person i in a vehicle with ADAS, $i = 1, \ldots, N$

$IR_{no\,ADAS}(i)$ injury risk of person i in a vehicle without ADAS, $i = 1, \ldots, N$

N number of persons in the considered database, not only target population

where $\sum_{i=1}^{N} f(i) = N^*$ for N^* being the number of injured persons in the considered market (e.g. Europe).

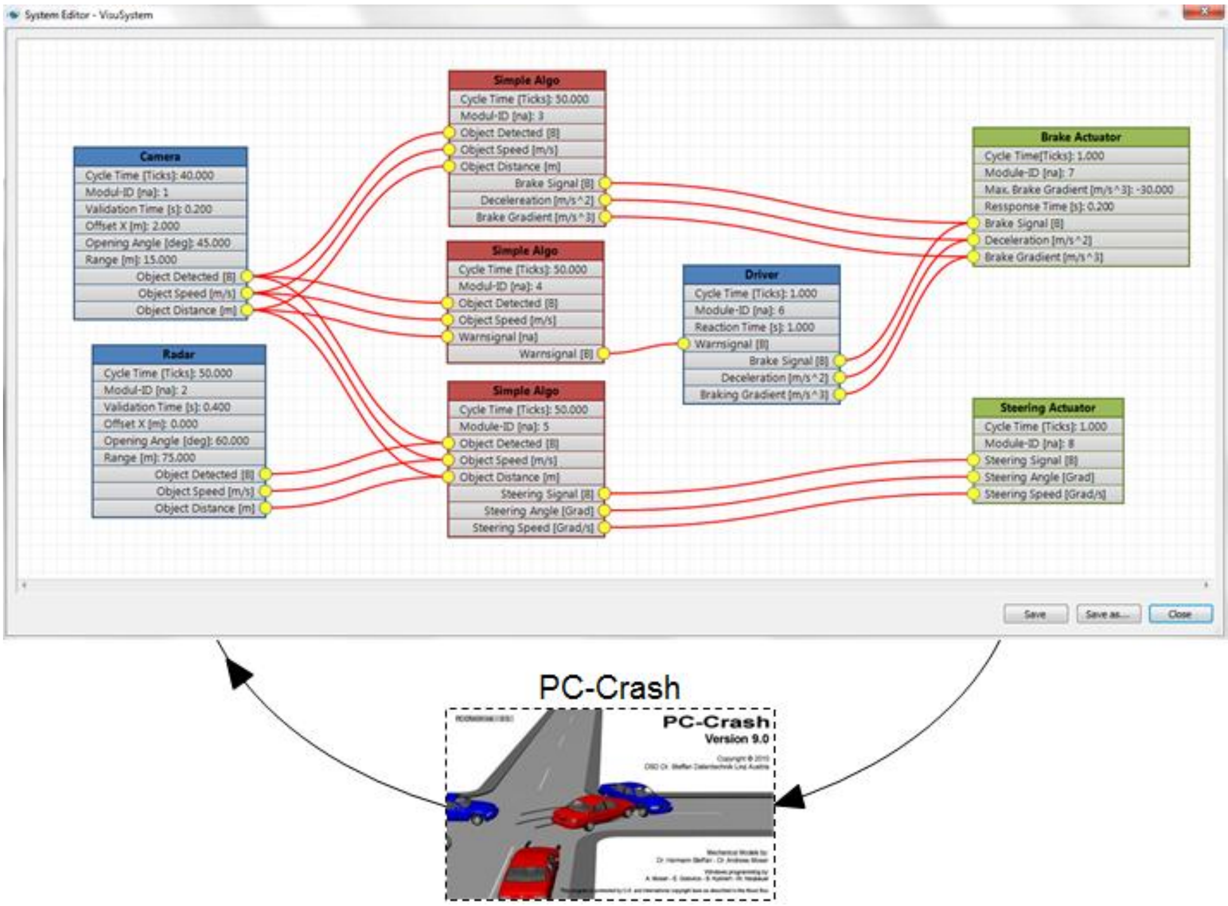

Figure 5: Simulation with rateEFFECT and PC-Crash

The rateEFFECT software developed by Volkswagen Group represents a possible way of implementing the previously described simulation set-up. The professional accident reconstruction software PC-Crash [DSD 2012] is used as a basis for calculating the driving dynamics. The DAS components (see figure 5) implemented in rateEFFECT that are assessed in each simulation step of PC-Crash and could have direct influence on the driving dynamics are incorporated via an interface.

1.7 Example for an Evaluation of an ADAS

The method for the evaluation of an ADAS described in the previous chapter shall now be explained in the context of a fictitious example. Therefore, a fictitious automatic emergency brake (AEB) is taken as a typical present ADAS. The benchmark for this evaluation is the effectiveness in the real German accident world, which means the reduction of severely injured people and fatalities. The according severe accidents are available in GIDAS and can be simulated by our tool.

1. Out of all available accidents in GIDAS, only those are selected which can potentially be influenced by the ADAS. In the case of a fictitious AEB, these are accidents e.g. between two passenger cars in longitudinal traffic with both vehicles travelling in the same direction.

   This subset of accidents is the target population of the ADAS. It describes the upper bound of the possible effectiveness which would be reached if all accidents in the target population could by avoided by the ADAS. The definition of the target population might also be stated more precisely by including additional technical restraints of the AEB e.g. still standing vehicles cannot by detected by the system's sensor. If those accidents are excluded from the target population, the target population itself is reduced but the effect within the target population is enhanced, as there will be less not influenced accidents. The dependency between the definition of the target population and the calculated effectiveness implies that only both results together describe the outcome of an evaluation completely.

As the benchmark for any type of ADAS is the reduction of severely injured people and fatalities, the target population for an active pedestrian safety system might be much higher than for the described AEB. Especially in the scenario of rear end collisions between two passenger cars all passengers benefit from the passive safety systems, so that severe injuries might only occur at higher collision speeds. If a pedestrian is hit by a passenger car, even at lower speeds the risk of severe injuries is rather high. This is one example why not only the final effectiveness but also the definition of the target population is important when interpreting the results of different systems.

2. After defining the subset of GIDAS accidents for the simulation, the ADAS has to be modelled in the tool. A typical AEB consists of a sensor to detect other vehicles, an algorithm to decide when the level of criticality for activation is reached and a brake actuator, which transfers the commands of the algorithm to a deceleration of the vehicle. For example, standard modules of previous evaluations for the sensor and the brake actuator can be used so that only a new software module for the algorithm has to be implemented.

   Generally, each new implemented software module should be validated before it is used for an evaluation. This validation might be realised by a comparison with another already validated software module in a different software framework. Also a simulation of defined test cases or a matching with measurement data of real test drives is possible. If all modules of a system are validated, a validation of the system as a whole using the same methods should be taken into account to guarantee the correct implementation.

3. In the step of the simulation, all accidents of the target population are recalculated implicating the modeled AEB. The result is an amount of avoided, influenced or not influenced rear end collisions.

   Some accidents might not be influenced by the AEB due to restraints of the system (e.g. no detection of still standing obstacles). Another reason might be the original driver reaction. If the driver already tried to avoid the accident by fully braking and if the AEB is not activated before the driver begins to brake, there will be no benefit of the AEB in this case.

   After the simulation modified crash parameters are available for all avoided and influenced accidents.

4. The recalculated accidents are evaluated using an injury risk function. In the case of collisions between two cars, such an injury risk function takes into account the size and the direction of the crash impulse. For each passenger in the cars, the new injury risk is calculated, regarding the seat position i.e. if he is sitting towards or away from the crash impact. The relative reduction of the injury risk for all simulated accidents represents the system's

effectiveness in the target population (see 1.5). If one parameter of the AEB is modified, e.g. the detection range of the sensor is shortened, the effectiveness of both systems can be compared directly.

To achieve a comparable standard benchmark for all types of systems, the results within the target population have to be mapped to a neutral base, e.g. the European accident statistics or the each national accident statistics. In this way it is possible to compare systems with different target populations.

1.8 Standardisation of assessment process

Standardisation of methods for estimating the effectiveness of active systems is also pursued at national level in Germany.

For instance in the joint project UR:BAN, 30 partners from the automobile and supplier industry, electronics, communications and software companies, universities as well as research institutes and cities have teamed up to develop driver assistance and traffic management systems for cities.

One focus of the project is increasing safety in city traffic through the continuous support of the driver in complex traffic situations, e.g. junctions. All urban challenges for which assistance functions are developed, are accompanied by target population estimates and effectiveness assessments.

In order to assess the influence on the accident occurrence of the assistance functions and to compare them according to specific function, standardisation of the assessment method is important. Furthermore this is the only way to assess the interaction of several assistance functions unequivocally.

2 CONCLUSION

In this report we discussed the different approaches to testing and validation of active safety systems. Though the retrospective look at a shift in the accident situation seems the easiest way to go, it's inherent time delay from getting the system into the market, a relevant number of deployed units, and finally a sufficient number of accidents of vehicles equipped with the system tint the usefulness of this approach for testing new systems and forecasting their effectiveness.

Direct testing of an ADAS requires intricate knowledge of the used algorithm like speed rage, sensor performance, as well as actuator characteristics. A universal test for a specific ADAS cannot take these specific characteristics into account. Thus a universal test procedure would influence future ADAS development in so far as ADAS developers would certainly try to obtain the best possible test result for their systems. A test procedure for a given ADAS would seriously hinder new implementation approaches. Furthermore the test of a single ADAS would not take the aggregated performance of several ADAS in a given vehicle into account, e.g. a rear traffic alert system could be used to modulate the braking deceleration of an automatic brake assist: In absence of rear traffic a higher braking pressure could be applied in order to avoid and not only to mitigate an accident.

In order to avoid an overburdening influence of ADAS testing procedures on ADAS design, either the number of different test scenarios has to be very high. As cost and time constraints hinder a very large number of real world tests, virtual testing seems to become a viable way to proceed. Using simulation tools accident scenarios can be varied in nearly infinite ways and efficiencies of single ADAS or sets of ADAS can be computed. These efficiencies can then be used to project to overall effect on the accident situation. Thus testing by simulation of ADAS is done using guidelines with the overall traffic situation in mind and not specific ADAS implementation limits.

A validation of the real world effectiveness of an ADAS or a set of ADAS should be performed using aggregated accident data, with the above mentioned market penetration issues and time constraints in mind. Currently we are at a cross road where too tight a testing regulation will hinder developing of new innovative and accident mitigating ADAS. But an unfocused use of resources will divert resources from ADAS with a high impact on the accident situation.

In order to create comparable results by all manufacturers, a standardisation of the possible test scenarios and the simulation methodology is needed. The process of standardisation is rather involved, as there are already countless in-house methods used for ADAS effectiveness evaluation. Defining a national standard requires further major effort.

SOURCES

DaCoTa D5.6 2012

Hautzinger, H., Pfeiffer, M., Simone, M.-C. (2012): Evaluation tools, Deliverable 5.6 of EC FP7 project of DaCoTa.

DSD 2012

Dr. Steffan Datentechnik (DSD): ***PC-Crash*** http://www.dsd.at/

Erbsmehl 2009

Erbsmehl, Christian: Simulation of real crashes as a method for estimating the potential benefits of advanced safety technologies, 21st International Technical Conference On the Enhanced Safety of Vehicles, 2009

GIDAS 2003

Otte, D., Krettek, C., Brunner, H., Zwipp, H. (2003): Scientific Approach and Methodology of a New In-Depth-Investigation Study in Germany so called GIDAS;
ESV Conference 18

OECD 2008
http://www.internationaltransportforum.org/jtrc/safety/targets/08TargetsSummary.pdf

UR:BAN, www.urban-online.org, 13/9/2012

Unfallverhütungsbericht Straßenverkehr 2010, Deutscher Bundestag 2012, Drucksache 17/10600
http://dipbt.bundestag.de/dip21/btd/17/106/1710600.pdf