Roadmap

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Deliverable D2D Roadmap
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0.6	01.07.2004	Comments on Effects from T. Alkim, G. Bootsma, AVV
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Abstract

The roadmap shows the future research activities of Advanced Driver Assistance Systems in Europe. It bases on discussions between the experts of the ADASE 2 project partners and results of the ADASE2 thematic workshops and concertation meetings. This process leads to a matrix, which shows the research projects and the interdependencies between system functionality and complexities concerning different aspects.

The derived matrix reveals the complexities of the technological, societal and legal aspects related to the various systems. The contribution to the guessed safety enhancement is mentioned.

Thus, technological gaps and future research needs can be identified in the given overview.

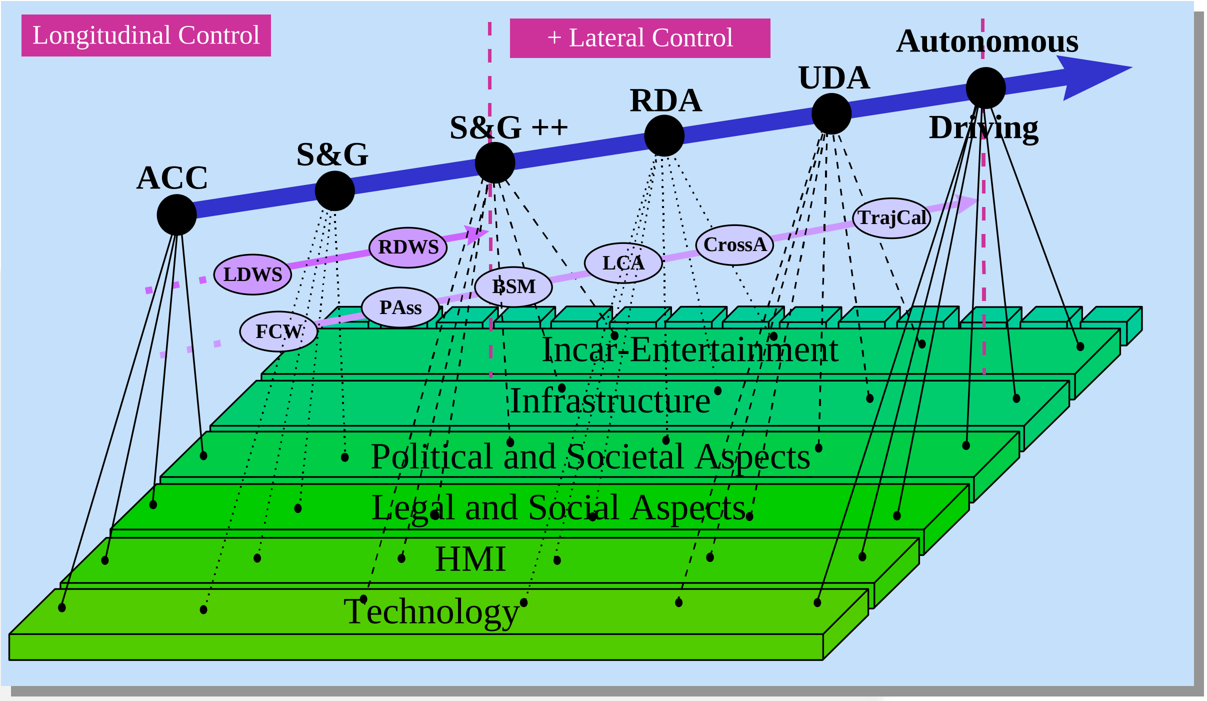
1 INTRODUCTION

The main goal of the ADASE 2 roadmap is giving a holistic overview of Advanced Driver Assistance Systems in Europe as well as information about interdependencies between systems and different ADAS related aspects. Therefore both, the system itself and the related aspects will be defined.

This overview should help to clearly identify the most important future needs by pointing out the complexities of such systems. It is a basis for the assessment of new projects for further research programs like PReVENT.

2 APPROACH

During the ADASE 1 project a first roadmap was introduced. This was an evolutionary approach shown in pic. 1.



Picture 1: ADASE1 roadmap.

Pic. 1 gives a view on the ADASE1 approach of an illustration including non-technical aspects. Based on the results from this work the ADASE2 roadmap was developed.

A goal of the ADASE2 project was to detail this available roadmap and keep it up-to-date. Thus, the previous approach is extended in many other aspects and the systems are adapted. In order to ensure actuality, different sources of information were included.

The concertation meetings of ADASE 2 are such an important source to collect data about the newest developments in the European research activities. (ADASE2 Deliverables D4A – D4C) Further on, the knowledge discussed in the expert workshops on the various themes are taken into account. (ADASE2 Deliverables D3A – D3E) At least the discussions between the ADASE partners and especially the specialists, who are involved in the most research projects funded by the EC and various other e.g. national funded projects, lead to an overall view of the research activities of the field of driver assistance systems. The project results concerning the state of the art and the state of practice are included into the reflections, in order to get a broad background of knowledge. (ADASE2 Deliverables D2A - D2C) The roadmap development process itself is explained later on in detail.

Thus, the most important aspects of driver assistance are taken into consideration. These aspects are not only focussing on technological topics. The relevant aspects, which were identified, are:

- System and system algorithms,
- Sensor,

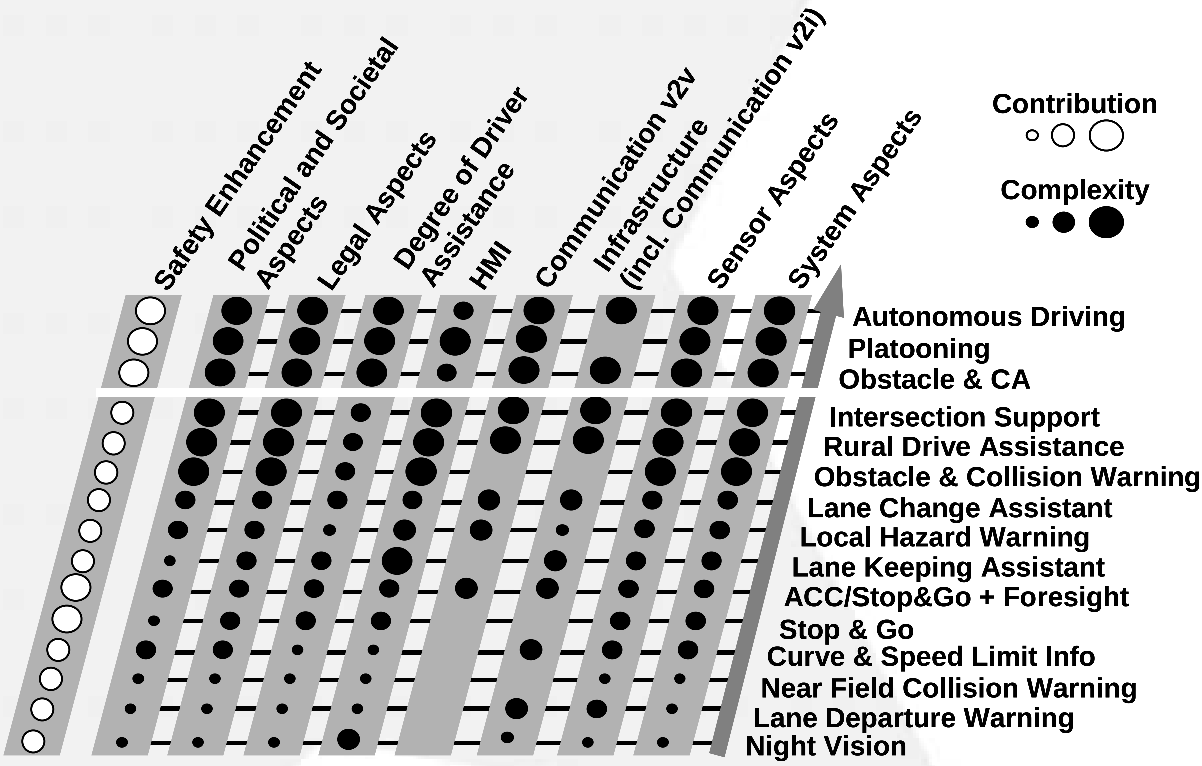
- Infrastructure (including Communication between vehicle and infrastructure),
- Communication between vehicles,
- Human machine interface (HMI),
- Degree of driver assistance,
- Legal aspects,
- Political and societal aspects,
- Safety enhancement.

These aspects are stated beneath in detail.

In order to estimate the importance of the listed aspects for the different ADAS, the complexity concerning the demands is shown in the adapted ADASE2 roadmap.

This approach allows a holistic view on the correlation of the listed aspects and selected ADAS. Thus, the stakeholders of different disciplines are able to identify the future needs of their working areas.

The resulting overall roadmap is shown in the following figure.



Picture 2: ADASE2 roadmap.

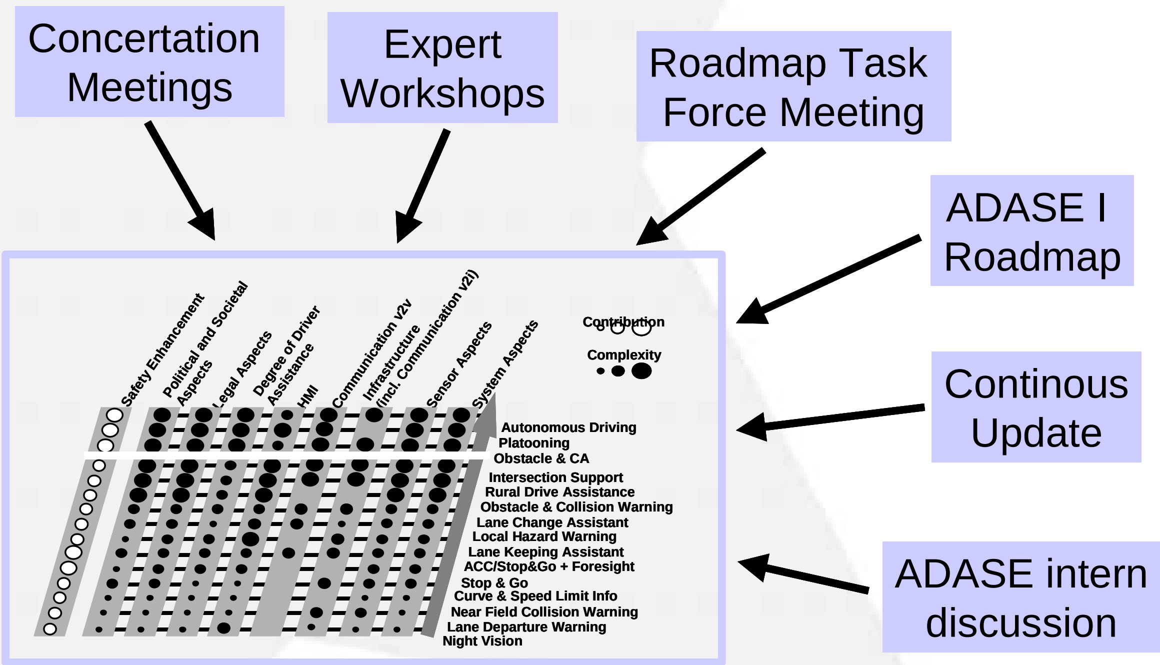
In each case the complexities of the systems concerning these aspects are shown by the size of the dots. The size of the dots is classified in three steps. Thus, it becomes clear that complex systems with a high need for further research activities can be identified by an accumulation of big dots.

The overall consideration of all these aspects and the functionality of the systems should lead to an assessment of the estimated safety benefit.

It has to be stated, that this ADASE2 approach is a research related roadmap. The order of the shown systems is established regarding the research stages. The last shown systems (Obstacle and Collision Avoidance, Platooning and Autonomous Driving) are displaced, because they are visions, which cannot surely be realized in the future on normal roads.

3 PROCESS

The development of a roadmap can only be seen as a continuous process not as a singular event. Thus, different sources of information are the basis for this process. Especially the ADASE events like Concertation Meetings, Expert Workshops, Roadmap and Task Force Meeting will be explained regarding their output concentrating on the roadmap needs. During some of these workshops the roadmap was disseminated and discussed. Further on, the discussion between the ADASE core team members and their colleagues in the different institutions and companies provide the actuality and completeness of the most important functions and aspects of ADAS within the roadmap.



Picture 3: Roadmap development process

In the following the major outcomes of different workshops and meetings will be wrapped up. This will provide an insight into the basis of information of the roadmap.

3.1 Concertation Meetings

Within Concertation Meetings different projects concerning ADAS have the possibility to introduce themselves. The goal is to set up a platform where these projects can find a way to exchange information and work together. Thus, several European as well as national funded projects showed their results.

Regarding the development of the roadmap, important points are:

- Getting an overview of the running FP 5 and starting FP6 projects.
- Getting an insight into national programs like the French (Arcos) and German (INVENT).
- Interdisciplinary discussions.

This leads to a holistic view on the current ADAS research and development, which is important to keep the roadmap up to date. Another important issue is the choice of the most relevant aspects shown in the roadmap.

Further information about the Concertation Meetings is available in the ADASE2 Deliverables D4A – D4C.

3.2 Expert Workshops

During the project duration, five expert workshops took place. They are documented in detail in the ADASE2 Deliverables D3A – D3E. Obviously, these workshops are important sources of information regarding the aspects in the roadmap. Taking this into account, the major outcomes are summarized as follows:

Workshop on Architecture and Technology Road Map:

The discussion on architecture shows the importance as a basis for ADAS. Further on, the importance of communication and telematic system was emphasised.

Workshop on Human Machine Interface and Interaction:

Identification of future needs for ADAS-HMI development (more general - not only focused on one concrete system), especially in the field of: HMI enabling technologies, evaluation tools and supporting measures.

The complexity of HMI for ADAS can be understood and estimated on the basis of this workshop.

Workshop on Vehicle to Vehicle and Vehicle to Infrastructure Communication:

The workshop gives a broad introduction into the state of the art of this new field of technology. The growing up importance, which could also be seen in the concertation meetings, led to an extension of the roadmap with a new aspect column for vehicle to vehicle-communication. Further on, the discussion of the need for standardization of frequencies aim at the importance of political issues.

Workshop on Sensors and Actuators Technologies:

Sensor technology is one of the key enabling technologies for ADAS introduction. Different technologies for various systems are available. The potentials and limits were discussed. Further technology development especially for complex systems were required, which is reflected in the roadmap estimations, as well as frequency allocation.

Workshop on effects of ADA systems on safety, throughput and comfort

During the workshop an impact assessment took place by the present experts. The aspects were safety, throughput and comfort. A comment on possible barriers was asked as well.

The safety enhancement impact for an ADAS bases upon the expected effect of that system. It is expected a medium and sometimes high contribution of the systems. This assessment leads to the safety contribution within the roadmap.

The expected effects on throughput were positive. For some systems like safe speed and following primary effects on the traffic flow were estimated. For others like the lateral support function and obstacle warning secondary effects due to the mechanism that prevented accidents lead to less congestion were assumed.

The overall expectations regarding the effect on comfort are predominantly positive, especially for safe speed and following as well as for night vision systems.

Furthermore, the policy framework was discussed during the workshop.

3.3 ROADMAP TASKFORCE MEETING

Discussing the needs of communication means, the major outcome of the communication workshop as well as the architecture workshop was the extension of the roadmap concerning this subject area. In order to have the possibility of a deep technical discussion, a task force meeting took place with the ADASE2 core team and some members of the EUCAR SG-A working group. The major results were:

- The differentiation of vehicle to vehicle communication aspects and infrastructure aspects including explicit infrastructure to vehicle communication.
- The update of the complexity estimation.

3.4 State of the Art / State of Practice

The reflection of the State of Practice (Deliverable D2B) and State of the Art (Deliverable D2A) were also taken into account.

State of Practice:

As the roadmap deals with research systems and the State of Practice with series production systems, only some small overlap at the very bottom of the system line can be noticed. Thus, both considerations complete each other.

State of the Art:

The main aspects of the outcome are important issues for the roadmap as well:

- Safety becomes more and more a main focus of complex systems.
- Nearly all of the systems are advisory.
- Fully automated driving can be seen as a vision, which cannot be foreseen as realisable on normal roads.
- The status of most projects is “under development”.
- Enabling technologies have to be developed.
- Cooperative systems based on communication technologies are emerging.

These aspects are covered in the roadmap as well.

3.5 Complexity Estimation

The connection between system and aspect are characterized by bold dots. The size of the dots represents the complexity. Complexity means in this context the required expense in order to fulfil the demand of the given aspect.

The technical oriented aspects are system, sensor and communication. The more human factors oriented aspects (HMI, degree of driver assistance) represent the complexity to show the driver clearly, what the ADAS is behaving in this situation. Legal and political as well as some parts of the infrastructure aspects are more related to the complexity of providing the boundary conditions.

Based on the databases described before, the complexity is estimated by the size of the dot, which is small, medium or large. These estimations are discussed and agreed by the interdisciplinary ADASE2 consortium.

The order of the systems is strongly connected to the complexity of the systems and hence with the research stage.

4 DEFINITION OF ASPECTS

In the future, ADAS have to be assessed related to different aspects. These aspects should not only cover technical but also human related aspects, legal aspects, roadside aspects and standardization aspects.

The consortium chose the main aspects for the ADASE2 roadmap on the basis of the concertation meetings and internal discussions. They are explained in detail below.

4.1 System Aspects

The System Aspects deal with the complexity of the controller algorithms. The main focus of the controller lies on the definition of the system behaviour. The controller algorithms include additionally interpretation and analysis of traffic situations as well as the prediction of the possible changes. Thus the complexity of the system is strongly linked to the complexity of the traffic situation the system is designed for. It is strongly linked to the other aspects like sensor, HMI and communication.

4.2 Sensor Aspects

One of the key technologies is the detection of the environment and the surrounding traffic. Different technologies like radar, lidar or video image processing have to be considered. Another requirement is the need of sensor data fusion if different sensors are used in parallel. In this case different fusion mechanisms are possible.

The complexity of the chosen sensor technology and the data fusion methodology define the overall complexity of the sensor system. This is strongly corresponding to the situations, which are covered by the system.

It has to be noticed, that also frequency regulation is an important issue. An example is the 24GHz bandwith, which is very important for short range radar sensors for safety applications.

4.3 Infrastructure (incl. Communication v2i)

The infrastructure aspects include measures in street construction (e.g. brightness of lane markers), technical devices as well as the communication between the infrastructure and vehicles.

Roadside measures, which help every car and in short term, as well as the infrastructure connected communication should be taken into account by the road authorities. The provided data has to be up-to-date with a high quality.

Thus, different parties have to work together on this field with the main focus on the tasks of the road authorities. The more complex the system is the more complex the needs are in the area of infrastructure. E.g. at intersection scenarios are specified by a huge number of parameters (e. g. traffic light status). This causes that the systems have to take most of them into account. In order to be able of detecting them by the means of communication, the support of road authorities is needed.

As mentioned before communication needs frequency allocation with support of the politics. Additionally, messages have to be standardized concerning protocols (understandable for all communication partners) and security against external interference.

4.4 Communication v2v

The direct information exchange between several vehicles can be realized by the means of communication. The complexity of the communication system is determined by requirement of the assistance system (e.g. concerning range, security, fast data availability). The requirements concerning frequency allocation, protocols and security are the same as for v2i systems. Especially safety systems need highest transmission quality and security.

Different technologies (e.g. W-Lan) have to be taken into account, when choosing the appropriate related to the task.

4.5 HMI Aspects

The HMI gives the driver the feedback of the system activities or available information. Further aspects related to this topic are user acceptance and usability.

This aspect represents the connection between the driver and the system, which means both technology and human factors have to be considered.

Thus, methodology shall be developed that is usable to investigate the driver vehicle interaction with a complex system in complex usage situations.

Thus, the methodology related to driver behaviour and HMI design has to be developed for complex systems because of new requirements.

4.6 Degree of Driver Assistance

The degree of driver assistance represents the different stages of driver support (e.g. information, warning, support, autonomous intervention). The more of the driving task is done by the system, the less the driver himself has to fulfil this task. This aspect is strictly connected with HMI, legal and system aspects.

4.7 Legal Aspects

As some of the assistance systems can possibly take over certain aspects of the control of the car, it is necessary to think about the legal aspects concerning liability of the manufacturer, the car owner, the driver and public authorities. A new aspect is the role of the road authorities and governments. Some systems depend on up-to-date information from the infrastructure (e.g. speed information).

The responsibility of all stakeholders will be questioned depending on the degree of driver assistance. In total the legal aspects are corresponding to the system complexity: the more complex the situation, the system reaction and the needed information is, the more unsolved the question becomes, who is responsible.

4.8 Political and societal

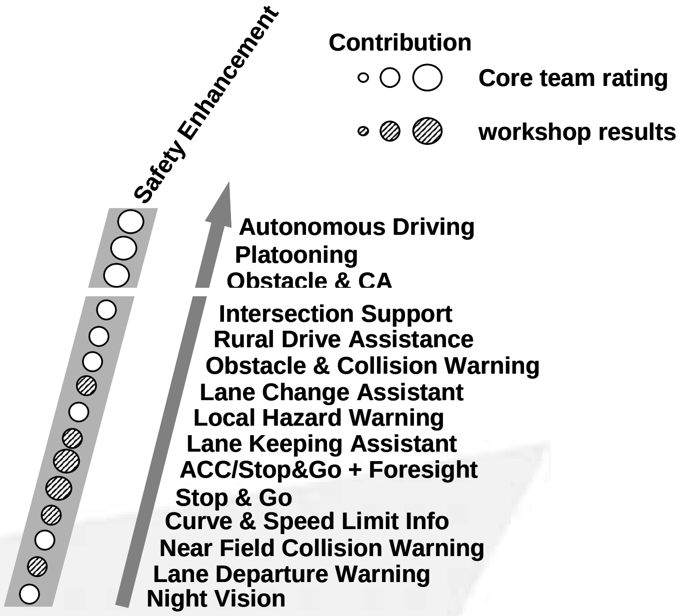
Driver assistance systems influence further on political and societal fields. E.g. the influence on traffic flow has to be investigated under the societal aspects or the costs and acceptance.

For introducing new technologies there are some tasks for removing regulatory barriers. One of the most important task is the frequency allocation. Key technologies like sensor and communication systems need frequencies. It can be stated that most of the efforts may be in vain and no mid term improvements may be gained, if no frequencies are available.

4.9 Safety Enhancement

The safety enhancement takes a special role within the driver assistance systems development. Each system should help to relieve the driver.

During the Expert Workshop on effects the safety contribution was discussed. All experts were asked to fill in their rating for some systems. These systems were due to limited time during the workshop reduced to Stop & Go, ACC/Stop&Go + Foresight, Curve and Speed Limit Info, Lane Keeping Assist, Lane Departure Warning and finally Lane Change Assist. The results were summarized in the roadmap. The ADASE2 core team assessed the other systems by the same procedure. The sizes of the dots represent the estimated safety contribution.



Picture 4: Assessment of contribution to safety depending on procedure

Safety enhancement impacts (large, medium or small dots) for ADAS are based upon the expected effect of that system in the relevant accident category like frontal, head tail, aside, vulnerable road users and singular accidents (due to the system functionality). For instance, lateral support systems have effect on aside and singular accidents and not head-tail collisions.

The systems have the potential to help effectively to reduce accidents. Thus, they have at least medium contribution to safety enhancement.

The visionary, more complex systems (platooning, autonomous driving) even promise a high contribution to traffic safety, but have to be checked if they are realizable. E. g. autonomous driving cannot be foreseen on normal roads.

A final assessment of driver assistance systems needs a common European accident database. As it is not yet available, the contributions shown in the roadmap are estimated according to the described procedure. Further on, the evaluation of the effect needs a comparable basis for all of the listed data. As they are in different research stages, some only exist as a concept, others in simulation and some few demonstrator vehicles. For comparability effect assessment has to be on a more general level.

5 DEFINITION OF SYSTEMS

The systems shown in the roadmap represent the most important research topics of ADAS. The detailing of the system description depends on the complexity of the addressed functionalities. In order to give a first impression which system functionality is mentioned the systems are defined below. As they are research topics and the development is away from being finished up to now, some systems cannot be explained in a detailed way.

At the end of each description, short hints regarding the main focus in the complexity are given.

5.1 Night vision

Based on camera techniques like near or far infrared it is possible to enhance the perception of the driver in dark light conditions. The picture of the camera will be shown to the driver by monitors or head up displays.

One of the major issues is to solve the HMI task of presenting the right picture at the right position, in order not to distract the driver.

5.2 Lane departure warning

If certain thresholds (like distance, time to lane crossing) allow a prediction of a lane departure this system warns the driver by means of acoustic, optic or haptic feedback. The detection of the lane markings results from e.g. video image processing.

In order to have a robust lane marking detection two needs can be identified:

- Good visible lane markings have to be provided by the infrastructure and
- a robust lane detection sensing system has to be implemented in the vehicles.

Both aspects are influencing the complexity of the system on the roadside and the technical level.

5.3 Near field collision warning

The near field collision warning includes the detection of especially vehicles in the near field like in the blind spot area. The detection area is very close limited to the vehicle. Suitable sensor systems for the detection of other cars are radar, lidar or vision based sensors. The warning can be acoustical, haptical or optical.

In this case frequency allocation is very necessary as in some cases 24 GHz sensor systems are particularly suitable.

5.4 Curve & speed limit info

These systems inform the driver about speed limits and the recommended speed in curves by e.g. an optic or haptic (at the accelerator pedal) feedback. Possibly the necessary information can be taken from digital maps, image processing or communication systems between vehicles and infrastructure.

The drivers have to be always aware of the problems arising from the actuality of the information e.g. from digital maps. Providing the up to date data is an important task, which only can be solved together with the road authorities. Additionally the appropriate speed – as the major problem - can only be chosen if some unforeseen events like partly low friction are taken into consideration. Taking these concerns into account, the question who will be responsible for a wrong decision (e. g. driver, information provider, road authorities) has to be solved, if the information becomes mandatory.

5.5 ACC/Stop & Go

During stop & go traffic situation the longitudinal control of a vehicle will be partly carried out by a system. Therefore it is necessary to detect the traffic in front even in the near field. In extension to an ACC the detection of this area is necessary to react on other cars swerving into the near field.

The ACC/Stop & Go system will be used in more complex situations than the series production ACC. This influences the complexity of all aspects.

It has to be stated, that frequency allocation for 24 GHz sensors is a precondition for a fast market introduction. Thus not only technical boundaries have to be considered.

5.6 ACC/Stop & Go + Foresight

The ACC and Stop & Go function can be extended to a traffic related system by the means of communication. Far away driving vehicles will be involved into the longitudinal control. Thus, an end of a traffic jam can be included into the longitudinal control, before a driver is able to see it e.g. in a curve. Thus the traffic flow and the safety can be increased.

Additionally to the described aspects of ACC/Stop & Go the communication systems have to be build up and frequencies for these systems have to be allocated.

5.7 Lane Keeping Assistant

The function of a lane keeping assistant system includes the lane detection and the feedback to the driver if he is leaving a defined trajectory within the lane. An active steering wheel can help the driver with a force feedback to keep on this trajectory. The lane is detected by a video image processing system.

Additionally to the Lane departure warning aspects especially regarding the infrastructure, especially the HMI becomes more important. As the driver is directly connected to the controller by the means of haptics, the direct feedback makes high demands on controller quality as well as on the other aspects.

5.8 Local Hazard Warning

If a hazard occurs far away in front of the vehicle, so that the driver cannot see it, this system will warn him. By the means of communication it is possible, to transfer this information over long distances. Ad-hoc networks can be used.

In this context some analysis of the necessary fleet penetration has to be done. An usable frequency has to be allocated. As in case of the Curve & Speed Limit Information the responsibility of the driver has to be clarified.

5.9 Lane Change Assistant

Before and during a dangerous lane change process, the lane change assistant will warn the driver. Several stages of such a system are possible from pure warning systems to even haptic feedback at the steering wheel to help the driver following a lane change trajectory. The detection of all vehicles around the own car is necessary as well as the detection of the lane.

As the lane detection is used, the system makes the same requirements on the infrastructure as the Lane Departure Warning. Additionally the detection and analysis of the surrounding traffic has to be made. The situation becomes more complex compared to longitudinal systems, because the lateral movement has to be taken into account. Further on, the driver has to be aware of functional limits as fast approaching vehicles.

5.10 Obstacle & Collision Warning

The driver will be warned if a potential collision is detected with e.g. another car or obstacle. This warning can be for example acoustic or visual. Complex scenarios like evading can be included as well as warn breaking, which is a very short brake in order to give a kinestetic feedback.

The functional limits of these systems have to be clearly pointed out. Therefore the addressed – complex - scenarios have to be defined in detail. The liability problem of these systems grows with the complexity of the scenarios.

5.11 Rural Drive Assistance

Most of the systems are developed for the use on highways. Between cities a lot of so-called rural roads exist. The requirements compared to highways are higher e.g. because of closer curves or sight obstructions in combination with oncoming traffic.

Some existing system functionalities have to be extended for this system. Combined with this, the overall complexity grows with the increase of the situations.

5.12 Intersection Support

In an intersection situation especially in cities a driver has to fulfil several tasks in parallel. Thus the potential for information overload is given. In order to assist the driver in such situations it is necessary to support certain tasks like approaching a stop sign / traffic light or right of way of crossing traffic. Here only examples could be named because of the early research stage of the intersection support systems.

The complexity of the possible intersection scenarios leads to the high overall complexity. E. g. the detection and interpretation of the scenario is very difficult. Furthermore, there are some requirements on the infrastructure e.g. regarding street markings (for video detection) or communication with traffic lights. The liability discussion will be the same as in the case of obstacle warning. Several parties have to work together on this topic.

5.13 Obstacle and Collision Avoidance

This system has an extended functionality compared to the Obstacle and Collision Warning. An autonomous intervention takes over the control of the vehicle in critical situations in order to avoid an accident. Longitudinal and lateral control will be done by the system during the defined time while the dangerous event takes place.

As the system controls the movement of the car, the scenario interpretation and the controller behaviour has to be improved essentially compared with the warning system. Fault actions of the systems may have fatal consequences. The liability issue is very critical. As the driver is not in the loop the HMI is not as important as for other systems. If the problems will be solved cannot be foreseen up to now.

5.14 Platooning

Several cars are connected electronically (e.g. by the means of communication) and follow one after the other in a platoon. An example is the connection of trucks in order to save space, fuel and to increase the traffic flow.

As the following vehicles are driven automatically, the system is complex concerning all aspects. The takeover of the driver at e.g. gateways has to be taken into account as well as the behaviour in mixed traffic at driveways.

5.15 Autonomous Driving

This is the theoretical highest level of driver assistance. The vehicle drives controlled by an algorithm in each situation. It is predictable that this stage assistance cannot be reached in the actual roadnet.

The complexitiy of Autonomous Driving is comparable to Obstacle and Collision Avoidance. If the problems will be solved cannot be foreseen up to now.

6. CONCLUSIONS

Altogether the roadmap helps to give an overview about the complexity of future ADAS. It takes different aspects like technical but furthermore legal and societal aspects into account and points out the related complexities.

As it is a research roadmap not all of the systems can be defined in detail. Thus, the aspect assessment is done on an overview-level because the systems should be comparable despite their different research stages. It can be shown, that the systems become more complex under nearly all aspects the higher the system aspects complexity becomes. The last shown systems (Obstacle and Collision Avoidance, Platooning and Autonomous Driving) are displaced, because they are visions, which cannot surely be realized in the future on normal roads.

The effect contribution is estimated, because comparable data is not available because of the different research stages of the systems.

Corresponding to the complexity of the different aspects the further needs can be derived from the size of the dots. As the different aspects are related to certain groups (car manufacturers, suppliers, road authorities, governments) it can be seen who is in charge of solving upcoming problems.

The roadmap is the result of several discussions with input from the ADASE2 workshops.

Glossary

ADAS	-	Advanced Driver Assistance Systems
INVENT	-	Intelligent traffic and user-oriented technology
HMI	-	Human machine interface
v2i	-	Vehicle to Infrastructure
v2v	-	Vehicle to Vehicle
ACC	-	Active Cruise Control

PReVENT -	Preventive and Active Safety Applications - Integrated Project Proposal