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RESPONSE 3
a PReVENT Project

Code of Practice
for the
Design and Evaluation
of ADAS

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Foreword

The Code of Practice (CoP) comprises a suitable ADAS (Advanced Driver Assistance System) description concept including ADAS specific requirements for system development. It summarises best practices and proposes methods for risk assessment and controllability evaluation. The Code of Practice has been produced by a group of experts within the RESPONSE 3 project, a subproject of the integrated project PReVENT, a European automotive industry activity, co-funded by the European Commission, to contribute to road safety by developing and demonstrating preventive safety applications and technologies.

The RESPONSE 3 project ended in October 2006 delivering the Code of Practice in its version 3.0. This document is a retranslation of a German adaption.

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Revision chart and history log

Version	Date	Reason
3.0	31.10.2006	Deliverable of the RESPONSE 3 project
3.04	31.10.2007	Draft of a english adaption according to German version 3.5
3.6	10.12.2007	Included remaining open topics of comment sheet and harmonized most recent changes with german version (now also 3.6)
3.6.1	26.9.2008	Clarification of formulations and typo correction in Annexes A.1 and A.2
4.0	15.12.2008	Formal revision of entire document (including annexes) for distribution to ACEA members; no change of content
5.0	13.8.2009	Formal revision of document for release by ACEA

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1 Introduction

1.1 Motivation

Advanced driver assistance systems will play a major role in road safety in Europe. Experience gained from research on ADAS shows, that many ideas have been applied in prototypes with safety features, but only few have been introduced in series production.

Existing technical limits as well as liability issues are currently delaying the market introduction of Advanced Driver Assistance Systems.

Resulting from the Response 1 project (1998 - 2001) the creation of a Code of Practice (CoP) was proposed for the development and validation of ADAS. This implies to establish “principles” for the development and evaluation of ADAS on a voluntary basis, as a result of a common agreement between all involved partners and stakeholders, mainly initiated by ADAS manufacturers.

The proposal to establish such a Code of Practice was confirmed by the Commissions Communication COM(2003) 542 of 15 September 2003.

The requirements for the Code of Practice have been elaborated within the project RESPONSE 2 (2002 – 2004).

RESPONSE 3 has now finally developed the CoP to provide the vehicle industry with the tools and common understanding to overcome and to help managing the problems about safety concerns and liability of Advanced Driver Assistance Systems.

The application of the CoP is a possibility to demonstrate that state-of-the-art procedures in ADAS development have been applied, including risk identification, risk assessment and evaluation methodology.

The current status of development makes it very difficult to describe the state-of-the-art knowledge of ADAS, because there are so many systems with different technology addressing even more different assisting functions.

This links the liability discussion to the question when a product is called “defective”. The term "defective product" is used in the European Product Liability Directive not only in a technical sense but also in the context of the use of a product. There it says: A product is defective if it does not provide the safety a person is entitled to expect, taking into account all circumstances, including: (a) the presentation of the product; (b) the use to which it could reasonably be expected to be put; (c) the time when the product was put into circulation. This includes requirements for system design, dependability, comprehensibility, predictability and misuse resistance.

The RESPONSE 3 consortium is now encouraging all people involved in the ADAS development to benefit from applying the Code of Practice in their companies

1.2 Scope

The Code of Practice applies to advanced driver assistance systems (ADAS). It is not specifically intended to be applied to systems providing vehicle stabilisation (such as ABS and ESP) or mere information and communication systems (such as navigation systems and telephones). It may be applicable to systems including vehicle to vehicle communication, but will not cover these completely.

ADAS are designed to actively support the driver in the primary driving task to either increase comfortable or safe driving. (see Table 7 in Annex E for a list of systems). Systems that support the driver by issuing warnings without intervention are not within the scope of this CoP although the recommended approach and the provided checklists may prove valuable also for these kinds of systems.

In contrast to conventional driver assistance systems, ADAS require the detection and evaluation of the vehicle environment with the respective sensors and a complex signal processing depending on the driving task to be supported. This also includes collection and evaluation of infrastructure data if available. This functional extension means a significant increase in system design complexity since the vehicle environment is incorporated into the assistance function. Due to the system limits of environmental sensing systems, the usage of the assistance functionality will also be limited. This implies that a direct interaction between the driver and the system is necessary. This interaction has to be controllable also with regard to current legislation (Vienna Convention)

The CoP serves as a support tool for the engineer engaged in the development of ADAS. CoP not only means a compilation of currently available procedures, but also offers clues for determining activities to be performed during the individual development phases.

Focus of the CoP is the system design against the background of system controllability and the total vehicle from the field of view of Human Machine Interaction. Of course system influences due to occurring defects/errors do play an important role as well as ADAS behaviour at system limits and foreseeable misuse.

Moreover, the CoP is also intended for automotive manufacturers and suppliers dealing with specification, realisation and assessment of ADAS. The CoP has been compiled by gathering best practices of the partner companies and also considers legal requirements and the RESPONSE 2 results

The CoP deals with specification and assessment of advanced driver assistance systems during the entire development phase. Therefore, it will not address issues arising after SOP (start of production).

The CoP structure allows implementation as part of a company specific development or quality process. Requirements are supplied for each development stage and are clearly separated from checklists and method descriptions in the document in order to provide an overview for each task. The use of the checklist procedure assists in the specification of ADAS in order to also consider aspects which may not be obvious right from the beginning. The hazard and risk analysis procedure provides assistance in setting up a systematic analysis of driving situations in order to determine potential risks.

The CoP also comprises the description of methods and tools for the assessment of ADAS safety.

The CoP should not stipulate a uniform ADAS design. It should be valid for various vehicle types and systems with many complexity and integration levels for the application in all ADAS.

All in all the CoP aims at serving as a guideline assisting persons involved in ADAS development to adhere to the state-of-the-art knowledge with respect to risk identification and risk assessment as well as methodology for the evaluation of driver controllability.

2 Terms and Definitions

2.1 Definition of an Advanced Driver Assistance System (ADAS)

This definition gives an overview and classification of ADAS as a basis for the correct application of the CoP.

Driver Assistance Systems are supporting the driver in their primary driving task. They inform and warn the driver, provide feedback on driver actions, increase comfort and reduce the workload by actively stabilising or manoeuvring the car.
They assist the driver and do not take over the driving task completely, thus the responsibility always remains with the driver.
ADAS are a subset of the driver assistance systems.

ADAS are characterised by **all** of the following properties:

- support the driver in the primary driving task
- provide active support for lateral and/or longitudinal control with or without warnings
- detect and evaluate the vehicle environment
- use complex signal processing
- direct interaction between the driver and the system

With respect to the well-known categories of driving tasks, ADAS are mainly focussing on the manoeuvring level. For a detailed description of driving tasks and typical ADAS please refer to Annex E.

2.2 Glossary

1. **Abbreviated Injury Scale:** An anatomical scoring system for ranking the severity of injury (Association for the Advancement of Automotive Medicine).
2. **Adaptive Cruise Control:** Enhancement to conventional cruise control systems, which allows the subject vehicle to follow a forward vehicle at an appropriate distance by controlling the engine and/or power train and potentially the brake. (ISO 15622)
3. **Advanced Driver Assistance Systems (ADAS):** See chapter 2.1 for a definition of ADAS.
4. **Action:** An event initiated by the driver or the application
5. **Action slip:** A human action deviating from the intended plan, e.g. the driver want to shift gears but unintentionally pressed the brake pedal due to a missing clutch in cars with automatic transmission. An action slip often occurs if the driver is absentminded and may increase in frequency under stress. [Red 97][1]

[1] [Red 97]: Redmill, F ; Rajan, J: Human factors in safety critical systems; butterworth-Heinemann 1997, p. 49

6. **Architecture:** The fundamental organisation (both Hardware and Software) of a system embodied in its components, interaction among components, and to the environment, and the principles guiding its design and evolution.

7. **Automotive safety integrity level (ASIL):** One of four steps to specify the risk and its requirements for risk reduction with *D* representing the highest and *A* the lowest risk reduction class (ISO/WD 26262-1).

8. **Behavioural Changes (Adaptation):** Changes of the driver behaviour, which may occur following the introduction of changes to the road-vehicle-driver system.

9. **Code of Practice (CoP):** Guidelines for procedures and processes that may be used during specification and realisation of ADAS in order to state reasonable safety and duty of care. [IP_D4 06][2]

10. **Collision Avoidance:** System for warning and avoidance of a pending collision. [IP_D4 06][2]

11. **Collision Mitigation:** System that minimises the impact forces of a collision for vehicle occupants or unprotected road users to alleviate the effects of an accident. This can be achieved e.g. by autonomously applying the brakes of a vehicle before during and after a first collision.

12. **Concept phase:** Development phase beginning with the first sketch and ending with the transfer to the serial development. According to the generic development process described in the this Code of Practice the concept phase can be divided in a definition phase, a phase of comparison of alternative concepts and finally a decision and proof of one concept (see Figure 1).

13. **Comprehensibility:** Degree to which information is understood that is conveyed to the driver; the quality to be comprehensible; capability to be understood

14. **Controllability:** likelihood that the driver can cope with driving situations including ADAS-assisted driving, system limits and system failures (for a detailed discussion see chapter 4).

    NOTE: this definition differs from ISO 17287

15. **Definition Phase** The first development subphase of the concept phase where the system definition is drafted (see Figure 1).

16. **Development phase:** The time in the product life cycle where the system is developed from the first idea to production.

17. **Driver Distraction:** The process of diverting the attention of the driver from the driving-task to something else.

18. **Driver Intent:** The aim of the driver to perform an action.

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[2] [IP_D4 06]: PReVENT IP public deliverable IP D4 on Functional Requirements

[4] see definition of „valid subject“ in glossary

19. **Error:** The difference between the desired and actual value or performance of a system or human action.
20. **Failure**: The inability of a component or system to perform its intended function as designed. Failure may be the result of one or many faults.
21. **Failure Mode And Effect Analysis (FMEA):** A method to examine potential failures in a system or process, to evaluate consequences and define remedial actions (see C.2 for a detailed description).
22. **Fault:** An abnormal condition or defect at the component or sub-system level which may lead to a failure.
23. **Fault Tree Analysis (FTA):** A deductive analysis method that begins with a general conclusion (a system-level undesirable event) and then attempts to determine the specific causes of this conclusion (see C.3 for a detailed description).
24. **Function:** a) A description of what something does or is used for; b) A routine that returns a result.
25. **Functional Requirements:** A description what the system is required to do. Functional requirements make the basis of the scope of work of the project, defining user functions, system limitations, types of inputs and outputs, etc.
26. **Functionality:** A set of functions associated with software or hardware.
27. **Harm:** Physical injury or damage to the health of people either directly or indirectly as a result of damage to property or to the environment (EN 61508).
28. **Hazard:** Potential source of harm (EN 61508).
29. **Hazard and Operability Study (HAZOP):** A systematic qualitative technique to identify process hazards and potential operating problems using a series of guide words to study process deviations (see C.1 for a detailed description).
30. **Hazardous Situation:** Circumstance in which a person is exposed to hazard(s) (EN 61508)
31. **Homologation:** The granting of approval by an official authority based on a set of strict rules or standards to determine whether such approval should be given
32. **Human Factors:** An umbrella term for psychological, cognitive and social influencing factors regarding the interaction between humans and technology. Subarea of ergonomics.
33. **Human Machine Interaction (HM Interaction):** All the possible modes by which an interaction (direct or indirect) between the driver and one or more vehicle systems occurs.
34. **Human Machine Interface (HMI):** Element or sub-element of a system with which the driver can interact, i.e. all the input and output devices (e.g. knobs, switches, levers, displays), which permit the interaction between the driver and one or more vehicle systems.

35. **Impact analysis:** Determines which areas and previous work products are impacted by an intended change.

36. **Intervening system:** A system that triggers actuators like a braking or steering system based on environmental sensor information to avoid e.g. a lane departure or to mitigate a forward collision. Intervening systems usually include a preceding warning phase, therefore showing characteristics of both, ADAS and active safety systems.

37. **In-vehicle Information System (IVIS):** A system supporting the driver in the navigation task, i.e. giving information to support the driver in reaching their destination. Also referred as “driver information system”.

38. **Macroscopic Effects:** Effects (and consequences) that are shown by a system considered as a whole. In other words, they are the “global behaviour”, due to the interactions between the single elements of a system; opposite to macroscopic effects, there are the microscopic ones, which are due to the single elements constituting a system. In this CoP the “system as a whole” is often considered to be the traffic system while the “single elements” are the cars.

39. **Malfunction:** Referring to a system that is not performing its intended function.

40. **Manoeuvring Level:** The second of the three levels of a driving task (see also stabilisation and navigation level). Tasks related with adhering to traffic rules and avoiding collisions are within this category.

41. **Misuse:** Use of the (TICS) functions intended by the manufacturer to be used while driving in a way or manner not intended by the manufacturer and which may lead to adverse consequences (ISO 17287). Note the difference to “abuse” which is not covered by the CoP.

42. **Naïve subject:** An expression for a person that tests the ADAS under evaluation with no more experience and prior knowledge of the system than a later customer would have.

43. **Navigation Level:** The highest of the three levels of a driving task (see also stabilisation and manoeuvring level). Tasks related with finding a route to the driver’s destination are within this category.

44. **Normal Operation:** a system working under standard conditions (inside its operative range).

45. **Open item list:** Means to collect, document and track issues or questions that cannot immediately be answered while working on a certain topic (e.g. an open question from a checklist). See also Figure 3.

46. **Outlier:** In statistics, an outlier is a single observation “far away” from the rest of the data.

    In most samplings of data, some data points will be further away from their expected values than what is deemed reasonable. This can be due to systematic error, faults in the theory that generated the expected values, or it can simply be the case that some observations happen to be a long way from the centre of the data. Outlier points can therefore indicate faulty data, erroneous procedures, or areas where a certain theory might not be valid. However, a small number of outliers are expected in normal distribution.

Outliers have to be removed from the dataset in order to achieve correct results and draw the correct conclusions after an experiment.

47. **Perceptibility:** The possibility for the driver to perceive information that is presented to them by the system (see also: perception)

48. **Perception:** In psychology and in cognitive sciences, it is the process of acquiring, interpreting, selecting, and organizing sensory information.

49. **Physical Control Loop:** A control loop describes algorithms arranged as to regulate the output at a setpoint. The algorithms are using feedback to continuously optimise the output. The term “physical” describes the fact that the driver is within the loop, i.e. the feedback of the driver to the system action (or warning) is needed in order for the algorithm the work as intended.

50. **Predictability:** The degree to which a correct prediction of a system's state can be made either qualitatively or quantitatively.

51. **Primary Driving Task:** Those activities that the driver has to undertake to maintain longitudinal and lateral vehicle control within the traffic environment (ISO 17287). Namely, all aspects involved to control a vehicle.

52. **Proof of Concept:** The (optional) last development subphase of the concept phase to justify the preceeding steps (see Figure 1).

53. **Risk:** Combination of the probability of occurrence of harm and the severity of that harm (EN 61508).

54. **Road Users:** All type of subjects (including vehicles, pedestrians, cyclists etc.), which use the road and its layout.

55. **Secondary Driving Task:** Additional driver activities that are not directly related to the vehicle control e.g. tuning the radio, changing settings of the air conditioning, programming the navigation system.

56. **Series Development:** The development phase after the concept phase. The targeted development of a system concept for a specific car series.

57. **Sign-off:** The last step during product development concluding that the system is ready for production; based on evidence collected during development.

58. **Situational Awareness:** The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future.

59. **Specification (framework):** A set of requirements that have to be met by a system.
60. **Stabilisation Level:** The lowest of the three levels of a driving task (see also stabilisation and manoeuvring level). Tasks related to keeping the car under control (lateral and longitudinal).
61. **System:** A collection of components organised to accomplish a specific function or set of functions.
62. **System Limit:** The operational limitations of a system. A limitation is defined during development or implicitly introduced due to physical/technical constraints, a restriction of operative scenarios, intrinsic functionality of hardware components etc.
63. **System State**: The state in which a system (or its sub-system) actually is.
64. **Usability:** Concept comprising the effectiveness, efficiency and satisfaction with which specified users can achieve specified goals in a particular environment (ISO 17287).

    NOTE As well as effectiveness, efficiency and satisfaction, usability involves learnability, controllability, error robustness and adaptability.
65. **Use Cases:** An intended or desired flow of events or tasks that occur within the vehicle and are directed to or coming from the driver in order to accomplish a certain system-driver interaction
66. **Valid subject:** A valid subject is a participant of an experiment who took part in the whole experiment, where the complete dataset is available and no reason for declaring the dataset as an outlier is given.
67. **Validation:** The process of evaluating a system or component during or at the end of the development process to determine whether it satisfies the expectations.
68. **Vehicle:** In the CoP specifically motorised road vehicles, i.e. cars, trucks, buses and motorcycles.
69. **Verification:** Assuring, e.g. by testing, that a component, a sub-system, a system or a process is working as required and specified.
70. **Vigilance:** The process of paying close and continuous attention or readiness to detect and effect an adequate response to unforeseen, small and specific changes of environment; proper attention in proper time.
71. **Workload:** Degree of mental, physical and perceptual effort required by the driver to undertake a particular task (ISO 17287).
    Also **mental workload**: the specification of the amount of information processing capacity that is used for task performance.

2.3 Abbreviations

Abbreviation	Meaning
AAM	Alliance of Automobile Manufacturers (US)

ACC	Adaptive Cruise Control
ADAS	Advanced Driver Assistance System
AIDE	Adaptive Integrated Driver-vehicle InterfacE (EC funded project)
AIS	Abbreviated Injury Scale
ASIL	Automotive Safety Integrity Level
C	Controllability
CoP	Code of Practice
DAS	Driver Assistance System
DIN	Deutsches Institut für Normung e.V. (German organisation for standardisation)
DUT	Device Under Test
E	Exposure to a situation where hazards exist
ECU	Electronic Control Unit
ESoP	European Statement of Principles on the Design of Human Machine Interaction
ESP	Electronic Stabilisation Programme
f	frequency (of occurrence of a hazardous event)
FMEA	Failure Modes and Effects Analysis
FMECA	Failure Modes, Effects and Criticality Analysis
FTA	Fault Tree Analysis
H&R	Hazard analysis and Risk assessment
HAZOP	HAZard and OPerability study
HIL	Hardware In the Loop
HMI	Human Machine Interface
I/O	Inputs/Outputs
ISO	International Organisation for Standardisation
IVIS	In-Vehicle Information System
MAIS	Maximum AIS (Abbreviated Injury Scale)
POST	Power On Self Test
R	Risk
S	potential Severity of the resulting harm or damage
SoP	Start of Production
SUV	Sport Utility Vehicles
TICS	Transport Information and Control System

Table 1: Abbreviations

3 Development process

Following, please find a generic development process provided to facilitate a classification of the elements described in the CoP. This generic development process reflects in general the logical sequence of product development phases of a product development as well as selected milestones, but not necessarily their time sequence (Figure 1). Therefore, it corresponds to a simplified presentation of reality. Possible iteration loops accompanying individual development phases are not shown.

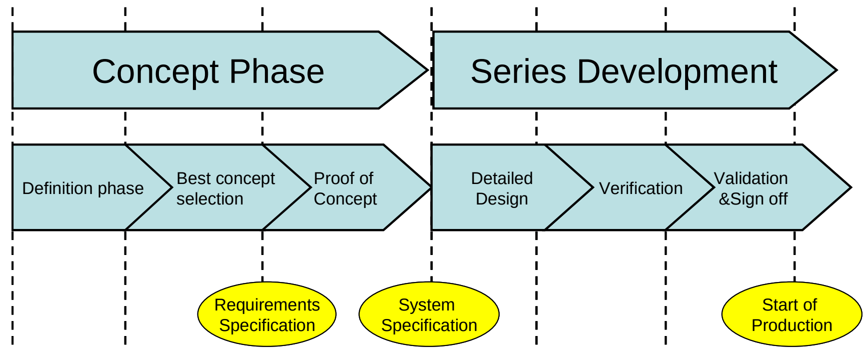


Figure 1: Phases of a development process

Since RESPONSE 3 is focussing on safety aspects of HM Interaction, Figure 2 shows activities regarding HMI development. This does not necessarily represent a separate development process, but the activities are normally integrated into the product development process.

In respect to this CoP the specific safety relevant aspects are now considered. Principally the ADAS safety aspects may be classified in three categories. HM Interaction and the related controllability is analysed

- within system limits (normal operation, ADAS assisted driving),
- at system limits and
- with system failures.

All categories are evaluated by means of measures confirming controllability with respect to possible risks 0(Annex A.3). Depending on the risk evaluation, requirements for the safety concept as well as the HMI are derived

For a system with safety implications additional safety related activities are performed. For the automobile industry requirements for a safety related development process are formulated in a domain specific safety standard. This is presently done in the ISO TC22 / SC3 / WG 16.

Figure 2 shows additional elements of a general safety process (in white) and activities regarding controllability (in yellow). The elements of a general safety process are depicted, as the elements of the CoP may be included into a company specific safety process. The CoP itself will focus on the activities regarding controllability. The concept of controllability is described in chapter 4. Regarding the safety of ADAS (for a definition of ADAS see chapter 2.1 and Annex E) the concept of controllability is the central issue. According to legal requirements, an ADAS is considered safe, as long as the driver is able to control the vehicle.

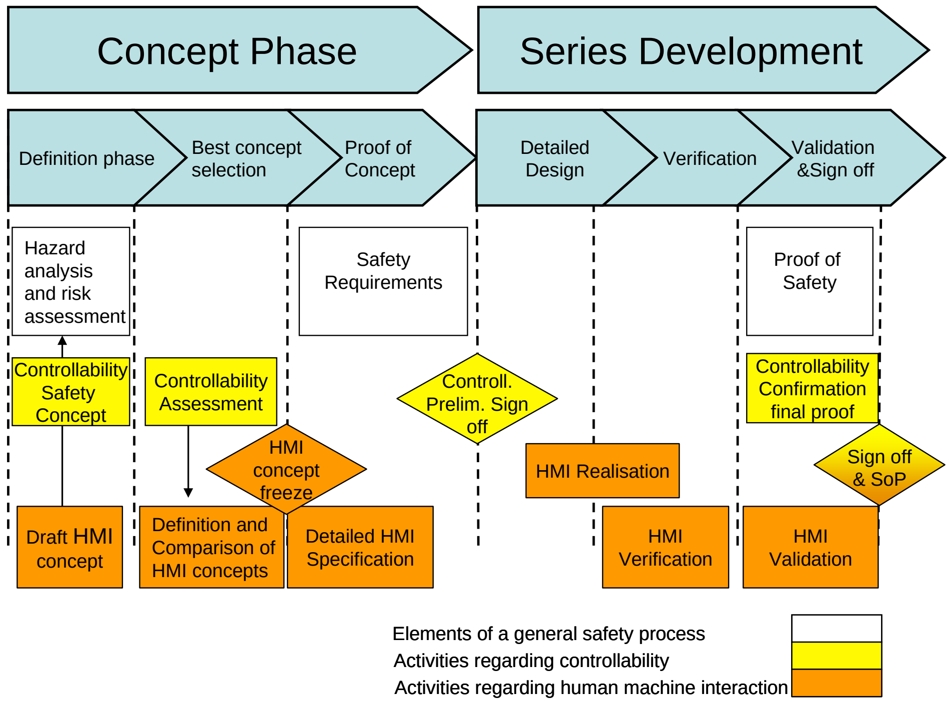


Figure 2: Elements of a safety process and controllability concept

The development process described above has only to be applied completely with regard to a new development of an ADAS system. In case of modifications (derivate or change) of existing systems, an impact analysis should be performed to assess the relevant areas affected by the modification.

The vehicle manufacturer is responsible for the application and documentation of the CoP. If development tasks and services are performed by a supplier, the supplier must be informed about the CoP and/or relevant information of the ADAS interfaces and the integration into the vehicle. Responsibilities need to be agreed between the vehicle manufacturer and the supplier.

4 Controllability

In this CoP controllability is a key requirement. Controllability refers to the entire ADAS-driver-environment interaction comprising:

- normal system use within system limits,
- usage at and beyond exceeding system limits and
- usage during and after system failures.

Controllability is dependent on

- the possibility and driver's capability, to perceive the criticality of a situation,
- the drivers capability to decide on appropriate countermeasures (e.g. override, system switch-off) and
- the driver's ability to perform the chosen countermeasure (e.g. reaction time, sensory-motor speed, accuracy).

Safety of usage requires controllability. Compared to controllability other design requirements are of secondary importance.

Controllability is a basic parameter in the automotive risk assessment (as described in the draft of the functional safety standard ISO WD 26262-3). Within this hazard analysis and risk assessment according to ISO/WD 26262 (H&R), controllability of safety related electronic devices has to be estimated in an early development stage.

The CoP assists controllability evaluations and later confirmation by providing checklists and references to state-of-the-art evaluation methods. The annexes provide checklists corresponding to the input to the H&R. Results from the H&R and checklist questions lead to open items that should be compiled in an Open Item List for further tracking of the development status. The list can also be used to derive a controllability evaluation plan.

Figure 3 provides an overview of a possible controllability related workflow.

At the end of the ADAS development the CoP recommends a Controllability Final Proof to confirm that sufficient controllability is achieved for the series-production version of the system.

For this purpose, the ADAS development team has to verify that drivers will react in relevant scenarios as previously anticipated or in another appropriate way. The data utilised may be from the H&R, the checklists and the results of tests that have been conducted according to the evaluation plan.

Three approaches regarded as equal are offered by the CoP to finally prove that the driver can and will react in an expected and appropriate way (Figure 3):

- Final proof of controllability by an interdisciplinary expert panel (chapter 4.1)
- Final proof of controllability by a test with naive subjects (chapter 4.2)

- Final proof by direct recommendation of controllability sign-off by the ADAS development team (chapter 4.3)

The ADAS development team is free to choose the appropriate way separately for each particular scenario i.e. a mixed approach is possible.

When the controllability relevant design of the system is confirmed by the ADAS development team a recommendation for sign-off can be given from the Code of Practice point of view.

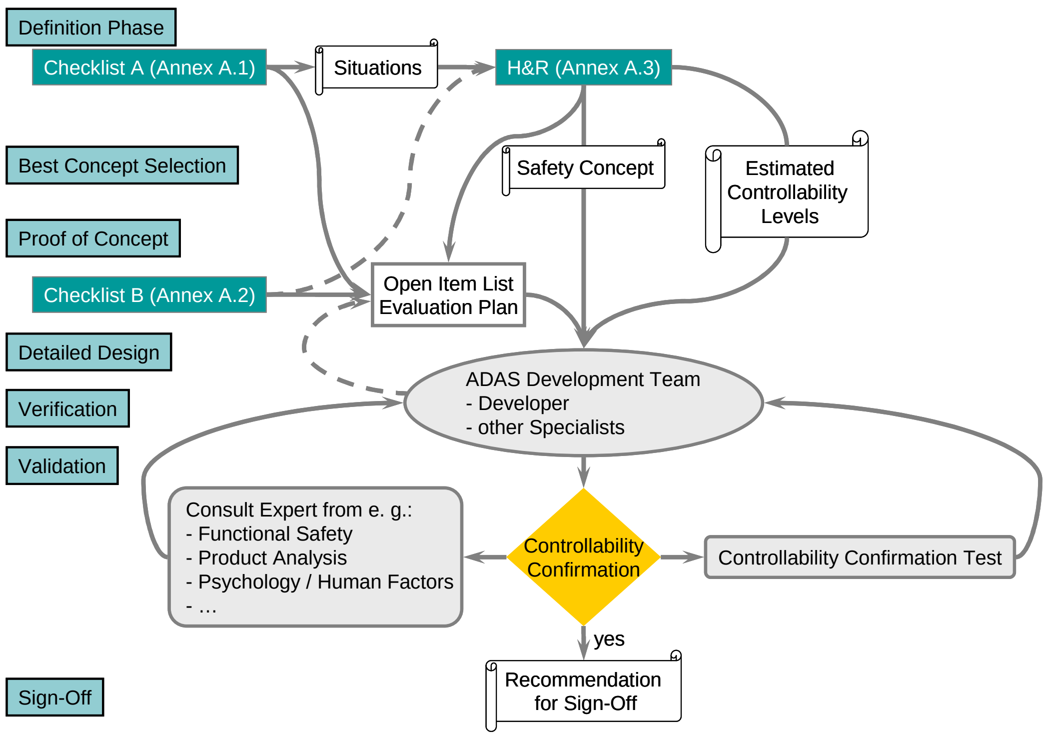


Figure 3: Controllability Workflow. Dashed lines suggest revision due to new information

4.1 Final proof of controllability by an interdisciplinary expert panel

The controllability estimations are reviewed by an interdisciplinary Expert Panel. This Expert Panel for Final Proof is a cross-functional group of individuals (the ADAS development team and additional specialists). It is recommended to include members of other departments in the panel to ensure "external" expertise and an independent view on the controllability esimations.

The Expert Panel has to judge and confirm the controllability estimates. Therefore, the members of the panel must be familiar with the system in adequate situations. The judgment can be based on analogies, literature and previous studies during development phase etc. When in doubt, the Expert Panel will gather additional information for clarification. For this purpose a test might also be performed.

4.2 Final proof of controllability by means of a test with naive subjects

Absolute controllability does not exist. A statistical verification that 99 % of the drivers “pass” a test in a certain traffic scenario is not realistic because an unfeasible huge number of subjects would be necessary to demonstrate this.

Consequently, the Code of Practice recommends a different approach.

Practical testing experience revealed that a number of 20 valid data sets per scenario can supply a basic indication of validity. A data set is not considered as being valid if a subject fails due to a reason that is not system related (e. g. due to motion sickness in a driving simulator). The test design should consider the possibility of the occurrence of outliers. Criteria for the classification of outliers should be established according to the state of the art in human factors testing. In order to enlarge the data basis it is possible to perform retests with the same subjects, prerequisite is that the effect on the subject behaviour is negligible.

To demonstrate controllability in accordance to the CoP naive subjects should be tested in relevant scenarios. Naive means that the subjects have no more experience and prior knowledge of the system than a later customer would have. The test-scenario is “passed” if the subject reacts as previously anticipated or in an adequate way to control the situation.

To show a controllability level of at least 85 % in a scenario all 20 out of 20 valid data[4] sets must fulfil the pass criteria.

Testing can be carried out in any of the following ways (see Annex D):

- On public roads,
- on proving grounds or
- in a simulator.

4.3 Final proof by direct recommendation of controllability sign-off issued by the ADAS development team

In some projects all open issues on the Open Item List are tackled easily by the ADAS development team themselves. In addition during development a sufficient number of tests in a technical status representing the final system design may have been conducted with positive results.

In this case the controllability evaluation of the system may be confirmed by the ADAS development team and a recommendation for sign-off can be given directly.

5 Recommendations

The objective of this chapter is to present the recommendations for a safe development of ADAS. The content of this chapter is structured according to the generic development process introduced in Figure 1 and Figure 2. Table 2 references the activities of the generic development process.

The entire concept phase splits into the parts 'definition phase', 'best concept selection' and 'proof of concept'. Comparison of concept alternatives and the selection of one of them is economically reasonable. Consequently, the definition phase deals with drafting HM Interaction concepts. Subsequently the drafted HM Interaction concepts are compared and the most suitable one is chosen for realisation. Finally, the concept selected has to be specified in the proof of concept section. Note that general ADAS development topics are only covered to the extent that controllability specific topics can be described.

Main phase	Sub phase	Recommended steps
Concept phase	5.1 Definition phase	5.1.2 Draft HM interaction concept and controllability safety concept
	5.2 Best concept selection	5.2.2 HM interaction concept specification 5.2.3 Selection of HM interaction concept
	5.3 Proof of concept	5.3.2 Preparation of preliminary sign-off 5.3.3 Controllability preliminary
Series development	5.4 Detailed design	5.4.2 Detailed HM interaction design
	5.5 Verification	5.5.2 Verification of HM interaction
	5.6 Validation and sign-off	5.6.2 Controllability confirmation and final proof 5.6.3 Sign-off

Table 2: Mapping of phases from the developing process to sections in chapter 5

The recommendations are described as activities. Each activity is presented in the same format. The tasks of each activity are presented in chronological order.

Activity *A*: *Name of activity (optional activities without grey shading)* requires: *reference to prerequisites*
a) *Name of task* • *Explanation of subtask* • *Explanation of subtask* ▶ Reference to Annex
a) *Name of task* • *Explanation of subtask* ▶ Reference to Annex

5.1 Definition phase

5.1.1 Objective

The objective of this section is to develop a level of comprehension of the intended system and its environment to an extent that other development cycle activities may be performed satisfactorily.

Recommendations that need to be considered at the start of a system development will be listed in this chapter.

5.1.2 Draft HM interaction concept and controllability safety concept

At least one ADAS concept is drafted in this subphase. Every concept should be drafted according to the set of recommendations of this section, which are related to the main aspects: ADAS functionality, ADAS HM Interaction, ADAS usage, ADAS standards and ADAS hazards & risks.

Activity A: ADAS functionality
a) Assigning function name • Introduce a suitable name for the ADAS function
b) Drafting functionality • Define system states, modes, transitions and actions • Characterise situational limits and initial sensor requirements • Sketch system behaviour under situational limits • Clarify interaction with other systems ▶ Annex A.1

Activity B: HM Interaction requires: 5.1.2 A, D
a) Drafting HM Interaction • Sketch driver activities to operate the system • Characterise transferred information • Define take over procedures ► Annex A.1
b) Drafting physical layout • Consider an integration of the HM Interaction concept in the vehicle • Draft controls and displays (system input and output) ► Annex A.1

Activity C: Usage requires: 5.1.2 A, B, D
a) Defining domain • Characterise the intended market for the ADAS • Describe the type of vehicle for which the ADAS is intended • Draft the environment and roads in which the ADAS is used • Characterise the user group of the ADAS ► Annex A.1
b) Characterising use • Draft operating scenarios • Sketch user expectations, misinterpretation, overestimation ► Annex A.1
c) Characterising misuse • Draft non operating scenarios • Identify reasonably foreseeable misuse • Find possible measures to avoid misuse ► Annex A.1

Activity D: Standards requires: 5.1.2 A
a) Ensuring conformity • Look for relevant standards and regulations ► Annex A.1

Activity E: Preliminary Hazard analysis and risk assessment requires: 5.1.2 A, B, C, D
a) Identifying hazards • Identify possible hazardous situations and the relevant sources of hazards within the drafted ADAS function for normal operation, system failure and system limits. ► Annex A.1, B.1
b) Analysing hazards • Perform hazard analysis paying specific attention to the controllability aspect ► Annex A.3
c) Assessing risk • Perform a risk assessment for the analyzed hazards ► Annex A.3

5.2 Best concept selection

5.2.1 Objective

In this part of the concept phase suitable criteria for discriminating various concepts are defined. Based on these criteria the results can be used to select a concept.

The selected HM Interaction concept will be incorporated into a detailed specification as part of the overall system requirements specification.

5.2.2 HM interaction concept specification

The concept specification is a general development activity. The detailed definition of system limits is part of the company individual design strategy and therefore not covered here.

Activity A: Controllability concept requires: 5.1.2 E
a) Specifying the controllability concept • Specify HM Interaction based on the draft concept and controllability results from a risk assessment ▶ Annex A.1, A.2

Activity B: HM Interaction requires: 5.1.2 B,
a) Specifying system transitions • Identify driver initiated transitions that correspond to operator control actions • Identify system initiated transitions, caused by changing environmental conditions as well as exceeding the system limits • Identify system initiated transitions, caused by system failure or failures of other iteracting systems ▶ Annex A.1
b) Specifying system dialogs • Describe the system feedback to the driver for controllability relevant system states and transitions • Describe the input/output modalities and dialogs ▶ Annex A.1
c) Specifying physical layout • Consider controllability aspects of system states and transitions for specification of the controls and displays ▶ Annex A.1

5.2.3 Selection of HM interaction concept

Activity A: Evaluation criteria requires: 5.1.2 E
a) Defining criteria • Define criteria for the evaluation of the concepts considering controllability requirements based on the risk assessment ▶ Annex A.3, B.3

Activity B: Selection of concept requires: 5.2.2 B
a) Finding a best concept • Evaluate the concepts and select the most suitable one according to the defined requirements. Check if the HMI is suitable for the intended task in normal operation, at system limits and with system failures ► Annex A.2, A.3

5.3 Proof of concept

5.3.1 Objective

In this part of the concept phase the drafted and selected ADAS concept has to be specified focusing on controllability. The structure of this activity is presented in the detailed HM Interaction specification section.

In order to finalise the concept specification a concept sign-off or equivalently a preliminary sign-off is recommended. The structure of this activity is supplied in the concept sign-off section.

5.3.2 Preparation of preliminary sign-off

The preliminary sign-off is an optional activity, which might be necessary or desirable for various reasons, e.g. the transfer of activities from a research to a serial development department.
Even if this is not the case it is still recommended to start with verification and validation as early as possible in order to minimise the risk of critical findings at a late stage of product development. However it is at the discretion of the developer when these activities are performed and therefore the recommended activities are optional in this early stage of product development.
Optional activities in this document have a white heading instead of a grey heading.

Activity A: Review of HM Interaction specification (optional) requires: 5.2.2 B
a) Define a validation strategy • Document the procedure in a preliminary review plan for the specified HM Interaction concept. ► Chapter 5.6 gives an overview on activities that are required in the validation phase
b) Performing the review • Review the HM Interaction concept specification according to the plan and identify possible problem areas ► Chapter 5.6

Activity B: Further proceeding (optional) requires: 5.1.2 A, 5.2.3 B
a) Considering additional tests • Check for further tests necessary to assess controllability (controllability relevant topics that can be clearly identified as easily controllable, according to the state of the art in the area of human factors, need not be tested). • Perform necessary tests (in cases of doubt or in lack of experience tests are recommended) ▶ Annex B, Annex D
b) Documenting important topics • Document the achieved results • Document the open controllability topics and the required phase of development necessary to perform a certain test. ▶ Chapter 5.6.2 Activity C, Open item list (Chapter 4, Figure 3)

5.3.3 Controllability preliminary sign-off

Activity A: Preliminary sign-off (optional) requires: 5.3.2 A, B
a) Deciding on concept sign-off • Sign-off the HM Interaction concept or initiate appropriate rework. (the responsible person / project manager etc.)

5.4 Detailed design

5.4.1 Objective

During the detailed design phase the development is continued based on the selected ADAS concept and the HM Interaction concept that was specified.

5.4.2 Detailed HM interaction design

Activity A: HM interaction detailed Design (optional) requires: 5.1.2 A, 5.2.3 B, 5.3.2 B

a) Designing HM Interaction architecture

- Develop functional subdivisions
- Define which functions are performed by the driver, by hardware, software or in combinations.
- Consider relevant user tasks and activities
- Define input and output by systematically detailing relevant system states & transitions and the related interactions between driver and system

► Annex A.1

b) Designing physical layout

- decide on the appropriate physical layout of the input and output devices (controls and displays)

► Annex A.1

c) Integrating into overall design

- integrate ADAS HM Interaction design into overall design regarding
  - prioritisation of system outputs (e.g. warnings and messages) in relation to other functions
  - driver workload

► Annex A.1

Activity B: Update hazard analysis and risk assessment

requires: 5.1.2 E, 5.4.2 A

a) Updating hazard analysis and risk assessment

- update by including information from detailed design of HM interaction

► Annex A.3

5.5 Verification

5.5.1 Objective

In this context verification relates to the HM Interaction design. That is, checking and documenting if and how the controllability related requirements of the developed HM Interaction design are fulfilled. Successful verification ends with the release of the HM Interaction design; otherwise rework needs to be performed.

5.5.2 Verification of HM interaction

Activity A: HM Interaction verification

requires: 5.4.2 A

a) Verifying HM Interaction • Verify the design based on its specification concerning HM interaction requirements for system and human performance ► Annex C
b) Documenting verification • Document and report the verification results. • Initiate necessary further actions if a non-conformance to requirements is found ► Chapter 5.6.2 Activity C, Open item list (Chapter 4, Figure 3)

5.6 Validation and sign-off

5.6.1 Objective

At the end of the development process a sign-off is carried out to confirm that the system complies with the specified controllability related requirements.

Controllability confirmation and the final proof may require specific actions and documents.

5.6.2 Controllability confirmation and final proof

The validation strategy is defined in the validation plan. It is possible to refer to earlier results e.g. from the preliminary controllability sign-off during the proof-of-concept phase, if still applicable.

Activity A: Planning validation scenarios requires: 5.4.2 A, B
a) Identifying driving situations • Consider the following situations - normal operation - behaviour at functional limits - behaviour in case of system failures • Compile a list of relevant driving situations for system validation and build reasonable clusters ► Annex B.1

Activity B: Planning approach for final proof (done by the ADAS development team) requires: 5.6.2 A
a) Selecting the appropriate strategy for each scenario • Controllability confirmation by an independent expert panel (chapter 4.1) • Controllability check by a test with naive subjects (chapter 4.2) • Direct recommendation of Controllability Sign-Off by the ADAS development team (chapter 4.3) ► Chapter 4, Annex B.2, B.3, B.4

Activity C: Final proof requires: 5.6.2 A, B
a) Controllability confirmation • The experts perform the validation strategy, decide if the design has passed and give a recommendation for sign-off ► Annex D
b) Documenting controllability • Document information that is sufficient to reproduce the recommendation for sign-off (e.g. approach, equipment, assumptions, decisions, test conditions) • Compile a set of documents to confirm the controllability for the system sign-off. If the documentation is already available a collection of references is sufficient. Documents from the risk assessment procedure, i.e. - System and HM Interaction concept description - Identified hazards - Assessed risks - Used checklists - Assumptions Controllability related HM Interaction requirements, i.e. - Requirements and references to risks

5.6.3 Sign-off

Activity A: Sign-off requires: 5.6.2 D
a) Signing-off the system The responsible person (project manager etc.) can sign-off controllability ► Annex F

Information Society Technologies

PReVENT

Preventive and Active Safety Applications
Integrated Project
Contract number FP6-507075
eSafety for road and air transport

RESPONSE 3
a PReVENT Project

Annexes to the **Code of Practice** for the Design and Evaluation of ADAS

Version number V5.0
Aug. 2009

ANNEXES

Annex A Response procedures

A.1 Checklist A – System specification

A.1.1 Scope

Checklist A refers to the specification of Advanced Driver Assistance Systems (ADAS).

It supports the concept phase in the development process (see chapter 3). It serves as a support tool in the preparation of the system specification in the definition phase. The checklist is based on the current state-of-the-art.

This checklist is intended as reference material for vehicle manufacturers and suppliers engaged in specification and implementation of ADAS. It provides support in ADAS specification and consideration of aspects, which might not be evident at first consideration. This checklist does not require a uniform ADAS design. It is applicable for various ADAS with varying complexity and integration levels as well as various vehicle models. This checklist helps to structure the ADAS concept description and therefore allows a comprehensive and consistent system specification.

Application of checklists

Checklist A supports the development team. The checklist comprises general questions concerning the ADAS system and system environment. The answers of the development team lead to a the ADAS system specification. Open items are identified for further activities and compiled in the "To do" column.

The completed checklist and specification are part of the documentation recommended for the (preliminary) sign-off. You may use your own (company adapted) check lists, which should be comparable to checklist A.

A.1.2 Structure of checklist A

Supported task (Table A1 - A3)

System users (Table A4, A5)

Vehicle type (Table A6, A7)

Market (country of application), (Table A8)

Homologation//Type approval and standards/traffic law conformity (Table A9 - A12)

Functional Description (Table A13)

User requirements vs. user expectations (Table A14 - A17)

Situational and sensor limits (Table A18 - A23)

Human Machine interface and interaction (Table A24 - A27)

Preparation of hazard analysis (Table A28 - A32)

Product information (Table A33)

Maintenance/Repair (Table A34)

A.1.3 Checklist A

Supported driving task

Please give a detailed description of the supported driving task. It will assist you in determining whether your system is an ADAS.

Background:

"Horizontal structuring" of the driving task is demonstrated below:

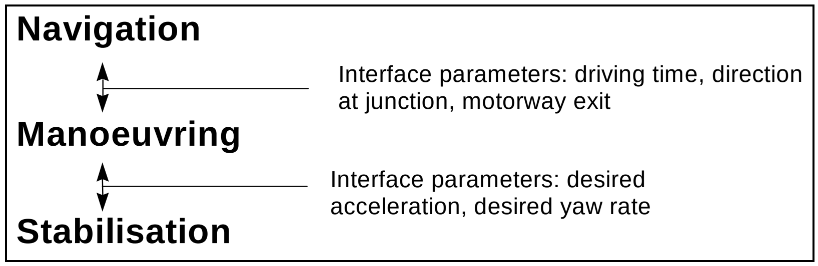


Figure 4: The three driving task levels

In addition, there is a general "human information processing behaviour". Principally, all human activities are affected:

Perception ⇨ Recognition ⇨ Decision ⇨ Action.

Question:	Typical examples:	Answer/Comments:	To do:
A1-1. Which driver operation level is supported by the ADAS? a) Perception b) Recognition c) Decision d) Action	Object recognition (radar, camera), navigation notice, steering, braking	a) y/n b) y/n c) y/n d) y/n	
A1-2. Which driving task is supported by the ADAS? a) **Navigation level** b) **Manoeuvring level** c) **Stabilisation level** d) If Navigation or stabilisation level applies: Check whether your system complies with the ADAS definition.	 Finding a suitable route to destination. Adhering to traffic rules, avoiding collisions. Steering and operating of accelerator and brake	 a) y/n b) y/n c) y/n d) y/n	

Warning and assisting/intervening ADAS

With respect to responsibility referring to the driving task it makes sense to classify the system as mentioned below. Please determine the system category the ADAS belongs to.

Warning systems

Warning systems are systems merely supplying information to the driver (e.g. visual or acoustic)

The following questions are also applicable for intervening systems providing additional information to the driver.

The responsibility for correct operation is always with the driver, even if the necessary information is missing or misleading

For example: Blind Spot Monitoring System:

If an object is not detected in the blind spot because it is not in the range of the physical limits of the sensor, the driver will not be informed about the object.

Therefore, the HMI should be designed in such a way, that the driver will not solely rely on the system, but will also double check the situation.

Question:	**Typical examples:**	**Answer/Comments**	**To do:**
A2-1. a) Are direct measurements presented to the driver? b) Is the information presented in a comprehensible way?	Direct measurement ACC: Information on distance (in meters) to the preceding object. Indirect measurement: Acoustic park assistant: variation of sound frequency as measure for the distance to the detected object.	a) y/n b) y/n	
A2-2. Are the selected senses for information and warnings suitable?	Visual, auditive, haptic, kinaesthetic	y/n	
A2-3. a) Have the effects of unexpected information for the specification of warnings and information been considered? b) Have the effects of missing information for the specification of warnings and information been considered? c) If yes, which measures are taken?	Blind Spot Monitoring System: If an object in the blind spot is not detected by the system because it is outside the physical limits of the applied sensor, the system will not inform the driver about the object. Subsequently the driver will interpret that there is no object in the field of view of the sensor, and will change lanes.	a) y/n b) y/n c) ___________________	

Assisting / intervening systems

During the operation of a system the responsibility for the driving task always remains with the driver. Therefore, all the assisting functions should be designed in a way that the driver can always override them. Exceptions to the ability to override may exist for intervening systems if the driver cannot take over the driving task because of lack of reaction time or the relevant driving status for the driver is no longer under control.

These systems may be classified as follows:

- Driver is able to override the function:

  The driver may override the system in operation at any point in time.

- Driver is not able to override:

  Driver inputs cannot override the system operation, and no on / off switch is available in the vehicle.

Question:	Typical examples:	Answer/Comments:	To do:
A3-1. Is the driver able to override the system in operation at any point in time?	ACC: If the ACC is in operation the driver may override the ACC control any time. By depressing the accelerator pedal the driver may accelerate the vehicle.	y/n	
A3-2. Did you check whether a driving status is no longer control-lable by the driver?		y/n	
A3-3. a) Are ADAS initiated situa-tions foreseeable when reaction time is not sufficient? b) If yes, please describe for a later hazard analysis and risk assess-ment		a) y/n b) ___________________	

System users

Intended user group

Please specify the user group the system under development is in-tended for:

Question:	Typical examples:	Answer/Comments:	To do:
A4-1. What are the intended user groups for ADAS? a) Professional drivers b) Private persons	 Truck, bus, taxi drivers, driving instructors Commuters, leisure trips	 a) y/n b) y/n	

Abilities and restrictions

Please specify the system users:

Question:	Typical examples:	Answer/Comments:	To do:
A5-1. Age of system user: a) All age groups 16-99 b) Core user group?	 Young inexperienced or older drivers with physical handicaps	 a) y/n b) from … until	
A5-2. Physical dimensions (Anthro-pometrics) a) Have all sizes and weights been considered? b) If no, state restrictions?	Physical dimensions affect field of view, reach area, operation forces, etc.	 a) y/n b) ___________________	

Question:	Typical examples:	Answer/Comments:	To do:
A5-3. Driving training a) Particular driving training or qualification standard required? b) If yes, please state	Theoretical or practical knowledge. Restricted driver's license exclu-sively for vehicles with automatic transmission.	 a) y/n b) ___________________	
A5-4. Driving habits:			

a) Have similar ADAS systems been marketed in other vehicles? b) Did you consider these systems in order to avoid operational confusion?	Change from ACC to conventional cruise control.	a) y/n b) y/n	
A5-5. Driving style / personality a) Does the ADAS require a driver identification? b) If yes, please state which	Adaptive systems and change of driver, ACC setting of personal warning thresholds	a) y/n b) __________________	
A5-6. Foreseeable misuse a) How and in which way may the ADAS be misused? b) Which information, warnings or measures are required?	ACC used in fog	a) b)	
A5-7. Risk compensation: a) Are significant changes in behaviour expected after short-term ADAS use? b) If yes, how would these changes become obvious? c) Are significant long-term changes in the driving behaviour expected? d) If yes, please state	Inappropriate speed, reduced attention to traffic situation, increased driving task distraction	a) y/n b) __________________ c) y/n d) __________________	
A5-8. Psychomotoric performance a) Are there special requirements to psychomotoric performance? b) If yes, please state	Reduced reaction ability of older persons concerning speed and operation accuracy	a) y/n b) __________________	
A5-9. Physical restrictions a) Would physical restrictions of the driver influence safe ADAS operation? b) If yes, please state the kind of restrictions	Sensoric, auditive, mental performance, mobility, amblyopia(poor eyesight),, colour blindness, amblyacousia (hardness of hearing), shoulder check problems	a) y/n b) __________________	
A5-10. Cultural driver backgroud a) Is there significantly different behaviour in countries where the system will be marketed effecting ADAS use? b) If yes, please state which	Traffic regulations and behaviour, lane change, distance behaviour, speed level, left-hand traffic	a) y/n b) __________________	
A5-11. System expectations a) Can user expectations be different when using similar ADAS from various manufacturers? b) If yes, please state	Vehicle changes, rental cars	a) y/n b) __________________	

Vehicle type

The following questions could be important if the ADAS system is intended for various vehicle types or if it is transferred to other vehicle types, and if the system is adjusted to them. Example: View obstructions from within trucks or SUVs due to design.

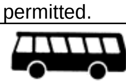
Question:	**Typical examples:**	**Answer/Comments:**	**To do:**
A6-1. Is the system designed for a particular vehicle type and thus for a vehicle specific function?	Only passenger vehicles for transport of persons	y/n	
A6-2. a) Are there any system properties which are influenced by application in other vehicle type or	Visual obstruction caused by truck or SUV design	a) y/n	

designs? b) If yes, please specify		b) __________________	

State vehicle type the system is developed for.

The following classification refers to the European driving licence classification according to regulation 91/439 EWG. The mentioned main classes are applied in all EU member states, whereas sub-classes (e.g. A1, B1, S, T, L) only apply on a national basis.

Vehicle classes

Question:	**Typical examples:**	**Answer/Comments:**	**To do:**
A7-1. Class A, **National Subclasses A1, A2, M** a) Is the ADAS system intended for this class of vehicle? b) If yes, are there any vehicle specific preconditions and effects that must be taken into consideration during the development phase? c) If yes, please specify.	 motorcycles with or without side-car	a) y/n b) y/n c) ___________________	
A7-2. Class B **National Subclass B1** a) Is the ADAS system intended for vehicles of this class? b) If yes, is it necessary to consider any specific preconditions and effects? c) If yes, which?	 Motor vehicles and three-wheel motor vehicles of an authorized mass of not more than 3.500 kg and not more than eight seats. Trailer of a limited authorised mass of not more than 750 kg are permitted.	a) y/n b) y/n c) ___________________	
A7-3. Class C **National Subclass C1** a) Is the ADAS system intended for vehicles of this class? b) If yes, is it necessary to consider any specific preconditions and effects? c) If yes, which?	 Motor vehicles, except class D, of authorized mass of more than 3.500 kg. Trailers of a limited authorised mass of not more than 750 kg are permitted.	a) y/n b) y/n c) ___________________	
A7-4. Class D **National Subclass D1** a) Is the ADAS system intended for vehicles of this class? b) If yes, is it necessary to consider any specific preconditions and effects? c) If yes, which?	 Motor vehicles for passenger transport with more than eight seats, excluding driver seat Trailers of a limited authorised mass of not more than 750 kg are permitted.	a) y/n b) y/n c) ___________________	

Question:	**Typical examples:**	**Answer/Comments:**	**To do:**
A7-5. Class E a) Is the ADAS system intended for vehicles of this class? b) If yes, is it necessary to consider any specific preconditions and effects?	 Trailer of a gross weight of more than 750 kg in combination with classes B, C, D (special regula-	a) y/n b) y/n	

c) If yes, which?	tion class B)	c) __________________	
A7-6. National Subclasses T, L, S a) Is the ADAS system intended for vehicles of this class? b) If yes, is it necessary to consider any specific preconditions and effects? c) If yes, which?	 Small three-wheel motor cycles and four-wheel light motor vehicles max. 45 km/h  Agricultural and forestry vehicles	a) y/n b) y/n c) __________________	

Market (country)

Depending on the market the vehicle is intended for, varying conditions may exist which influence the system design.

Question:	**Typical examples:**	**Answer/Comments:**	**To do:**
A8-1. Infrastructure a) Do extraordinary infrastructural conditions have to be taken into consideration? b) If yes, which?	Right or left-hand traffic, lane width and quality, lane markings	a) y/n b) __________________	
A8-2. Approval regulations a) Are there any country specific approval regulations which have to be taken into consideration for ADAS? b) If yes, please specify.	FMVSS Federal Motor Vehicle Safety Standard	a) y/n b) __________________	
A8-3. Vehicle population a) Are there special vehicle population profiles which influence ADAS? b) If yes, which? (refer to 3.2 vehicle type)	Proportion passenger vehicle, SUV, truck etc.	a) y/n b) __________________	
A8-4. Target market a) Do ADAS restrictions exist concerning the market? b) If yes, specify?	Country specific customer expectations	a) y/n b) __________________	

Homologation / Type approval and compliance with standards and traffic law

Compile a list of all mandatory directives and regulations and of applicable national and international standards.

Possible standards and regulations are shown in the following overview:

Type approval

In order to introduce a vehicle with all its components in a market, it is necessary to comply with required market specific type approval regulations. Harmonised regulations apply for the EU member states.

Question:	Typical examples:	Answer/Comments:	To do:
A9-1. a) Do any national / international guidelines or regulations concerning the ADAS function exist? b) If yes, please specify	ECE regulations for steering and braking	a) y/n b) __________________	
A9-2. a) Are existing guidelines and regulations violated? b) If yes, is it required to modify an existing guideline to allow vehicle approval with this ADAS function?	In the past: only direct operation of brake pedal by driver: Today: driver switches on ACC, then automatic brake control and brake light control	a) y/n b) y/n	

Compliance with directives and regulations is the minimum requirement a product must meet in order to be marketed by a manufacturer. Due to the traffic safety obligation of a manufacturer it is also necessary to adhere to standards and technical specifications when designing a product.

General standards

The standardisation is a systematic harmonisation compiled by the affected experts. Harmonisation may affect many areas, for instance procedures, measurements, properties etc.

German standards, for instance, are created by the DIN (Deutsches Institut für Normung e.V.).

European standards are created by the CEN/CENELEC (European Committee for Standardisation) of which the national standards institutes are members. European standards aim at a voluntary technical harmonisation in Europe. The introduction of standards may be requested by any national standards institute. The International Organisation for Standardisation (ISO) is the competent authority for international standardisation. The national standards institutes are ISO members.

Please note: Always differentiate between general standards and safety standards. Safety standards as for instance in USA and Canada are laws and are of course legally binding

The application of a general standard, regardless whether national, European or international is voluntary, even if the standard is considered a safety standard by certain product safety laws. However, a product must be at least state-of-the-art (see "State-of-the-Art"). Deviating from the standards requires reasoning that the deviation will not result in reduced safety in this specific case.

However, the application of a general standard may lead to the presumption that a product is not defective and / or that the manufacturer has observed the necessary duty of care. Therefore, this assumption may become binding, even if it is not legally binding.

Examples for standards for ADAS HM interaction design that may be applied:

- ISO Ergonomic aspects of transport information and control systems 15005 - 15008 Standards
- ISO/WD 26262 Road vehicles - Functional safety
- ISO 15622
- ISO 15623
- ISO Standard “Safety of Machinery”
- ISO 17287:2003 „Suitability“ Standard

Question:	Typical examples:	Answer/Comments:	To do:
A10-1. a) Do ADAS function standards exist or are they being prepared? b) If yes, please specify.	ISO 15622 maximum deceleration at ACC $3 m/s^2$	a) y/n b)__________________	
A10-2. a) Are the existing function standards violated? b) If yes, is the specification of the ADAS function at least as safe as the ADAS function which would comply with this standard? c) If yes, has a remedy been provided or a reason been given why this fact is not relevant?		a) y/n b) y/n c) y/n	

Technical rules

A technical rule serves as an instruction to resolve a multitude of issues in the field of engineering, and is accepted among experts in the relevant specialist area. Accepted means that the experts are familiar with this specification and that they apply it convinced that the specification is correct. The application of a technical rule by any manufacturer is voluntary, meaning that the manufacturers may apply alternative procedures or techniques as long as they prove safe.

Examples for technical rules and guidelines for ADAS HM interaction design that may be applied:

- ESoP: European Statement of Principles of the Design of HM Interaction
- AAM Guidelines
- MISRA Development Guidelines for Vehicle Based Software

Question:	Typical examples:	Answer/Comments:	To do:
A11-1. Do technical regulations for the ADAS function exist?	Internal regulations and instructions from OEM or suppliers	y/n	

Question:	Typical examples:	Answer/Comments:	To do:
A11-2. a) Does the ADAS function comply with these technical regulations? b) If no, is the selected ADAS function specification at least as safe as the ADAS function which complies with the technical specification? c) If no, give reasons why this fact is not relevant? d) If reasoning is not possible, which remedy must be provided?		a) y/n b) y/n c)___________________ d)___________________	
A11-3. a) Are there any voluntary self-commitments between OEM? b) If yes, please specify	US-Market: Alliance of Automobile Manufacturers AAM "Principles, criteria and verification procedures for driver interactions in advanced vehicle information and communication systems" ACEA 1999/125/EG CO_2 emission	a) y/n b) __________________	

State-of-the-art

In addition to the existing regulations of type approval and existing standards as well as technical specifications the state-of-the-art of the respective product group must be considered in order to provide compliance with the traffic safety duty of a manufacturer.

The state-of-the-art is continually developing in a product group. Amongst others the state-of-the-art defines itself through a comparison with of competitor products. In order to determine the relevant technology status a competitor comparison is required.

Designers should take into consideration that the state-of-the-art is constantly changing and therefore must consider future changes in the market in order to ensure conformity with the state-of-the-art throughout the period the product is marketed in.

Question:	Typical examples:	Answer/Comments:	To do:
A12-1. a) Does a state-of-the-art already exist for ADAS? b) If yes, is the ADAS function in compliance with this state-of-the-art?	Comparison to existing systems	a) y/n b) y/n	
A12-2. Is it ensured that the ADAS is in accordance with the state-of-the-art at the time of marketing regarding safety technological factors?		y/n	

Functional description

The following section will help to produce a detailed description of the ADAS function.

The supported task must be described in detail and give a clear definition of how the system supports the driver also beyond the system limits.

At this development stage it makes sense to supply a structured and complete description of the system to allow a logical hazard analysis and risk classification. This is an important contribution for the evaluation of the system effect on driver vehicle control.

Question:	Typical examples:	Answer/Comments:	To do:
A13-1. Is a detailed systematic system description of the ADAS function available?		y/n	
A13-2. Has an overview of all system components and their tasks and interaction been supplied?	Possible presentation media are State Transition diagrams, Petri Net or lists	y/n	
A13-3. Has an overview of system status/system mode and intermodal switching been supplied in connection with the environmental situation?	Button operation for switching on and off. When is the system active/not active? System is always active at ignition on, temporary status	y/n	
A13-4. Has an overview been supplied on activation, deactivation and system-driver take-over procedures?	Controlled by driver. button, controlled by system	y/n	
A13-5. Has an overview been supplied on system reactions to correct and incorrect driver inputs?	System availability, system/vehicle reaction	y/n	
A13-6. Has an overview been supplied on system reactions to sensor inputs?		y/n	
A13-7. a) Has an overview been supplied on means and possibilities for the driver to intervene in system actions? b) If this possibility is given, please describe. Which possibilities are available in which situation?		a) y/n b) ___________________	
A13-8. Has an overview been supplied on the system behaviour at approaching or exceeding situational limits?	System limits may exist due to physical limits of the employed sensors	y/n	
A13-9. Has an overview been supplied on differences between system driving behaviour and regular human driving behaviour in relevant traffic situations?		y/n	

User requirements vs. user expectations

It is advisable to check whether the system to be developed creates exaggerated or / and false user expectations, leading to incorrect system use and driving behaviour.

On the whole one can say, the higher the level of automation, the higher the driver expectation regarding system reliability, situation coverage, system accuracy and system performance.

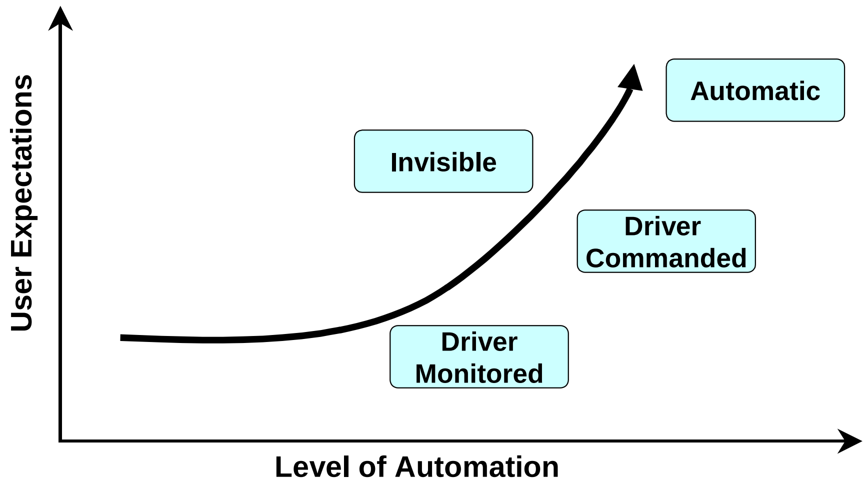


Figure 5: Level of automation

The following questions will assist in specifying technical user requirements or system expectations.

Question:	Typical examples:	Answer/Comments:	To do:
A14-1. a) Is special user knowledge required? b) If yes, specify	Menu navigation knowledge	a) y/n b) ___________________	
A14-2. a) Does the ADAS create special user expectations? b) If yes, specify	ACC is keeping a safe distance	a) y/n b) ___________________	
A14-3. a) Can it be expected that the automation level of the system may lead to higher user expectations than the system actually offers? b) If yes, which precautionary measures must be taken?	The Driver is expecting from a Stop&Go system that it also brakes on stationary objects	a) y/n b) ___________________	
A14-4. a) May exaggerated or false expectations concerning the extent of system functions be expected? b) If yes, which precautionary measures must be taken?	User expectations regarding radar 360 degrees circumferential view from aircraft monitoring in contrast to ACC Radar with limited opening angle	a) y/n b) ___________________	

Safety aspects of user expectations

The driver wants to drive a safe vehicle. This means safe vehicle operation as well as occupant safety in real accident scenarios. Therefore, an ADAS may be perceived by the customer as related to an active safety system. Costumer expectation is mainly subject to the marketing statements of the manufacturer. Customer expectations may perceive a system as a safety system, although developers have possibly never designed it as a safety system.

Question:	Typical examples:	Answer/Comments:	To do:
A15-1. Does the customer expect the ADAS to be an active safety system?	Active lane keeping	y/n	
A15-2. Does the customer expect	Reversible belt preten-	y/n	

the ADAS to be a passive safety system?	sioner used as haptic warning		

Workload

In order to operate a vehicle safely the driver needs to be physically and mentally fit and able to operate a vehicle. ADAS can influence the driver's workload.

Question:	Typical examples:	Answer/Comments:	To do:
A16-1. In which way does the ADAS influence the driver work load?	Take-over of a partial task		

System reliability

Depending on the product, users have varying expectations concerning system reliability. User expectations result from a multitude of influencing factors, like presentation or marketing of the product, advertisement statements or media presentations. The view of the user is however not limited to the evaluation of relevant information on new technologies, but also the knowledge about products used in the past.

Question:	Typical examples:	Answer/Comments:	To do:
A17-1. Have provisions been made that the ADAS function will be marketed under an appropriate name?	Don't use the word "safe" for an assistance system	y/n	
A17-2. Have provisions been made that the system limits are considered at the time of marketing the ADAS?	ACC: stationary obstacles are not considered.	y/n	
A17-3. Have provisions been made that the customer will be informed about differences compared to similar systems?	ACC with distance control vs. cruise control without distance control	y/n	
A17-4. Have provisions been made that the system will not create exaggerated or misleading user expectations which could lead to incorrect system use and driver behaviour?	No shoulder check using Lane Change Assist	y/n	

Please be aware that you might be confronted with a multitude of different user expectations due to the high number of potential users. The same applies to similar products or product names marketed by competitors prior to or after market introduction of the ADAS.

Situational system and sensor limits

This chapter deals with the situation parameter range in which the system works as expected by the driver. Please consider here the influence of external conditions on the system and the driving behaviour.

A risk analysis may help in obtaining an initial overview concerning relevant situations.

Please note: Do not mistake task related system limits for situational limits of the system.

Question:	Typical examples:	Answer/Comments:	To do:
A18-1. a) Within which situational boundaries does the system work as expected? b) What are the main system limits?	System reaction to moving or stationary objects Sensor limits, processing time	a) ___________________ b) ___________________	

Environmental conditions

Question:	Typical examples:	Answer/Comments:	To do:
A19-1. Visibility a) Has the ADAS been designed in a way that it will support the driver only in specific visibility conditions? b) Are there any system limits under these visibility conditions which impair reliable operation of the ADAS function? c) If yes, give the most important examples?	a) Night vision support with infrared cameras at night b) Camera based Lane Keeping Assist with grey shade evaluation of the camera image may not work on roads where the lane markings are covered with snow. Further vision inhibiting factors: snowfall, rain, mist/fog, wind/gusts of wind, direct sunlight, darkness/twilight	a) y/n b) y/n c) ____________________	
A19-2. Climate a) Is system reliability ensured under various climatic conditions? b) Have combinations of climatic influences been taken into consideration? c) Which measures must be taken for which influences?	Humidity/water, temperature, dust, UV radiation, sensor soiling/icing	a) y/n b) y/n c)____________________	
A19-3. Electromagnetic compatibility Is the ADAS function influenced by electromagnetic waves under regular operating conditions of the vehicle?	Transmitters (mobile telephones, overhead power cables), electromagnetic waves emitted by other ADAS vehicles	y/n	

Dynamic driving status with respect to system limits

Question:	Typical examples:	Answer/Comments:	To do:
A20-1. a) Has the ADAS been intented to support the driver only in one or more dynamic driving status? b) If yes, under which conditions? c) Are there any dynamic ADAS system limits impairing reliable operation? d) If yes, which limits?	Speed, longitudinal acceleration/lateral acceleration, distance/route/relative speed in view of other traffic participants or objects, yaw rate, lateral distance in view of lane limits, other traffic participants or objects, engine rotation speed, gear engaged	a) y/n b) __________________ c) y/n d) __________________	

Infrastructure

Please consider implicit assumptions or prerequisites referring to the system to be developed:

The infrastructure also comprises systems and facilities transmitting information to the ADAS vehicle. The ADAS function may be based on information made available via infrastructure?

Question:	Typical examples:	Answer/Comments:	To do:
A21-1. a) Is the system intended for use in a certain environment? b) If yes, please specify.	Permitted speed	a) y/n b) __________________	
A21-2. Objects a) Is it required to place particular emphasis on influences of objects of the infrastructure on the ADAS? b) If yes, please specify.	Tunnels, bridges (also traffic sign bridges), illumination poles, traffic lights, guard rails, manhole covers, other statonary objects in or outside the lane	a) y/n b) __________________	
A21-3. Infrastructural limits a) Is it foreseeable that further market specific infrastructural limits must be considered? b) If yes, please specify.	There is only limited availability of tyre filling stations with tyre pressure control in the USA. England has left-hand traffic and the rest of Europe right-hand traffic.	a) y/n b) __________________	
A21-4. Road a) Are there any influences depending on the kind of road b) If yes, please specify.	Highway, national road, local road, local road in building areas	a) y/n b) __________________	
A21-5. Lane geometry a) Must the influence of the road geometry be considered? b) If yes, please specify.	Lane dimensions, number of lanes, uphill or downhill grade, corner radius, gradient	a) y/n b) __________________	
A21-6. Road surface a) Must any influences be considered concerning road surface? b) If yes, please specify.	Frictional coefficient and local distribution, lane markings, potholes, lane grooves, multi-colour lane markings (USA, Canada, Australia, or additional markings at construction sites)	a) y/n b) __________________	

Question:	Typical examples:	Answer/Comments:	To do:

A21-7. Lane boundaries a) Must any influences be taken into consideration concerning to lane boundaries? b) If yes, please specify.	Continuous or intermittent lane boundaries, crash barriers, plants (trees or bushes) resulting in obstructed vision	a) y/n b) __________________	
A21-8. Road construction/ construction sites a) Must the influence of road work/ construction sites be taken into consideration? b) If yes, please specify.	Stationary objects ("chicanes" serving speed reduction), moving objects (mobile barriers)	a) y/n b) __________________	

Interaction of vehicles with and without ADAS

Question:	Typical examples:	Answer/Comments:	To do:
A22-1. a) Does the ADAS and its function have effects on other traffic participants? b) If yes, which effects can be expected?	Behaviour (manoeuvre) of other traffic participants, trucks with and without trailer, vans, vehicles with and without trailer, motor cycles, bicycles, pedestrians, material and shape of vehicles of other traffic participants which are difficult to be detected by the sensor. Further moving objects within or outside the lane (trees swaying in the wind)	a) y/n b) __________________	
A22-2. a) Can special effects on other traffic participants be expected if other vehicles are also equipped with ADAS? b) If yes, which effects can be expected?	Vehicles with identical ADAS	a) __________________ b) __________________	

Traffic conditions

Please consider effects under various traffic conditions

Question:	Typical examples:	Answer/Comments:	To do:
A23-1. a) Can particular ADAS function effects under various traffic conditions be expected? b) If yes, under which traffic conditions?	High traffic density (rush hour, traffic congestion), medium traffic density (dense traffic), low traffic density (smooth traffic flow)	a) y/n b) __________________	

Human Machine Interface and interaction

Please take into consideration the variety of existing ADAS HM Interfaces.

The questions below will help to describe the Human Machine Interface using the following structure.

System input

Direct driver input via ADAS controls

Question:	Typical examples:	Answer/Comments:	To do:
A24-1. a) Which kind of input operation elements did you consider? b) Why did you consider these?	Buttons, control stalk, rotary control, toggle switch, thumb wheel, voice entry	a) ___________________ b) ___________________	
A24-2. Are all inputs possible with this operation element?	Control stalk and additional adjustments in infotainment system	y/n	
A24-3. Which location is planned for the operation elements? (field of view, reachability) see Annex G.2.1	Control panel, center console top / bottom, door, roof module		
A24-4. What kind of input does the system allow: a) Is it required that the system can be switched on/off? b) Do further system states exist? c) Is it necessary for the driver to be aware of these system states? d) If yes, does the system provide clear description/feedback on the system state? e) Is the input of target data required? - If yes, please state which? f) Is it necessary to supply the possibility of setting system parameters? - If yes, please state which?	a) System switched on/off b) System active / passive d) Text message, pictogram, operation element illumination, warning signal e) Navigation: desired destination ACC: desired speed and desired following distance f) Sensitivity, signal/ volume, brightness	a) y/n b) y/n c) y/n d) y/n e) y/n -___________________ f) y/n -___________________	
A24-5. a) Is personalisation required/intended? b) If yes, specify medium?	Personalisation by means of „fingerprint“ person recognition (note: key memory is not driver related)	a) y/n b) ___________________	

Indirect driver input via non-ADAS control elements

Question:	Typical examples:	Answer/Comments:	To do:
A25-1. a) May the ADAS system be operated with other vehicle control elements? b) If yes, specify with which other vehicle control elements the system may be influenced?	Brake pedal operation influences ACC (switch-off); operation of indicator influences LDW system	a) y/n b) ___________________	
A25-2. a) Does the system change status due to the operation of a different subsystem? b) If yes, specify which?	If the driver drakes, ACC concludes that driver intends to decelerate and subsequently ACC switches off	a) y/n b) ___________________	

System feedback

Describe function and kind of system feedback.

Please check if system feedback may be switched off by the driver. If this is the case, consider and describe the effect.

Direct system feedback

Methods of system feedback:

Question:	**Typical examples:**	**Answer/Comments:**	**To do:**
A26-1. Which sensory modalities are used for system feedback?	Visual, auditive, kinaes-thetic	____________________	
A26-2. a) Which kind of presenta-tion is used? b) Have existing standards been taken into consideration?	Warning lamp, monitor display, loudspeaker output Location, shape, colour etc.	a) ___________________ b) y/n	
A26-3. What is the location of feed-back?	Control panel, head up display		
A26-4. Which kind of feedback does exist? a) System information b) Warning c) Instruction	 a) System status, System parameter b) „Sensor defective“ c) „Distance: Brake!“	 a) ___________________ b) ___________________ c) ___________________	
A26-5. Which kind of information coding is used?	Texts, symbols, voice, noises		
A26-6. Has the existing hierarchy of the overall vehicle concept been taken into consideration for infor-mation, warnings and feedback in terms of the type of feedback?	Infotainment (navigation, traffic messages, phone call), warnings (priorities: brake, oil pressure, wind-screen cleaning liquid)	y/n	

Indirect system feedback

Describe the affected vehicle sub-systems:

Question:	**Typical examples:**	**Answer/Comments:**	**To do:**
A27-1. a) Does the ADAS supply feedback to other vehicle systems? b) If yes, please specify.	Steering system, engine control, suspension etc.	a) y/n b) ___________________	

Preparation of hazard analysis

The following questions will be helpful for the preparation of a hazard analysis and risk assessment (H&R). The questions will also help to check completeness of an analysis.

Top level hazards

Question:	Typical examples:	Answer/Comments:	To do:
A28-1. Has a hazard analysis been performed?		y/n	
A28-2. If no, define for every system function the possible hazards at the top level. Please consider every mode of the system status.	Modes: active, switched off, stand-by etc.		

Operating modes

Question:	Typical examples:	Answer/Comments:	To do:
A29-1. Define all operation modes.	On, off, active, passive, stand-by, graded there may be several levels)		

Failure modes

Failure modes may be structured according to the Questions A30-A32. Please note that a detailed analysis of failure causes is not the objective at this stage of delvelopment. This will be performed in a later product development phase (e. g. by means of a FMEA)

Question:	Typical examples:	Answer/Comments:	To do:
A30-1. Compile a list of all failure modes on the functional level.	Function not available on driver request, function fails during operation - completely - partly Function switches on without request False system output - prompt response (too early / too late) - change of mode - false output value		

System limits

System limits can have the same effect on ADAS performance as system failures. For example in case of ACC (speed range, road curvature range)

Question:	Typical examples:	Answer/Comments:	To do:
A31-1. Evaluate the system limits stating the respective effect on the ADAS performance.	Sensor limits (e. g. limited field of view, sensor blindness due to snow), measuring error, misinterpretation or classification of sensor data, data processing limit, control unit, hardware/software limits, false alarms or irritating system messages		

Detection of system errors

Question:	Typical examples:	Answer/Comments:	To do:
A32-1. Determine for each individual system error whether it is detectable and how it is detected. Please take the operation modes into consideration.			
A32-2. Is detection during self-diagnosis when switching on or off sufficient?		y/n	
A32-3. Is a continual self-diagnosis necessary?		y/n	
A32-4. Define a remedy for each detected error.	Change to default characteristic, if vehicle speed is unknown: Driver information (auditive, visual, permanent warning)		

Product information

In general, product information means information about ADAS via all available media. Amongst others these are product advertisements, direct distributor information (sales talks etc.), but also user manuals.

In order to ensure correct system operation product information should comprise the following:

Question:	Typical examples:	Answer/Comments:	To do:
A33-1. Describe which product information is essential to ensure proper operation of ADAS	Print media, multimedia, personal instruction		
A33-2. Have existing user expectations been considered in the product description (e.g. owners manual, maketing brochures)?	User expectations regarding radar 360 degrees circumferential view from aircraft monitoring in contrast to ACC Radar with limited opening angle		

Maintenance / Repair

Please consider different elements for maintenance and system diagnosis:

Question:	**Typical examples:**	**Answer/Comments:**	**To do:**
A34-1. a) Is it necessary to perform maintenance work on the system to be developed during the entire vehicle operation? b) If yes, state maintenance procedure for the system?	Hardware maintenance, adjustment of sensors, cleaning, lubrication, integrity tests. Software maintenance: updates, patches, self-diagnosis	a) y/n b) ___________________	
A34-2. a) Is it necessary to have sub-system data available? b) If yes, please state which?	Own system, sub-systems of interfaces	a) y/n b) ___________________	
A34-3. a) Which environment data should be stored?	Mileage, date, time stamp		
A34-4. Where should the data be stored?	Control unit, installation location		
A34-5. Which storage capacity is required concerning data volume?			
A34-6. Which signal should be the triggering signal for data storage?	Airbag signal		
A34-7. Who will receive access to the data?	PIN query		
A34-8. What equipment is necessary to read out diagnosis data and evaluate them?	Workshop diagnosis tester		
A34-9. What maintenance intervals should be determined?	Integration into vehicle maintenance schedule		
A34-10. Who may or should perform maintenance work?	User, workshop, others		

A.2 Checklist B – Evaluation concepts for system specification

A.2.1 Introduction

This annex proposes an approach to evaluate the system specification regarding controllability of the system. The evaluation is based on a checklist.

The purpose of the checklist is to give the system developer clues about system improvements. This implies that for a successful development it is not necessary to answer all the questions with "yes".

The checklist questions are structured using a number of concepts that focus the view of the evaluator on a specific topic and should help to check the specification from different perspectives.
All of the concepts are related to, or contribute to the controllability of the evaluated system and are presented in an order according to the three levels of information processing where they fit best:

- Driver perception of the criticality of a situation
- Driver decision of an appropriate countermeasure
- Driver performance of the countermeasure

Overview of concepts

Driver perception:

- Predictability
- Emotional issues
- Trust
- Perceptibility (message transfer to driver)
- Vigilance
- Workload / Fatigue

Driver decision:

- Traffic safety / Risk
- Responsibility / Liability
- Learnability
- Behavioural changes
- Comprehensibility
- Error robustness

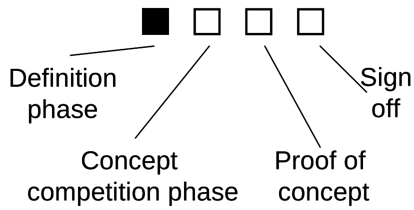
Driver performance:

- Misuse potential
- Macroscopic effects and driving efficiency
- Benefits / Acceptance
- Operability
- Control issues

Checklist layout

Each concept is presented in a separate subchapter. The concepts are evaluated by means of questions presented in the form of a checklist.

The first “Phase” column refers to the development phases as they are defined in this document. A solid box means that the question is applicable for this development phase.



The phase column is for information only and to support the identification of the most relevant questions at each specific stage of system development.

The second column contains the questions related to the particular evaluation concept.

Column 3, 4 and 5 provide empty space to answer the question by either checking “yes” or “no” or “Not suitable”. If “not suitable” is checked a comment should be given, why the question is not suitable

The “comment” column at the end can also be used by the evaluator for example to justify an answer, to refer to other activities or to define further steps if the evaluator is uncertain about the answer.

<u>Example:</u>
The question in the example below is related to the concept of “Predictability”. If it can be answered with “Yes” everything is OK. If the answer is “No” then additional care should be taken during system development to reach the goal of “conformity with driver expectation”.

Phase	Predictability	Yes	No	Not suitable	Comments
□□■□	1. Are system reactions predictable in a sense that they correspond to the previous experiences and expectations derived from driving or using related systems (**conformity with user expectation**)?				

A.2.2 Predictability

Phase	Predictability	Yes	No	Not suitable	Comments
□■□□	1. Are system reactions that may occur **understood by other road users**?				
□■□□	2. If it is likely that the system **will change or increase the variability in the behaviour of other road users** (in different vehicles) in the traffic system: Will the driver or the ADAS be able to predict the actions of other road users?				
□□■□	3. Are system reactions predictable in the sense that they correspond to the previous experiences and expectations derived from driving or using related systems (**conformity with driver expectation**)?				
□□□■	4. Does the driver get a clear understanding of the different **modes of operation / system states**?				

A.2.3 Emotional issues

Phase	Emotional issues	Yes	No	Not suitable	Comments
□■□□	1. Have you considered (potential) traffic situations during system development where the driver's stress level **(workload)** may be expected to be **negatively changed** (too high / too low) when the system is available?				
□□■□	2. Has it been considered that **the passenger's comfort may be negatively modified** by the knowledge about the presence of the system function (e.g. a warning that is intended only for the driver)?				

A.2.4 Trust

Phase	Trust	Yes	No	Not suitable	Comments
□■■□	1. Are **warnings** displayed in time with respect to the criticality of the hazard?				
□■■□	2. Are **system messages**, which are relevant for the driving task, **appropriate** (in type, frequency) with respect to the situation?				
□□■□	3. Does a warning **alert the driver only to genuine hazards** that have not been indicated earlier?				
□□■□	4. Do the system messages consider the different modes of operation and traffic situations?				
□□□■	5. Is there a strategy to avoid the system issuing **too many warnings** (false alarms), which the driver may begin to ignore?				

A.2.5 Perceptibility (message transfer to driver)

Phase	Perceptibility (message transfer to driver)	Yes	No	Not suitable	Comments
□■■□	1. Are **multiple information channels** used to convey critical messages? (e. g. acoustic in addition to optical display)?				
□□■□	2. Are the system **messages perceptible for the driver** in typical ADAS related traffic situations?				
□□■□	3. Does the system provide appropriate **timely feedback about a system reaction** in a given traffic situation (e. g. take over request from adaptive cruise control)?				

Phase	Perceptibility (message transfer to driver)	Yes	No	Not suit-able	Comments
□□■□	4. Is the **presentation of information / warning** (output) of the new system **consistent with the structure** of al-ready existing information / warnings of other systems (e. g. type, presentation, timing)? Consider the whole vehicle / driver interface.				
□□■□	5. Does the **location** of the new system interface and op-eration elements (input and output) **fit the existing inter-faces** with respect to the relevance of the supported task?				
□□□■	6. Can system outputs and **information be perceived** by the driver **quickly** enough to enable them to react ap-propriately (e. g. take over request from adaptive cruise control)?				
□□□■	7. Is the **driver** sufficiently **informed about the system status and function** at all times?				
□□□■	8. Are the system **messages comprehensible and un-ambiguous** for the driver?				

A.2.6 Vigilance

Phase	Vigilance	Yes	No	Not suit-able	Comments
□□■□	1. Have you considered that the use of the system may provoke monotonic situations (e.g. monitoring tasks), if so **will the driver remain attentive**?				

Phase	Vigilance	Yes	No	Not suit-able	Comments
□□■□	2. Can the operation or observation of the system be achieved **without a major change in the distribution of attention** relating to the driving task so that potentially hazardous situations may not occur?				
□□■■	3. Does the HM Interaction of the system prevent the driver from losing situational awareness (e.g. keeping the driver “in the loop”, providing a consistent warning strategy)?				

A.2.7 Workload / Fatigue

Phase	Workload / Fatigue	Yes	No	Not suit-able	Comments
□■■□	1. Is the HMI layout constructed in a way such as to avoid an overload of the driver’s sensory channels in ADAS specific traffic situations?.				
□□■□	2. In case of an incorrect input: Can the desired result be achieved with no or small **correctional effort** (e.g. with-out increasing the stress level or workload for the driver)?				
□□■□	3. Have traffic situations been considered during system development that may cause a higher stress level **(work-load)** for the driver compared to driving without the sys-tem?				
□□■□	4. Does the system require sufficient driver activity to avoid the driver becoming inattentive or tired during system supported driving?				

A.2.8 Traffic safety / Risk

Phase	Traffic safety / Risk	Yes	No	Not suit-able	Comments
□■□□	1. Are **system reactions understood** by other road users? If not can they still **control the situation** (e. g. system based deceleration without activation of brake lights)?				
□■□□	2. Is the **reaction performance of other road users** sufficient to interact with a vehicle that is equipped with a rapidly (hard, intensive) reacting ADAS system?				
□■□□	3. Is the driver's attention necessary to keep them in the **physical control loop** while the system is running?				
□■□□	4. Does the design provide **reliable system predictions** if the **behaviour of other road users** changes?				
□■□□	5. Is the vehicle **controllable** in the case of a system **malfunction by overruling or switching off** the system?				
□■□□	6. Can **system parameters** be **changed whilst driving** without causing unexpected behaviour?				
□■■□	7. Is the system function **self - explanatory** (i.e. without user manual)?				
□■■□	8. Can the operation or observation of the system (e.g. possible driver distraction by displays) be achieved **without a major change in attention distribution** relating to the driving task so that potentially hazardous situations may not occur?				
Phase	**Traffic safety / Risk**	**Yes**	**No**	**Not suit-able**	**Comments**
□□■□	9. Have other driving tasks been considered during system development to avoid a conflict with the operation of the ADAS?				

□□■□	10. Have measures been taken to avoid the system **function irritating the driver** while the system is operating (e. g. if the driver is not familiar with a system function because they are using a rental car)?				
□□■□	11. Is the **driver informed** if a detectable **system malfunction** occurs?				

A.2.9 Responsibility / Liability

Phase	Responsibility / Liability	Yes	No	Not suitable	Comments
■□□□	1. If **type approval rules or other laws prevent market introduction** of a system under development (Annex A.1) is there a realistic possibility to change type approval rules or laws?				
■■■■	2. Have **methods** been applied that assist and optimise the **design** process (e. g. ISO 9001, VDA quality management, methods for safety and risk evaluation, checklists …)?				
□■□□	3. Have you considered the possibility that **specific skills** may be required for a safe operation of the system that some drivers may not have (consider particularly inexperienced or physically impaired drivers)?				
□■□□	4. Has the need for **special skills** been taken into account?				
Phase	**Responsibility / Liability**	**Yes**	**No**	**Not suitable**	**Comments**
□■□□	5. If the use of the equipped vehicle removes the driver from the **physical control loop**, is this in line with current legislation?				

□■□□	6. Is the **vehicle behaviour predictable** for other road users if they do not know whether the vehicle was equipped or not equipped with the system?				
□■□□	7. Has the **state-of-the-art** been taken into consideration (ask your domain experts e.g. active safety, HMI, vehicle dynamics)?				
□■■■	8. Have **legal requirements** and **standards** been complied with (ask your homologation or law department for more information)?				
□■■■	9. Have **demands of consumer protection organisations** been taken into consideration?				
□□■□	10. If special skills are needed: Was the **restriction to a specific user group** explicitly addressed during development (e.g. restriction to passenger car drivers)?				
□□■□	11. Does the system indicate that it is **unsuitable for certain groups of users** (e.g. function permitted via personalisation; feedback with respect to operational readiness of a personalised function shown in display)?				
□□■□	12. Is the system **function intuitively understandable** (i.e. without the user manual)?				
□□■□	13. Has the **possibility of misinterpretation** of the system function been considered?				
□□■□	14. Is it possible for the driver to **deactivate** or overrule **a system** at any time**, which assists** a driving task?				

Phase	Responsibility / Liability	Yes	No	Not suitable	Comments

□□■■	15. Can the system be **operated safely by the driver without having read the user manual before** initial operation? This question refers to the situation, where the driver has the opinion that it would be possible to use the system intuitively.				
□□■■	16. Are the **system limits clearly understandable** for the driver?				
□□□■	17. Does the **user manual** describe system functions, handling and limits in an **understandable** way?				
□□□■	18. Are system messages unambiguously formulated and easy to understand? This question refers to the situation that misinterpretation may lead to a potentially hazardous situation.				

A.2.10 Learnability

Phase	Learnability	Yes	No	Not suitable	Comments
□■□□	1. If specific **skills** are required for safe use of the system, is it possible for a driver to gain these specific skills during vehicle operation?				
□■□□	2. If **specific skills** are required for safe use of the system, or if the use of the system needs to be restricted to a specific user group: (consider particularly inexperienced or physically impaired drivers): Is this obvious for the driver and does the driver know what to do?				

Phase	Learnability	Yes	No	Not suitable	Comments

□□■■	3. Is it likely that the driver's mental representation of the system, which they will develop during operation, will correspond to the technical function (**compatibility of mental and technical model**)?				

A.2.11 Behavioural changes

Phase	Behavioural changes	Yes	No	Not suitable	Comments
□■□□	1. Have you considered that the **feedback from the vehicle (e.g. haptic, visual) may confuse the driver** if they were used to performing the task in an unequipped vehicle?				
□■□□	2. Does the system design **avoid negative influence** to **external persons** (other road users, overtaking / overtaken drivers, etc) that have knowledge about the existence of the system function in the vehicle?				
□□■□	3. Are the driver tasks with ADAS support still an essential part of the overall vehicle operation in a way that the driver will not neglect relevant tasks as a result of the use, activation or deactivation of the new system (e.g. less use of mirrors or shift of attention to secondary tasks) as a result of the use, activation or deactivation of the new system?				
□□■□	4. Have you considered that the system does not encourage the driver to **overestimate their abilities** and skills?				

A.2.12 Comprehensibility

Phase	Comprehensibility	Yes	No	Not suit-able	Comments
□■■□	1. Is the **behavioural pattern of the driver,** concerning system operation, taken into consideration for the operation of the new system (A behavioural pattern is a behaviour that has been acquired in the past by using existing vehicle systems e. g. deactivate an operating cruise control by depressing the brake pedal)?				
□□■■	2. Are generally understandable, **simple terms** used for system outputs and driver information?				
□□■■	3. Are the **limitations of correct operation / system limits** comprehensible and predictable for the driver in different environments, weather and visibility conditions (e.g. fog, animals on the road)?				
□□■■	4. Are **the limitations of sensory detection** capabilities understandable, particularly when compared to human sensors especially where metaphors are used, e.g. the "machine eye”?				
□□□■	5. Is it likely that the driver’s mental representation of the system, which is developed when using the system, corresponds to the technical function (**compatibility of mental and technical model**)?				
□□□■	6. Does the driver understand the system feedback to their performed input / control actions (feedback could be e.g. acoustical, optical or dynamic vehicle behaviour)?				
□□□■	7. Is the system function **intuitively understandable** (i.e. without user manual)? If not, consider how to ensure that user manual is read or if driver needs other training.				
□□□■	8. Does the **user manual** present system functions, handling and limits in an **understandable** way?				

A.2.13 Error robustness

Phase	Error robustness	Yes	No	Not suit-able	Comments
□■□□	1. Are **physical constraints** (e.g. a threshold for a minimum activation velocity) implemented to prevent incorrect operation?				
□■□□	2. Can the driver control the system if s/he wants to activate the system and the **system is not available**? This refers especially to the situation in which the driver is not informed that the system is unavailable.				
□■□□	3. Have you considered the situations under the aspect of unintentional activation/deactivation?				
□□■□	4. In case of an incorrect driver input: Can the desired result be achieved with no or small **correction effort**?				

A.2.14 Misuse potential

Phase	Misuse potential	Yes	No	Not suit-able	Comments
□■□□	1. Is the system designed in such a way as to **minimise** the possibilities of **external manipulation or sabotage**?				
□□■□	2. Have potential cases for misuse been considered by the system designers?				
□□■□	3. Does the design of the system function discourage a misuse potential with respect to **'testing the limits'**?				
□□■□	4. Does the system implementation consider the potential usage of the system as an **'entertainment'** system?				

Phase	Misuse potential	Yes	No	Not suit-able	Comments
□□□■	5. If it is possible to **adjust system parameters** to different traffic conditions (e.g. distance to front traffic) or environmental conditions (e.g. view conditions): Is the **driver aware of the effects** of these adjustments?				
□□□■	6. Is the driver supported **in striving for safe driving** when using the system (minimise risk compensation)?				
□□□■	7. Does information about the system (manuals, graphics in system messages, advertisement, press publications etc.) raise **realistic expectations** without **promoting risky behaviour**?				
□□□■	8. Does the system function **support the driver's duty to exercise due diligence** and avoid promoting thoughtless or careless use, which can lead to safety-critical situations?				

A.2.15 Macroscopic effects and driving efficiency

Phase	Macroscopic effects and driving efficiency	Yes	No	Not suit-able	Comments
□■□□	1. If it is likely that the system **will change or increase the variability of the behaviour of other road users** (different vehicles) in the traffic system: Have you considered if this change in variability could reduce the potential gain of the introduction of a new ADAS?				
□■□□	2. If the driver will **lose skills and capabilities** when using the system then have you considered that this could lead to negative macroscopic effects e.g. traffic congestion or increase in overall travelling time?				

Phase	Macroscopic effects and driving efficiency	Yes	No	Not suit-able	Comments
□■□□	3. Does the use of the system support an efficient way of driving?				
□■□□	4. Does the system support driving economy (e.g. reduction of fuel consumption)?				

A.2.16 Benefits / Acceptance

Phase	Benefits / Acceptance	Yes	No	Not suit-able	Comments
□■■□	1. Is the **presentation of warnings appropriate** (in type, frequency and timing) to the criticality of the hazard?				

A.2.17 Operability

Phase	Operability	Yes	No	Not suit-able	Comments
□■■□	1. Are **physical impairments taken into consideration concerning** the prevention of incorrect operation?				
□■■□	2. Are all **human-machine-interaction procedures inter-ruptible** by the driver once initiated?				
□□■□	3. Is it possible **to undo, correct or change driver inputs** at any time?				

A.2.18 Control issues

Phase	Control issues	Yes	No	Not suitable	Comments
■■□□	1. Can the driver control the system after a **transition** from full system functionality **to a degraded mode**?				
■■□□	2. Can the driver control the system after an **unintended** or **accidental system deactivation**?				
■■□□	3. Can the driver control the system after an **unintended** or **accidental system activation / use**?				
■■□□	4. If the system can execute a function without being requested or expected, can the driver control it?				
□■□□	5. Can the driver control the situation if they want to activate the system and it is not available e.g. the car is currently operated outside the system limits?				
□■□□	6. Have you considered the reaction to a system failure of drivers with different driving education/experience? Consider also the background of drivers from different cultures / countries.				
□■□□	7. Is it always ensured that **driver actions**, which should overrule the system, are **intuitive**, e.g. activating brake pedal to switch off ACC?				
□■□□	8. Could the use of the equipped vehicle increase the **probability of loss of longitudinal and / or lateral control?** Consider also the use of the vehicle if a system failure occurs.				
□■□□	9. If the system is for use by a specific user group only: Have you considered that **specific skills or a special training** may be required for safe use of the system that some drivers may not have (consider particularly inexperienced or physically impaired drivers)?				

Phase	Control issues	Yes	No	Not suitable	Comments
□■■□	10. Have you considered the possibility of **system activation** or deactivation in situations, in which it would lead to potentially hazardous driving conditions?				
□□■□	11. Is the controllability in the case of a system failure also ensured for a driver with **impaired capability** (e.g. elderly person)?				
□□■□	12. Have you considered (if such data is available) that the driver may **lose relevant driving skills and capabilities** after long-term system use? This is especially relevant if the system is suddenly unavailable or the driver changes to a car without such an ADAS.				
□□■□	13. Is the system or vehicle still controllable in the case of a system malfunction / automatic system deactivation e.g. are the **time windows** sufficiently large, so that the driver can take over control safely whenever necessary?				
□□■□	14. Are **system messages**, which are relevant for the driving task, displayed in time with respect to the situation?				
□□■□	15. Have you considered that an erroneous system message could lead to a driver-reaction, which leads to a potentially hazardous situation (e.g. map based speed warnings)?				
□□■□	16. Have you considered the possibility of **action slips** that may occur during the operation of the system (e.g. activation of wrong control e.g. pressing the brake pedal with the left leg after switching from a manual transmission to an automatic transmission vehicle)?				
□□□■	17. Can the driver control the system regarding speed or precision of their psycho-motor performance (particularly in situations where the driver is required to take over)?				

A.3 Hazard analysis and risk assessment procedure

The Hazard analysis and risk assessment procedure described in this annex is currently being developed in the ISO TC22 / SC3 / WG16 “Functional safety” for the automotive industry. The release is expected in 2009. Parts of this chapter (A.3.2 – A.3.6) are directly linked to the ISO/WD 26262-3 in the version dated 2007-06-28.

A.3.1 Objectives

The objective of the hazard analysis and risk assessment (H&R) is to identify and categorise the potential hazards of the item[5] and formulate goals related to the prevention of these hazards in order to achieve an acceptable residual risk. For this, the item is evaluated with regard to its safety implications and a Automotive Safety Integrity Level (ASIL) is assigned. The ASIL is determined by a systematic evaluation of potentially hazardous driving or operating situations. The rationale of the ASIL evaluation is documented and takes into account the estimation of the impact factors severity, probability of exposure and controllability..

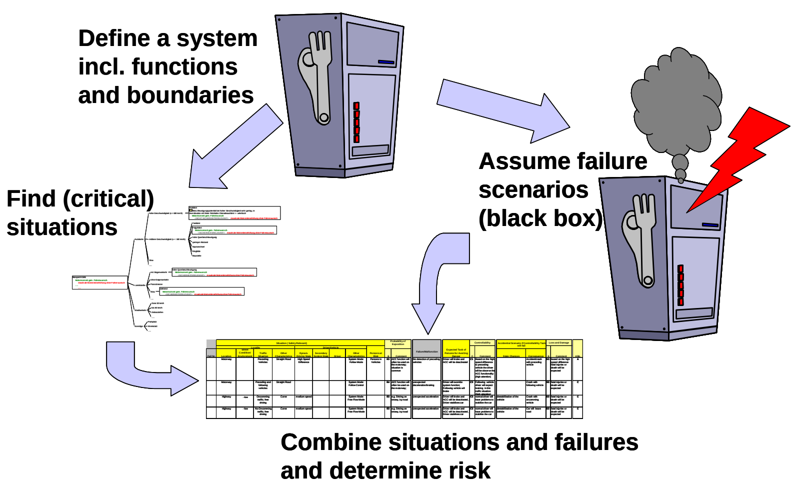


Figure 6: Methodology of risk assessment

A.3.2 General remarks

For the analytical approach a risk (*R* = risk) can basically be described as a function *F* of the frequency (*f* = frequency) of occurrence of a hazardous event and the potential severity of the resulting harm or damage (*S* = severity):

$$R = F(f,S)$$

[5] Definition of “Item” in ISO/WD 26262: E/E system (i. e. a product which can include mechanical components of different technologies) or a function which is in the scope of the development according to this standard. (NOTE: There can be only one item per development)

The frequency of occurrence *f* is in turn influenced by several parameters:

One factor to be taken into account is how frequently and for how long individuals find themselves in a situation where the aforementioned hazards exist (*E* = probability of exposure).

Another factor that influences the occurrence of an hazardous event is the avoidance of specified harm or damage through timely reactions of the persons involved (*C* = controllability).

The combination *E x C* represents the value for the probability that external circumstances occur where a failure has the potential to produce the aforementioned extent of specified harm or damage.

A further factor is the probability that the system to be implemented may itself cause a hazardous event. This factor, which is not considered in the formula above, is characterised by undetected random hardware failures of the system components and by hazardous systematic faults that remained in the system. Because development in accordance with ISO/WD 26262 should lead to safe systems, the resulting ASIL describes the minimum requirement to be fulfilled by the final system to avoid those failures. For this reason, the probability is initially not considered in the risk assessment

A.3.3 Input

The prerequisites for the hazard analysis and risk assessment are:

- Item definition: Description of the item, its interfaces, functional requirements, already known safety and reliability requirements, and the field of application of the item
- Failure modes and preliminary known hazards: Documentation of failure modes and preliminary known hazards

A.3.4 Hazard analysis

The hazard analysis and risk assessment method comprises of three steps:

1. Situation analysis and hazard identification: The goal of situation analysis and hazard identification is to identify the potential unintended behaviour of the item that could lead to a hazardous event.
2. Hazard classification: The goal of hazard classification is to determine for each failure mode considered the classes of probability of exposure (E), controllability (C) and severity (S) for each potentially hazardous driving situation.

3. Risk assessment: Risk assessment determines the required automotive safety integrity level.

The following sections give on overview on hazard classification and risk assesment. Informative references from the annex of ISO/WD 26262 are included in the tables.

Classification of the severity of a potential hazard

The severity of potential harm shall be estimated. The potential severity shall be assigned to one of the severity classes S0,S1, S2, S3 in accordance with Table 3.

Class	S0	S1	S2	S3
Descrition	No injuries	light and moderate injuries	Severe injuries, possibly life-threatening, survival probable	Life-threatening injuries (survival uncertain) or fatal injuries
Reference for single injuries (informative)	AIS 0 Damage that cannot be classified safety related, e.g. bumps with the infrastructure	more than 10% probability of AIS 1-6 (and not S2 or S3)	more than 10% probability of AIS 3-6 (and not S3)	more than 10% probability of AIS 5 and 6

Table 3: Categorisation of Severity

Classification of exposure in the initial situation

The driving or operating situations of vehicles range from everyday parking and everyday driving in the city or on the highway to situations that require a constellation of various environmental parameters and therefore occur extremely rarely. The probability of exposure of the driving situations shall be classified into the classes E1 , E2, E3, E4 in accordance with Table 4. The given classes differ between each class by an order of magnitude and represent a rough classification of probability of exposure.
The proportion of vehicles equipped with the item shall not be taken into account for the estimation of the probability of exposure.

Class	E1	E2	E3	E4
Description	Very low probability	Low probability	Medium probability	High probability
Definition of duration/ probability of exposure	Not specified	< 1% of average operating time	1% - 10% of average operating time	> 10% of average operating time

(informative)				

Table 4: Categorisation of Exposure

Classification of possible controllability

The evaluation of chances to avert danger, i.e. the controllability, is an estimation of the probability that the driver or other traffic participants cannot gain control of the hazardous event that is arising and are not able to avoid harm or damage..
One assumes that the driver is in an appropriate condition for driving (for example not exhausted) with respect to general population, has appropriate driver's training (has a driver's license) and is complying with legal regulations. However, a reasonably foreseeable misuse should also be taken into account.

The controllability by the driver or other traffic participants shall be classified into the classes C1, C2, C3 in accordance with Table 5. For situations which are regarded as simply distracting or disturbing but as controllable in general, the class C0 may be introduced. No ASIL assignment is required for hazards that are assigned to class C0.

Class	C0	C1	C2	C3
Description (informative)	Controllable in general	Simply controllable	Normally controllable	Difficult to control or uncontrollable
Definition	Distracting	More than 99% of average drivers or other traffic participants are usually able to control the damage.	More than 85%[7] of average drivers or other traffic participants are usually able to control the damage.	The average driver or other traffic participant is usually unable, or barely able, to control the damage.

Table 5: Categorisation of Controllability for risk assessment

A.3.5 Risk assessment

The Automotive Safety Integrity Level (ASIL) shall be determined for each hazardous event using the estimation parameters severity (S), probability of exposure (E) and controllability (C) in accordance with Table 6.

The ASIL is named ASIL A, B, C and D, where ASIL A implies low safety requirements and ASIL D implies high safety requirements. In addition to these safety-related levels, there is also the class

[7] in ISO/WD 26262 currently 90%. Considering the results of chapter 4.2 Final proof of controllability by means of a test with naive subjects the value of 85% is kept here

QM, which stands for Quality Management. A requirement rated as QM is not considered as a safety-related requirement.

		C1	C2	C3
S1	E1	QM	QM	QM
	E2	QM	QM	QM
	E3	QM	QM	A
	E4	QM	A	B
S2	E1	QM	QM	QM
	E2	QM	QM	A
	E3	QM	A	B
	E4	A	B	C
S3	E1	QM	QM	A
	E2	QM	A	B
	E3	A	B	C
	E4	B	C	D

Table 6: Automotive Safety Integrity Level (ASIL) assignment

A.3.6 Work products

- Documentation of failure modes and preliminary known hazards
- List of potentially hazardous driving situations and operating conditions
- Documentation of driving situations and operating conditions in the hazard analysis and risk assessment, including severity, probability of exposure, controllability classification and resulting ASIL
- Documentation of the safety goals

A.3.7 References

Detailed information for risk analysis can be found in:

ISO/WD 26262-3: Road Vehicles – Functional Safety

Annex B Recommendations for controllability evaluation

B.1 Condense hazardous situations

ADAS Systems generate a large number of situations, where a safe use of the system has to be considered (List of potentially hazardous situations), if every possible circumstance is taken into account. On the other hand many of these situations are very similar and might be tested or evaluated at the same time (e.g. ACC looses target during daytime or during night time – on a motorway or major country road …).

Due to practical reasons the scenarios for expert evaluation and for test evaluation should be limited to most relevant ones.

B.1.1 How to get the complete list of potentially hazardous situations

After a system is defined situations are compiled in a list or in a table considering

- where the system should work (normal function),
- where the system could be used but it is not designed for (misinterpretation and potential misuse),
- where the system limits are reached (system limits)
- and where situations caused by malfunction of the system (failure).

In each situation the driver may behave or react differently, depending on additional conditions and circumstances (see Figure 7).

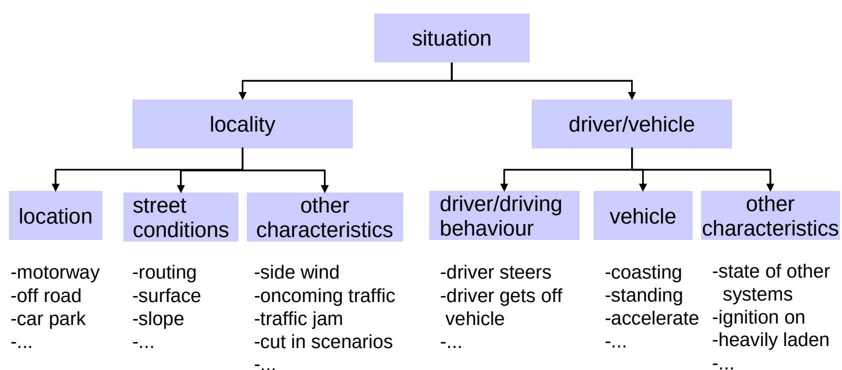


Figure 7: Collection of driving situations

B.1.2 How to condense potentially hazardous situations

The maximum number of system relevant situations makes it likely that no important situation is left out or forgotten. On the other hand there are many situations that are not safety relevant. After deleting these not safety relevant situations there are a couple of situations, which are not controllable and therefore technical solutions are developed. Only the remaining ones take credit from controllability (the driver is needed as part of the safety system).

Similar situations and conditions now can be condensed to a reasonable number of scenarios that cover all controllability relevant situations. (Figure 8)

The remaining list of situations is the basis to start controllability evaluation.

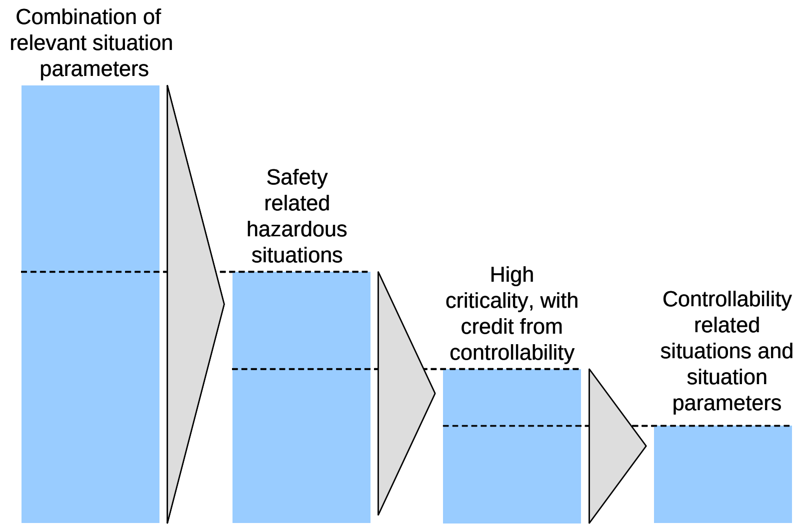


Figure 8: Extracting controllability related situations

B.2 Conducting a test with subjects

Before conducting a driving test with subjects several prerequisites have to be fulfilled. Objectives, methodological approach and experimental design have to be defined.

Further a decision for the test environment has to be made, test equipment, skilled and trained test instructors and a trial plan are needed to conduct a test with subjects.

The following checklist may assist in conducting your own empirical test trials.

Topic	Action	Examples / Comments	Done
Test Hypotheses	Specify each research hypothesis to be explored in the study in clear and explicit terms	e.g. drivers react in time by depressing the brake pedal after receiving an acoustic warning in a specific situation XY	❒
Experimental design	Specify the number and nature of any groups	e.g. an experimental group driving with ADAS and a control group driving without ADAS	❒
	Specify the dependency of any groups	e.g. plan an independent or dependent measures design	❒

	Make a decision for the test environment • On-the-road-trials • Test track • Simulator (see Annex D)	<u>On-the-road-trials - advantages</u> - realistic environment - normal driving behaviour - high validity of results <u>On-the-road-trials - disadvantages</u> - difficult to create and instrument - costly and time consuming - not fully controlled - potentially less safe, provoking of risk situations and failure states (fault injection) is often too unsafe <u>Test track trials - advantages</u> - Allows testing of (simulated) potentially hazardous situations - Fault injection possible - Control of influencing variables (Reliability) - safer than on-the-road trials, although an element of risk is still involved <u>Test track trials - disadvantages</u> - Artificial situation - No routine driving behaviour - difficult to create and instrument - expensive particularly if traffic conditions are to be simulated	❒
	Specify procedures for controlling extraneous variables	e.g. randomise or permute the sequence of test scenarios for the subjects to avoid sequence effects	❒
	Specify the number and sequence of observations made on the groups	e.g. repeat measurements if possible; but some treatments may allow only a single measurement, afterwards the subjects are aware of and change their expectations, e.g. after fault injections or hazard braking manoeuvres	❒

Topic	**Action**	**Examples / Comments**	**Done**
Operational Definition	Specify the test scenarios including - traffic participants and their behaviour, - system status, - environmental conditions, - specific hazard situations	Due to the decision for the test drive type (test track, real traffic, simulator) the controllability of traffic and environmental conditions is more or less difficult.	❐
	Specify an operational definition of each of the following: All independent variables All dependent variables All controlled extraneous variables All other extraneous variables	independent variables can be e.g. number of buttons on steering wheel, ADAS normal use or an ADAS system failure (fault injection) dependent variables can be e.g. response time, velocity, brake pressure, standard deviation of steering angle, time-to-collision, time-to-line-crossing, driver's comprehensibility of system status etc. controlled extraneous variables can be e.g. road type (urban, motorway or rural), other extraneous variables can be e.g. weather & road conditions, traffic density	❐
	Specify the briefing of subjects	Is a familiarisation drive required so that the participant can get used to the vehicle and ADAS? Is it intended to give information about the ADAS to the subjects or will the subject be left alone with the function and instrumentation? Further subjects may be asked to accomplish a specific list of tasks. Which instructions have to be given, when and in which order?	❐
	Specify the test procedure with the run of events	The test procedure needs to be detailed and listed e.g. in a trial timetable Pre-testing the whole test procedure can be very useful to identify and avoid possible problems as well as optimise and fine-tune the test run.	❐
Sample	Specify the procedures for sample selection	Just describe how to make a test with the average driver A random sample is representing the real population best and therefore the favoured procedure due to its reduced likelihood of bias. With smaller sample sizes, the Quota sampling is very popular ensuring the quota of subjects of specified type (age, gender, driving experience, etc).	❐
	Specify the number of subjects (sample size)	The sample size needed depends mainly on the experimental design.	❐

B.3 How to setup pass-fail criteria

Pass-/fail criteria are necessary for the final proof of the controllability of ADAS systems.

No matter which method is chosen to do a final proof, the experts have to make up their mind which driver reactions are relevant to solve certain situations of system failure or malfunction.

Pass-/fail criteria are then generated as certain values in the expected driver reactions.

All these criteria can then be evaluated with any method mentioned in Annex D.

The list of risky situations is the basis for setting up the test scenarios and for the agenda for the Expert Panel. For a discussion of the relevant driver behaviour a team of system engineers and human factors specialists is relevant. The first group provides knowledge over the exact system functionalities, time lines and failure mode "experience".

With the help of the human factors specialists the foreseeable driver reactions can be estimated with high probability.

It is not possible to set up quantitative safety relevant measures for future ADAS systems. A yes/no answer as pass/fail criterion is needed.

Every risky situation that the driver may end up in must be considered. Taking into account driver controllability, at least one possible remedy must be specified by the developer.

For the final proof the test-scenario is “passed” if the subject reacts as previously anticipated or in an adequate way to solve the situation.

Certain quantitative and qualitative measures to come to the result of pass or fail have to be developed individually for each new system by evaluation experts.

B.4 How to evaluate controllability by experts

To conduct the Expert Panel ADAS Verification the following checklist may assist in the selection of expert and input collection for assessments.

Topic	**Action**	**Content**	**Done**
Selecting Participants	Determine, which competences are needed to be included in the Expert panel ADAS Verification	Engineers from the ADAS development team	❒
		HF department engineers	❒
		External engineers experts on vehicle dynamics and ADAS compounds	❒
		Safety systems experts	❒
		Experts on vehicle integration	❒
		Accident research experts	❒

Gathering Inputs	Collect all inputs needed to the assessment	List of potentially hazardous scenarios coming from the Risk Analysis	❒
		List of tasks to be performed in potentially hazardous situations.	❒
		Answers to Response Check list B and/or complementary Check-Lists	❒
		List of open questions arising during the design process (Open Item List)	❒
		Vehicle equipped with the system under evaluation and the definitive HMI	❒
		Estimated controllability levels targeted	❒
		Results of HM Interaction tests conducted during the design process	❒
		Results of HM Interaction tests coming for similar systems or HMI already tested.	❒
		Results of previous expert panel assessments done during the designing process	❒
		Accident research data	❒
Carrying out the verification procedure preparing sign-off recommendation	Making the assessment under static and dynamic conditions For scenarios including - traffic participants and their behaviour, - system status, - environmental conditions, - specific hazard situations	In static conditions, review the all questions coming from checklists and Open Item List and verify that all problems are solved	❒
		Experts look for weakness and inconsistencies.	❒
		For each situation the expert panel confirms anticipated driver reaction.	❒
		Consider the case of more vulnerable users related to abilities involved in controllability	❒
	Additional testing	If critical information to signing of is lacking, perform appropriate testing.	❒
Editing	Compile the result of the verification in a document		❒

Annex C General methods for safety analysis

C.1 Early risk assessment by HAZOP

HAZOP (hazard and operability study) is a procedure that has been developed in the process industry (e.g., Kirwan, 1994), but that has recently been proposed for application in assessing the human and behavioural element in traffic safety measure evaluations as well (Jagtman, 2004).

A HAZOP searches for every conceivable process deviation from normal operation and then looks at possible causes and consequences. The typical thing about a HAZOP is that the search is done in a systematic way by a team of specialists from different backgrounds, so as to minimise the probability that any essential factors are overlooked.

The search is assisted by putting up a matrix of *process parameters* and *guide words*. A combination of a process parameter (e.g. 'flow') and a guide word (e.g., 'reverse') is a cell in this matrix and could form a possible deviation.

A) Input / Requirements

- System description, block diagrams etc. to discuss causes and consequences
- Process parameters and guidewords

	No(ne)	(Too) high	(Too) low	Wrong	Failure of	Un-known	Un-expected
Speed							
Direction							
Location							
Focus of attention							
Attention							
Travel time							
Speed difference							

- List of questions to be asked for each combination of process and guidewords:
  - Could the deviation occur?
  - If so, how could it arise?
  - What are the consequences of the deviation?
  - Are the consequences hazardous or do they prevent efficient operation?
  - If so, can we prevent the deviation by changing the design or the method of operation?
  - If so, is the change reasonable?
- Experts representing all possible relevant disciplines

B) Effort

- Time consuming
- experts to discuss the causes and consequences

C) Output / Results

- Identification of potential deviations, causes and consequences
- Hazardous potential and possible mitigation strategies of deviations

D) Pro / Contra

Pro

- Structured approach, aims at completeness
- Detects hazards and proposes solutions

Contra

- Time consuming to discuss every combination of process deviation and guideword
- Team of experts needs to be carefully chosen
- Well known method for processes, application to ADAS recently in research

E) References

Jagtman, H.M. (2004). Road Safety by Design: A decision support tool for identifying ex ante evaluation issues of road safety measures. Thesis, Delft University of Technology.

Kirwan, B. (1994). A Guide to Practical Human Reliability Assessment. Taylor & Francis

C.2 Failure Modes and Effects Analysis (FMEA)

The Failure Modes and Effects Analysis (FMEA) and Failure Modes, Effects and Criticality Analysis (FMECA) are methods of reliability analysis intended to identify failures with significant consequences affecting the system performance in the application considered.

The FMEA is based on that defined system, component or subassembly level where the basic failure criteria (primary failure modes) are available. In a narrow sense, the FMEA is limited to a qualitative analysis of failure modes of hardware, and does not include human errors and software errors, despite the fact that current systems are usually subject to both. In a wider sense, these factors can be included in the FMEA.

FMEA is a technique for design review support and for assurance and assessment, which should be put into use from the very first steps of system design. FMEA is appropriate to all levels of system design.

A logical extension of the FMEA is the consideration of criticality and probability of occurrence of the failure modes. This criticality analysis of the identified modes is widely known as FMECA.

FMEA is a standard procedure in the automotive industry whereas FMECA is rarely used due to the difficulty of obtaining criticality data at this stage of system development.

A) Input / Requirements

- Basic system description of the function, e.g. block diagram, component drawings
- Expert(s) of the domain concerned

B) Effort

- Depends on complexity
- Panels of 6 to 8 experts from different domains depending on subject covered by the assessment

C) Output / Results

- Starting from the basic element failure characteristic and the functional system structure, the FMEA determines the relationship between the element failures and the system failure, malfunctions, operational constraints and degradation of performance or integrity.

D) Pro / Contra

Pro

- FMEA is a standard procedure in the automotive industry

Contra

- Multiple failures and redundancies are not covered by FMEA

E) References

IEC 60812 – FMEA

VDA vol. 4 part 2.

C.3 Fault tree analysis (FTA)

Fault tree analysis is concerned with the identification and analysis of conditions and factors, which cause or contribute to the occurrence of a defined undesirable event, usually one, which significantly affects system performance, economy, safety or other required characteristics. FTA is often applied to the safety analysis of systems.

The fault tree is particularly suited to analyse complex systems comprising several functionally related or dependent subsystems with different performance objectives. This is especially true whenever the system design requires a collaboration of many specialised technical design groups. Examples of systems to which fault tree analysis is commonly applied include nuclear power generating stations, aeroplanes, communication systems, chemical and other industrial processes.

The fault tree itself is an organised graphical representation of the conditions or other factors causing or contributing to the occurrence of a defined undesirable event, referred to as “top event”.

Fault tree analysis is basically a deductive (top-down) method of analysis aimed at pinpointing causes or combinations of causes that can lead to a defined top event. The analysis is mainly qualitative but, depending on certain conditions may also be quantitative. Reliability and availability prediction techniques, current test and field use data may be used to establish the quantitative values.

The FTA is widely use in other industries but is also seen more and more in the automotive industry.

A) Input / Requirements

- Basic system description of the function, e.g. block diagram,
- Definition of undesired event
- Failure rates of basic events

B) Effort

- Depends on system complexity

C) Output / Results

- Probability of undesired event
- Conditions of other events under which the top event will occur

D) Pro / Contra

Pro

- Delivers quantitative estimations on hazardous events
- FTA-Software is available

Contra

- Depends on failure rates of basic components. Failure rates are often vague
- Dependencies between failures should be known

E) References

IEC 61025 – Fault tree analysis

C.4 Hardware in the loop (HIL) testing

HIL testing can be applied as soon as a hardware prototype of the system or even a part of it (e.g. an electronic control unit of a car) is available. The prototype, called Device Under Test (DUT), is embedded “in a loop”, which is a software simulated virtual environment resembling the real environment as closely as possible. The DUT is operated under real time conditions.

The software simulation consists of various parts for a vehicle system (all the parts that are not available in hardware) and the environment. Towards the DUT all the communication including sensor and actuator data has to be simulated. The underlying vehicle dynamics simulation receives data from the DUT, and calculates the vehicle response depending on the virtual driving state, road surface, traffic situation and other system specific environmental data.

An optional visualisation can be used to observe the simulation from a developer defined perspective. Depending on the design stage, the availability of hardware and the required test accuracy the parts of the system that are implemented in hardware (ECU only, sensors, actuators,…) will vary.

A) Input / Requirements

- Hardware to be tested
- Simulation models of vehicle systems that are not available in hardware
- Simulation models of vehicle dynamics and environment

B) Effort

- Test system needed
- Implementation of simulation software

C) Output / Results

- Real time behaviour of a new system

D) Pro / Contra

Pro

- Tests are under real time conditions
- Component testing and optimisation can be done before integration
- Tests are repeatable with exactly the same parameters
- Tests can be automated
- System behaviour a system limits can be tested
- Failures and potentially hazardous situations can be simulated to test system response

Contra

- Overall vehicle simulation must be available, may be difficult for a new vehicle prior to system integration
- Quality of results depends on the quality of the simulation models

Annex D General methods of assessment

D.1 Expert panel

Expert panels' assessment is an analytical approach that can be used in each development phase. Depending on the subject various expertises from experts of different domains is needed. Therefore, expert panels may consist of: R & D engineers, human factors specialists, marketing specialists, accident research specialists, traffic psychologists etc.

Nevertheless, when controllability issues are concerned, human factors specialists are essential in expert panels as their evaluation takes into account scientific knowledge about human behaviour and cognitive limits (e. g. reaction times, workload assessments, etc.).

A) Input / Requirements

- From basic system description of the function, e. g. text, block diagram, model to mock-ups and early prototypes.
- Use cases coming from preliminary task analysis.
- List of potentially hazardous situations to promote complete assessment

B) Effort

- Low (use of experience + time)
- Panels of experts from various domains depending on subject covered by the assessment (number of functions, alternative solutions etc.).
- A constant core team (leads to efficient discussion).

C) Output / Results

- Identification of potential or actual problems and causes (diagnosis)
- Decision and choice support (amongst various solutions or various warning modalities)
- Most important technical features
- Expert know-how should cover knowledge about benchmark and the state-of-the-art, if there are already similar functions on the market or in the development process
- Possible difficulties
- Possible misuse situations
- Recommendation for Sign-Off

D) Pro / Contra

Pro

- Beneficial cross-checks resulting in various points of view gathered, as experts can have various technical backgrounds
- Rapid detection of critical problems and their causes
- Possible even with a low level of description or partial prototypes in early development phases

Contra

- Based on previous experience, therefore limited efficiency if fully innovative function
- Experts' judgements are often divergent. Synthesis may not always be easy to do

D.2 HMI concept simulation

HMI concepts are visualised by computer based rapid prototyping tools. This enables developers to see what the system looks like and how the interaction works. The HM Interface should be represented in real sizes, colours and sounds (and optional: position in the vehicle). It is used to explore the interaction between driver and system. Various HMI concepts might be compared using usability criterions like interaction time, number of errors etc.

A) Input / Requirements

- Description of the system functions and transitions
- First concepts of HM Interface and Interaction

B) Effort

- Time for setup and the driver tests (depending on question and method)

C) Output / Results

- Usability and comprehensibility of dialogue
- Checking how the system fits into the overall concept of vehicle systems and the influence of the system on other systems
- Easy comparison of various concepts

D) Pro / Contra

Pro

- No real hardware necessary, maybe suitable “rapid prototyping” software to show the functions
- Fast method available at very early system stages
- Gives an idea of system integration possibilities

Contra

- Interaction with driving task is ignored

E) References

Johansson, E., Engström, E., Cherri, C., Nodari, E., Toffetti, A., Schindhelm, A., and Gelau, A. (2005): Review of existing techniques and metrics for IVIS and ADAS assessment. Del 2.2.1, Project AIDE - IST-1-507674-IP.

D.3 Driving simulator test

Driving simulation uses models of vehicle dynamics and virtual driving scenarios. This allows artificial driving situations and repeatable tests with various subjects. Potentially hazardous traffic scenarios can also be tested because in contrast to real driving the virtual scenario is harmless.

There are different types of simulators, e.g.

- Mock-up
- Fixed based simulator
- Moving base simulator

During the simulation subjective and objective methods can be used to measure the performance of test subjects and methods in the driving task:

- Subjective methods are ratings from the subject itself or an observer using scales (e.g. NASA-TLX, ZEIS, modified Cooper-Harper Rating Scale, etc.) and open or closed questionnaires. They can be combined with video observation (robustness of behaviour, interview with video replay -> reasons for reactions).
- Objective data can easily be derived from simulator log files and physiological measurements on the subject. Typical examples of quantitative and qualitative data from the driving scene are reaction times and lane keeping performance.

Controllability can be tested by some of these methods depending on the kind of (potentially hazardous) situation to be explored. Typical situations are: Testing in high risk situations, driver reactions at system take over, testing of false alarms in certain situations and driver interaction if there is more than one ADAS in the vehicle.

A) Input / Requirements

- Alternative system designs should be specified
- Appropriate sceneries have to be created
- Test design has to be created

B) Effort

- Effort depending on simulator type and duration of simulation test

C) Output / Results

- Quantitative and qualitative data in repeatable situations
- Data output method in real hazardous situations

D) Pro / Contra

Pro

- ADAS hardware (prototype) is optional – Simulation can be used in any development stage
- Comparison of alternative system concepts
- Parameters and restrictions are quite easy to control

Contra

- May lead to subject's simulator sickness. This will influence the test results.
- Exploring driver behaviour in high vehicle dynamics situations is difficult because of the missing or lacking acceleration feedback. In these cases just the first reaction might be similar to real driving.
- Due to the missing impression of acceleration, the driving results at high vehicle dynamics are not transferable to real driver behaviour in most cases.

E) References

Östlund, J. et al. (2004): Deliverable 2 – HMI and Safety-Related Driver Performance. Human Machine Interface and the Safety of Traffic in Europe. Project HASTE GRD1/2000/25361 S12.319626.

D.4 Driving tests with professional test drivers

Driving tests with professional test drivers provide useful feedback based on empirical data. Professional drivers are trained to quickly identify and diagnose actual and potential inadequacies of a system. Their judgments are based on double competence: experience of multiple and different systems and the ability to express their assessment in a quite standardised manner that is easy to compare (mainly using scaled questionnaires or check lists). Check lists are also useful to grant a complete review of critical items.

Professional test drivers are mainly consulted for two purposes:

1. To make comparative assessments (to compare a system against other systems on the market or comparisons between different solutions)

2. To assess a feature or a system behaviour according to an internalised reference (the test drivers play the role of "gold-standard" or human metrics)

In addition, professional drivers may represent a particular portion of global drivers' characteristics distribution (i.e. elderly, young, tall, short and so on) in order to match some of the particular needs of those drivers' classes.

Professional drivers are trained to quickly identify and diagnose actual and potential inadequacies of a system. When controllability issues are concerned, professional drivers can estimate, based on their actual and previous experience, whether or not a system can be easily handled by an average driver group.

To make comparable judgements between professional drivers, checklists may be useful to grant complete review of critically items. Defining particular scenarios may also be necessary to guide the assessment.

A) Input / Requirements

- Early prototypes and latest versions
- Test scenarios from preliminary task analysis and risk analysis.
- Check-list of critical issues to provide complete assessment and to compile remarks.

B) Effort

- The required number of professional test drivers depends on the amount of work to do, completion, and other relevant influences
- Test campaigns require time (static and dynamic conditions) depending on number of test variations / vehicles tested.

C) Output / Results

- Identification of potential or actual problems and causes (diagnosis)
- Comparative results between concurrent HMI
- Helps to make a decision and choice (amongst various solutions or thresholds)
- Most important technical features
- Possible misuse situations

D) Pro / Contra

Pro

- Rapid detection of critical problems and their causes (where driving tests provide facts only after a long time of use).
- Assessment possible even with partial prototypes

Contra

- As judgments are based on previous experience, their efficiency may be limited for a fully innovative function
- Test results may be biased if the group of professional test drivers does not represent the intended user group (age, sex, level of training).
- Since the judgment of professional drivers may vary a lot, synthesis may not always be easy to do and elimination of extreme judgements may be necessary

E) References

Only a few formalised references are available. The method is based on know-how and subjective appreciation.

D.5 Car clinic with naive subjects

The term "clinic" results from the fact that subjects are usually invited to a special test location. In a static car clinic subjects evaluate a vehicle without driving. In a dynamic car clinic the test persons usually have to accomplish different driving tasks.

The dynamic car clinic as a tool allows to test driver behaviour and performance while driving the vehicle equipped with the ADAS system in defined situations in a realistic environment.

Experimental design, type of testing and test scenarios have to be defined. This includes

1. A decision for test environment

   In principle the car clinic can be carried out on public roads (= highest validity) or on test tracks (= better repeatability and safety).

2. Data to be collected

   Depending on the ADAS function and the related test design different measures are necessary, e. g.: speed, headway, steering control, lateral control, gaze, handling errors, observer ratings etc.

3. Test scenarios to be used

   During controllability assessment process different test scenarios may be considered and compared during controllability assessment process. Test scenarios might include type of traffic, road type, weather and road conditions.

4. The experimental design & sample selection

   The design of the test trials needs to be carefully considered e.g. choosing short term or long term testing with or without control group and the sample size and selection.

5. The test procedure to be used

   The test procedure needs to be detailed and documented e. g. in a trial schedule.

6. The statistical analysis to be used

   For each measure, the type of scale and the statistical analysis should be specified, e.g. whether a mean or overall score, minimum or maximum will be applied.

7. A health and safety risk analysis

   A health and safety risk analysis of testing must ensure that participants are not exposed to any risk.

A) Input / Requirements

- As described above detailed and extensive planning by validation experts is needed
- Further requirements are a prototype vehicle equipped with ADAS system and data recorder as well as an appropriate test track and test environment

B) Effort

- A car clinic is time consuming (depends on necessary sample size, number of test situations etc.)
- May require a high personnel effort (instructor, observer, various collaborators) and a high monetary effort (for test track, data recording equipment etc.)

C) Output / Results

- Detailed results about driver's psycho-motor performance (reaction time, forces etc.) and mental capabilities (comprehension, learnability) are gained

D) Pro / Contra

Pro

- This method provides comparably the most valid results concerning driver's ability to control an ADAS in assisted driving situations including system failures and limits
- Testing by average/normal drivers in almost real environments delivers realistic results

Contra

- May be very time-consuming

E) References

Becker, S., et al. (2000). Experimental Assessment of Driver Assistance Systems: Method (RESPONSE Project TR4022, Del. No. D5.1.1). Brussels: EC, DG XIII.

Johansson, E., et al: (2005): Review of existing techniques and metrics for IVIS and ADAS assessment. Del 2.2.1, Project AIDE - IST-1-507674-IP. Brussels: EC.

Östlund, J. et al. (2004): Deliverable 2 – HMI and Safety-Related Driver Performance. Human Machine Interface And the Safety of Traffic in Europe. Project HASTE GRD1/2000/25361 S12.319626.

Wiethoff, M. (2003). ADVISORS Final Report Annexes. EU project ADVISORS, project no. GRD1/2000/10047.

Annex E Definition ADAS

Driver Assistance Systems are supporting the driver in their primary driving task. They inform and warn the driver, provide feedback on driver actions, increase comfort and reduce the workload by actively stabilizing or manoeuvring the car.
They assist the driver and do not take over the driving task completely, thus the responsibility always remains with the driver.
ADAS are a subset of the driver assistance systems.

ADAS are characterised by **all** of the following properties:

- support the driver in the primary driving task
- provide active support for lateral and/or longitudinal control with or without warning
- detect and evaluate the vehicle environment
- use complex signal processing
- direct interaction between the driver and the system

Table 7 gives an overview on driver assistance systems, and highlights systems that do not fulfil the above given properties. The list includes already existing systems as well as potential future systems that have been defined in Response 2 [ResD2 04].

System name	ADAS yes	ADAS no	Comment if no ADAS
Safe Speed (warning only)		x	warning only
Safe speed (intervention)	x		
Safe Following	x		
Vision Support (with object detection and intervention)	x		
Vision Support (without object detection)		x	no assistance, no complex signal processing
Vision support (adaptive lighting)		x	
Lane Keeping Support (active support)	x		
Driver Monitoring		x	No environmental sensing
Vehicle Dynamics Monitoring (e.g. roll over warning)		x	No environmental sensing
Pedestrian Protection			
detection and warning		x	
automatic hood (impact detection)		x	Passive safety
Intersection assistant (active support)	x		
ESP, ABS		x	No environmental sensing
Cruise Control, CC		x	No environmental sensing
Speed Limiter		x	No environmental sensing

System name	**ADAS yes**	**no**	**Comment if no ADAS**
Speed Alert Device			
preset speed for winter tires		x	No environmental sensing
environment based dynamic speedadaption	x		
Advanced Front Light System		x	No environmental sensing
Adaptive Brake Light		x	No environmental sensing
Collision warning and braking	x		
Active Front Steering		x	No environmental sensing
Lane Keeping Assist / Heading Control	x		
Adaptive Suspension System		x	Stabilisation level
Lane Departure Avoidance	x		
Rear Vision System		x	See vision support
Parking assistance (ultrasonic)		x	No complex signal processing
Parking assistance (active guidance)	x		
Brake Assist + Preconditioning (no warning)		x	No environmental sensing
Adaptive Cruise Control (ACC)	x		
Rain Sensor Systems		x	No support in driving task
Tyre Pressure Monitoring		x	No environmental sensing
Night Vision System			See vision support
Lane Change Assistance	x		
Blind Spot Monitoring		x	
ACC Stop & Go	x		
Automatic Emergency Brake			
with possible interaction	x		
without possible interaction		x	Active safety system/ no interaction

Table 7: Driver assistance systems and ADAS criteria

The driving task respectively driver activity may basically be classified into the following levels:

- Stabilisation Level
- Manoeuvring Level

- Navigation Level

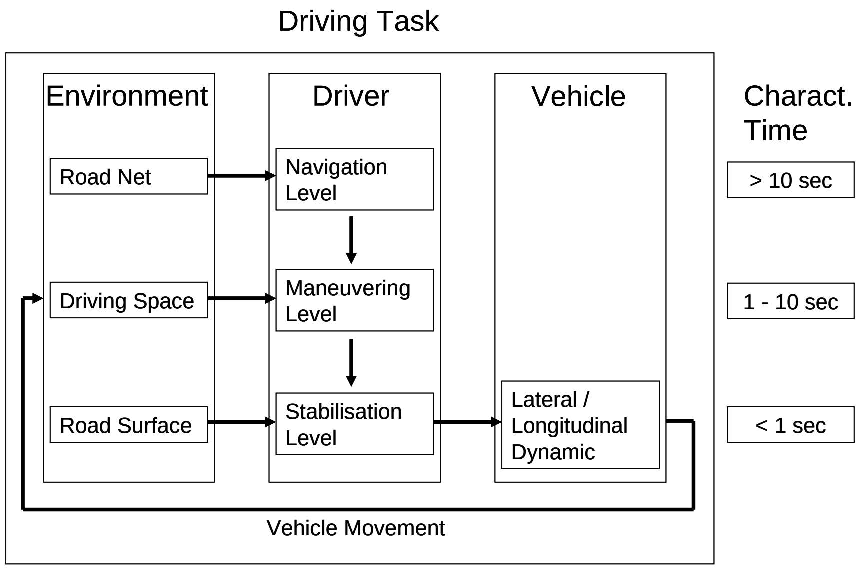


Figure 9: Driving task levels (RESPONSE 1, Del. No. D2.2, page 29)

To every level of the above described driving tasks a corresponding characteristic time period is allocated in which the respective driving task is typically performed. In relation to this time period and the driver action / reaction that is performed, required skills or knowledge may be assigned to the respective driving task level.

Stabilisation level	➔	automatic driver action
	➔	skill-based
Manoeuvring level	➔	driver makes decision and applies acquired rules
	➔	based on acquired rules
Navigation level	➔	driver applies knowledge
	➔	knowledge-based

The above mentioned considerations serve to form the following groups:

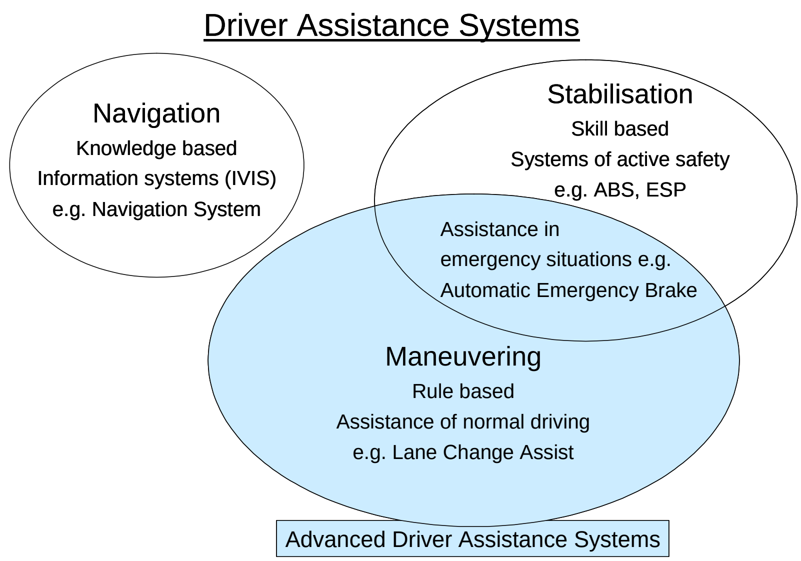


Figure 10: Driver Assistance systems

Previous driver assistance systems (DAS) evaluate vehicle internal data and support the driver on the stabilising or navigation levels. Thus, the systems supporting the driver in vehicle stabilisation may be classified as "active safety" systems. Systems supporting the driver in the navigation task may be defined as driver information systems.

Advanced Driver Assistance Systems (ADAS) support the driver essentially on the manoeuvring level. In contrast to previous DAS it is required to detect and evaluate the environment of the vehicle by means of sensors. This also includes the collection and evaluation of infrastructure based data if these are available. Depending on the partial task of manoeuvring to be assisted by ADAS, the driving respectively traffic situation will therefore be monitored and evaluated by the system specific sensors. The interaction with the driver is another key property of ADAS.

On the stabilisation level driver activities are performed by means of automatic activities in short time frames (typically < 1 sec). Driver Assistance Systems (DAS) are designed to support the driver in difficult driving situations as for instance ESP. In contrast to this, driver activities on the manoeuvring level are performed by means of application of known rules in medium-range time frames (typ. 1 – 10 sec). The driver will be supported by Advanced Driver Assistance Systems (ADAS) in their "regular driving profile" of the day-to-day driving tasks, as for instance Lane Keeping Assist. They will provide support in safe vehicle operation. But there are also ADAS available, which do assist on the manoeuvring level, however only in emergency situations. They will intervene in situations, which no longer belong into the regular driving profile as for instance an automatic emergency brake. Therefore, these ADAS provide support in resuming a safe vehicle operating condition.

Examples for Driver Assistance Systems classification:

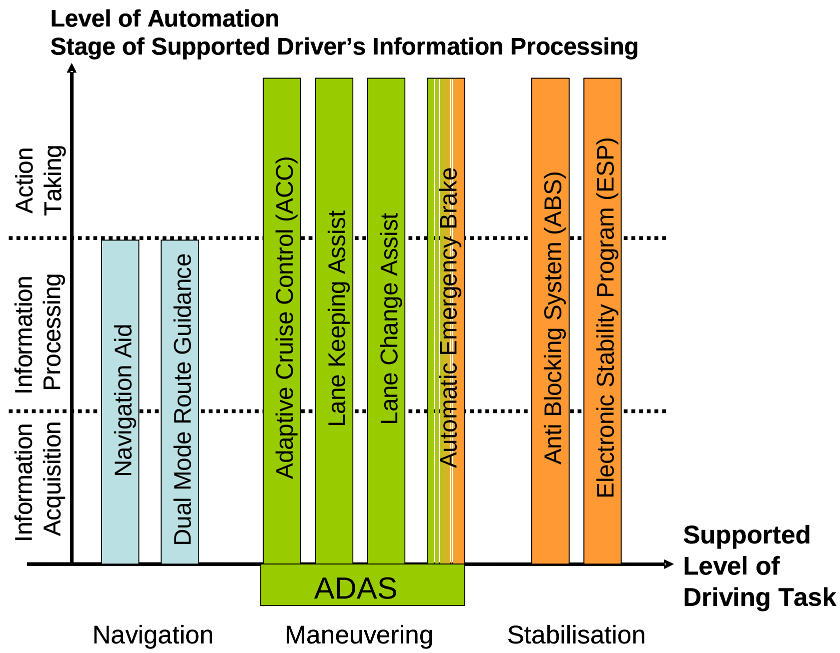


Figure 11: Examples of Driver Assistance systems

Navigation Level

Navigation Support: The navigation system uses data from an existing data medium (CD-Rom or DVD) in connection with current traffic news and calculates the desired driving route. The driver receives visible and/or acoustic information, which facilitate navigation respectively destination search. The vehicle steering task remains with the driver.

Stabilisation Level

Electronic Stability Program (ESP) with vehicle integrated sensors like for wheel torque, steering wheel angle or the vehicle yaw movement the system evaluates whether the vehicle remains in a driving physically stable state. If the vehicle exceeds a defined threshold in the direction of under or over steering the drive and brake system automatically takes over and performs a stabilising intervention on the wheels. The driver has no direct influence on this mechanism.

Manoeuvring Level

Adaptive Cruise Control (ACC): The ACC is one of the first ADAS. This function is a further development of the CC (Cruise Control), which allows the driver to only set a defined speed in the vehicle. CC is not sensitive to the vehicle environment, in particular not to the preceding traffic. The ACC however monitors the area in front of the vehicle by means of a sensor (radar or lidar). If a vehicle with a lower speed is in front of the vehicle the ACC will respond with a vehicle deceleration in order to not exceed a pre-set distance to the preceding vehicle. Nowadays, the driver is always able to interact.

Annex F Documentation sheet

The documentation sheet may be used after completion of the CoP as proof for implementation.

For documentation purposes you may attach the completed checklists to the documentation sheet.

A differentiation must be made between ADAS new development or a further development of an existing ADAS. For a further development it suffices to only document relevant modifications and give a reference to the original system.

The documentation sheet serves as confirmation that the ADAS is safe to use.

Documentation Sheet
Code of Practice for ADAS:

Organisational unit:

____

Name of ADAS:

____

Brief description of function:

____

____

ADAS new development ☐

ADAS further development of system:

____

This ADAS has been developed in compliance with the CoP and is recommended for sign off.

____

Date, signature

Annex G Criteria for HMI concept selection (background information)

For the integration and classification of an ADAS to be developed the knowledge of already existing HM Interaction and vehicle architecture is required. It makes sense to compare the possible HMI concepts by means of the following matrix and perform a concept evaluation.

	Driving task (Annex G.1)	**Driver perception** (Annex G.2)	**Work field driver** (Annex G.3)	**Interaction priorities** (Annex G.3)
Criteria	**-primary** Navigation Manoeuvring Stabilisation **-secondary** **-tertiary**	- **visual** -w/o eye movement -foveal -periphery -With eye movement -With turning of head **- auditive** **- haptic**	Operation areas **- Reach areas** -Hand w/o / with torso movement **-Foot well**	**- Safe driving** **- Additional tasks** Time requirement Operation frequency
HMI concept 1				
HMI concept 2				
HMI concept n				

Table 8: Concept comparison for HMI

G.1 Classification and evaluation according to driving tasks

Discriminating consideration of driving tasks serves to lead to a classification of ADAS concerning importance for safe vehicle operation. In order to assist the integration of the new ADAS system into the vehicle the ADAS is classified into these driving tasks.

The primary tasks of the driver may be classified into the following levels according to Response 1 (deliverable 4.1 / 4.2):

A) Primary tasks (vehicle operation, vehicle control)

- Navigation

  The navigation level comprises mainly destination finding via a suitable driving route

- Manoeuvring

The manoeuvring level comprises several sub-tasks (e. g. track manoeuvring, collision avoidance, adhering to traffic rules)

- Stabilisation

  On the stabilisation level we may differentiate between the sub-tasks longitudinal manoeuvring (e. g. vehicle speed control) and transverse manoeuvring (e. g. cross wind balancing, rough lane surface, cornering).

B) Secondary tasks

(Source: Bubb H. "Umsetzung psychologischer Forschungsergebnisse in die ergonomische Gestaltung von Fahrerassistenzsystemen", 1992)

- Secondary reactive tasks: Driver reacts traffic related. This includes for instance dipping headlights, operating wipers but also clutch and gear shifting.
- Secondary active tasks: Driver acts. The task is not directly traffic related. For instance driver wishes to receive current information (navigation, traffic news).

C) Tertiary tasks (Source: Bubb H.)

Tertiary tasks are not directly linked to the driving task. They merely serve to satisfy comfort, entertainment or general information requests. These are amongst others radio, telephone or miscellaneous entertainment devices.

G.2 Driver information perception

Humans receive information via their sensory organs. These receptors are also called sensory modalities and may percept various stimuli and sensations in limited spectra.
Human perception varies from human to human. The performance of senses typically deteriorates with increasing age.

Human perceptions may be classified in five senses:

- sense of smell (olfactory)
- sense of taste (gustatory)
- hearing (auditive)
- vision (visual)
- sense of touch and motion (haptic)

As for Human Machine Interface for the comparison of ADAS concepts visual, auditive and haptic information perceptions are important and are discussed in the following:

G.2.1 Visual information perception

Concerning the design of display and control elements it must be taken into consideration that human visual information perception is limited by various conditions.

Limits of visual information perception in the field of view

The human eye may only see sharply in the area of approx. 3 degrees (foveal vision), while the periphery (peripheral vision) mainly serves the recognition of movements and three-dimensional recognition.

Without eye and without head movement

If the gaze is fixed onto an object (foveal) sharp seeing is possible in the fixation area (Figure 12: green (most inner) sight cone, area approx. +/- 3°). Outside the fixation area, the so- called periphery area the partly limited perception ability of the eye is compensated by the brain. Perception in the periphery is largely limited to light / dark contrasts. Here events may occur that a human may overlook.

With eye and without head movement

Figure 12 shows the field of view without head movement within a red vision cone. The field of view defines the maximum area, which may be covered with a fixed head by eye movements only.

In order to cover the field of view it is necessary to direct the gaze by eye movement onto a new location. During such a change of gaze, a so-called saccade, the eye does not receive any information. A sight cone of approx. +/- 15 degrees (Figure 12: Yellow sight cone) is considered as optimal field of view. This area corresponds to approximately half of the maximum field of view and may be achieved by means of “comfortable” eye movements. The maximum field of view (approx. +/- 35 degrees horizontally and – 20 to + 40 degrees vertically, see Figure 12) is shown in the red sight cone.

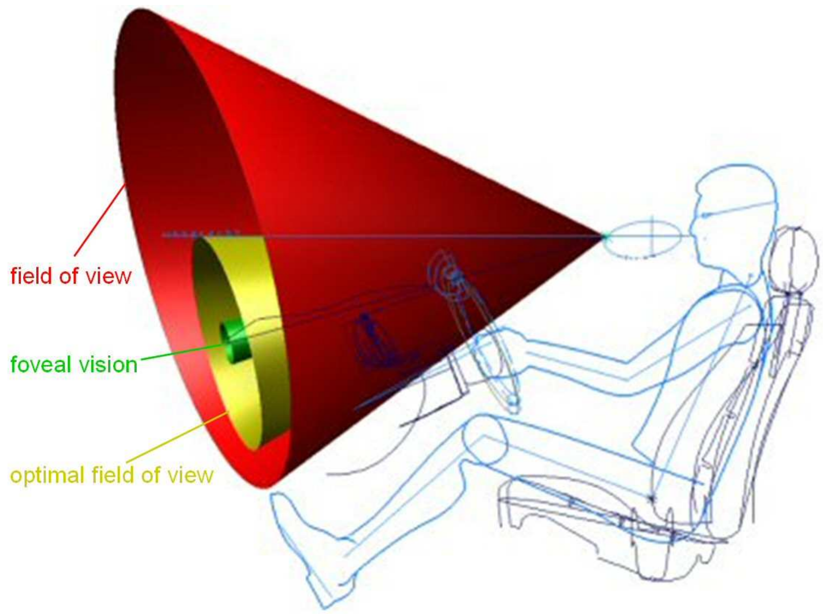


Figure 12: Simplified demonstration of field of view limits

With eye and with head movements

In order to cover further areas, a head movement with the required time period is necessary. This is called the overall/entire field of view.

Information perception limits depending on display

Considering the display design of the ADAS Human Machine Interface further restriction must be taken into consideration.

Every human has a different colour perception. The sensitivity of the receptors (cones on the retina) is genetically coded. There are three kinds of colour sensors, which have a good perception of blue, green and red. Also the ability of humans to perceive light is not the same for all colours. There are humans who are not able to differentiate between certain colours due to colour blindness. Restrictions in visual information perception due to colour recognition deficits may be compensated by clear shapes. Here it may be of help if a uniform optical picture language is used (e. g. standard symbols ISO 2575).

Further perception limits are due to brightness influences (e. g. insolation, dazzling by opposite traffic) and darkness (e. g. driving at night).

G.2.2 Acoustic information perception

The human audibility range is shown in Figure 13. With increasing age the hearing ability decreases.

Figure 13 shows the bold bottom line as the human hearing threshold level. The grey top line corresponds to the threshold of pain. The thin lines in between are graphs of the same sound intensity.

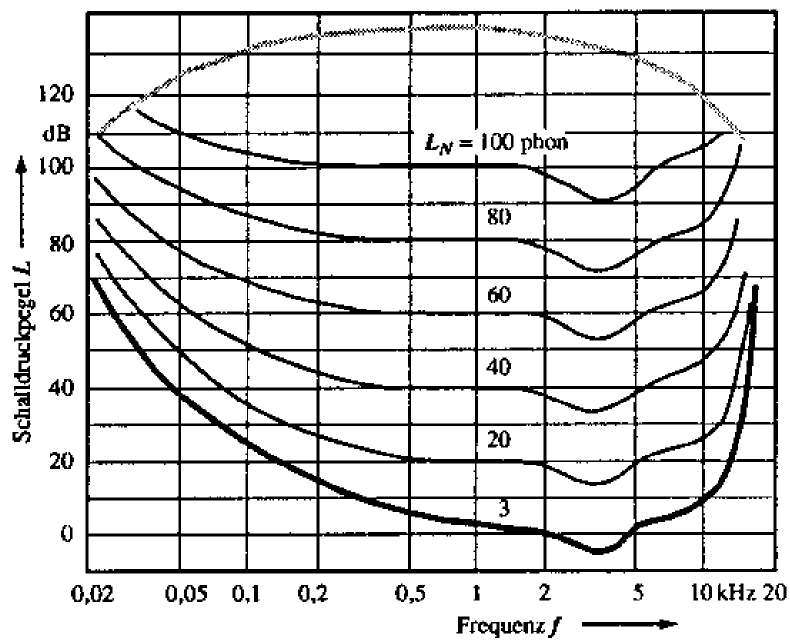


Figure 13: Limits of acoustic perception. Source Pompino-Marschall (1995), page 145

G.2.3 Haptic information perception

Tactile perception describes surface sensitivity, which is also referred to as sense of touch. Sense of touch describes the perception of mechanical environmental influences via various mechano receptors in the skin. In combination with the haptic perceptions this information enables the brain to locate and evaluate touch, pressure and temperature.

We differentiate the following:

Quality	Receptor	Character	Adaptation
Pressure	Merkel cells, Ruffini bodies	Intensity detectors (proportional)	Slow
Touch	Meissner bodies, hair follicle receptors	Speed detectors (differential)	Fast
Vibrations	Vater-Pacini bodies	Speed detectors	Very fast
Pain	Free nerve ending (Nozi receptor)	Non-adapting	
Temperature	Warm and cold receptor	Proportional and differential	Adaptation between 20 and 40 degrees Celsius

Table 9: Haptic perception

Out of the mentioned sense qualities, for ADAS vibrations may be used for driver information. All contact areas between body and vehicle can be considered for applying the vibrations. Vibrational perception has the lowest threshold of 150 – 300 Hz at the finger-tips. Higher amplitudes are necessary outside this frequency range and other application areas.

When driving a vehicle the perception of speed plays a significant role. This speed is enabled by means of kinaesthetic as well as vestibular perception. Kinaesthetic perception is a further component of haptic perception, which enables recognition of the direction of motion via muscles, tendons and sinews. Vestibular perception recognises dislocation and change in location respective rotation via the auris interna.

G.3 Driver's field of work

The driver's work field comprises the operation areas for the hands (reach area) and the feet (foot well). For the following differentiation of the operation areas it is a prerequisite that the driver sits upright in the driver seat and wears a seat belt.

Figure 14 gives and overview of reach areas, within which the driver can operate in an upright seating position. We must differentiate reach areas, which can be reached without torso movement (Figure 14: Red areas) and the extended reach area, which can be reached by slight torso movement respectively by turning the shoulder (Figure 14: blue area). The foot well (Figure 14: Green square) describes the area, which can be reached with the feet.

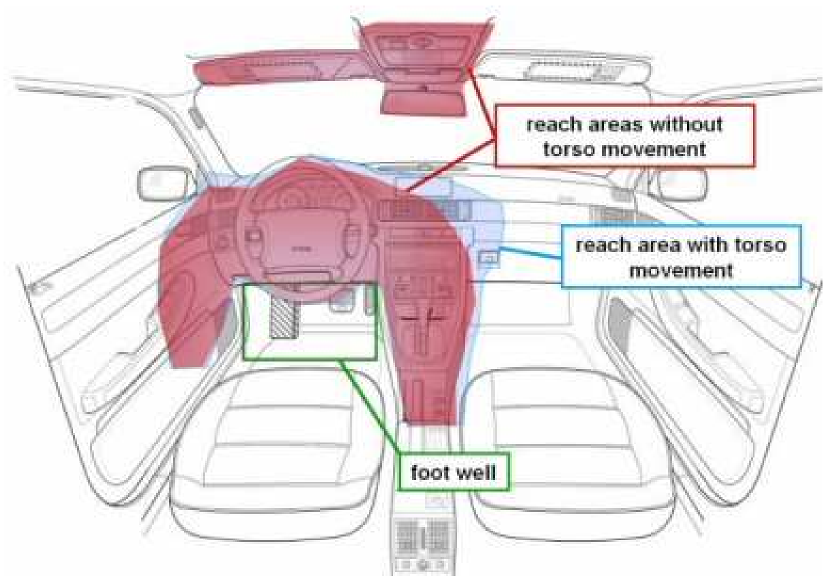


Figure 14: Detailed description of foot well and reach areas

Priorities of HMI Interaction

Required HM Interactions of ADAS and driver may be differentiated according to importance related to the driving task.

The most important task is safe manoeuvring of the vehicle, which is the primary task on the stabilisation level. Additional tasks are for instance navigation operation or air condition setting.

From this consideration priority classes may be derived. The classification is mainly oriented on urgency, task fulfilment. Further classifying factors are time need for the interactions and interaction frequency.

Urgency

- very important (direct influence on traffic and operation safety, information and activity in short time periods)
- important (influence on driving sequence, activity required in short time periods)
- less important (relevance secondary, activity not time relevant)
- more or less unimportant (gaze aversion possible without time consequences, e. g. activity in vehicle at standstill)

Time requirement for interactions on control and display element

- short interaction times (< 1 sec.)
- medium interaction times
- long interaction times (>2 sec)

Interaction frequency

- very frequent (repeatedly per journey)
- frequent (every journey)
- rarely (every x journey)
- very rarely (occasionally)
- not during journey (activity / display) only in vehicle at standstill necessary respectively possible)

G.4 HMI architecture principles

The following interpretation notes serve to support a driver-suited HMI design:

Regulations and standards (see Annex A, page 9)

- Type approval

  In order to introduce a vehicle with all its components in a market, it is necessary to comply with the required market specific type approval regulations.

- Standards, HMI Standards

  Standardisation is a systematic establishing of a standard by the affected experts. The standardisation may affect many areas, as for instance procedures, measurements, properties etc. The application of a standard, regardless whether national, European or international is voluntary, even if the standard is considered a safety standard in certain product safety laws. However, the application of a standard may lead to the presumption that a product is not defective and / or the manufacturer has observed the necessary duty of care. Therefore, this assumption may become binding, even if it is not legally binding

- Technical rule

  A technical rule serves as an instruction to resolve a multitude of issues in the field of engineering, and which is accepted among experts in the relevant specialist area.

- State-of-the-art

  In addition to the existing regulations of type approval and existing standards as well as technical specifications, the state-of-the-art of the respective product group must be considered in order to ensure compliance with the traffic safety duty of a manufacturer.

Consumer expectation

A defect-free design is a justified consumer expectation. The following principles serve as assistance to a driver-suited HMI design:

- Unambiguity of display and control elements is the design objective

- A further objective in the design of control and display elements is self-descriptiveness resulting in intuitive correct use.
- The influence of vehicle design on structure and location of displays and control elements shall be evaluated taking into consideration ergonomic and functional factors.
- It makes sense to adhere to the same arrangement and structure of display and control elements within one production series of an OEM.
- A uniform control logic facilitates intuitively correct operation for the driver
- The history of the HMI design serves as a significant basis for further development
- Existing „mental models“ should be taken into consideration when designing the new ADAS
- It makes sense to adhere to known functional principles (e. g. switches with raster function in contrast to pushbutton)
- Innovation steps should not be too extensive. Often it makes sense to either modify only the display elements or only the control elements.
- Consider competitor solutions if available prior to the first layout and design of new displays or control elements.
- Information from the dialogue between driver and ADAS should fit into the hierarchy of the existing systems
- Suitability of various sense channels (visual, acoustic, haptic) should be checked individually and also in combination

Stimulus satiation should be avoided. Take into consideration that besides ADAS also other systems are interacting with the driver. For the layout of system feedback consider possible driver reactions to these ADAS interactions with the driver.

Annex H References

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