ADAS for the Car of the Future

Interface Concepts for Advanced Driver Assistant Systems
in a Sustainable Mobility Concept of 2020

Design Report

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Preface

The main reason why I got interested in this project and the assignment was a previous Industrial Design research assignment about autonomous vehicles. The knowledge gathered for that assignment could be useful for this new project. One of my personal objectives was to keep the theoretical research limited to a small literature research, and then spend most time on sketching and designing new concepts.

After working on the assignment for a while, it was found impossible to limit the theoretical research. A lot of aspects of the assignment had to be considered in order to end up with a feasible concept design like I'd like it to become. This is the reason that the majority of this design report describes introductory research and analysis, before getting to the concept design chapter.

Though the personal objective wasn't reached, I'm pleased with the result. I think it does provide a pretty feasible and well thought-out collection of concepts which may actually be used in the Car of the Future someday.

Jos Thalen

Enschede

August 25, 2006

Abstract

"ADAS For the Car of the Future"

Interface Concepts for Advanced Driver Assistant Systems in a Sustainable Mobility Concept of 2020

Background - Intelligent Vehicle Systems offer great potential to future mobility. An increase of intelligent in-vehicle applications may improve safety and provide comfort. Several sources indicate the benefits of Advanced Driver Assistance Systems and other Intelligent Transportation Systems to be significant. For the Car of the Future, a concept development challenge initiated by the Dutch Society for Nature and Environment, it's therefore vital to be equipped with these systems. It can improve the active safety aspects of the vehicle, and make the car more attractive to buy and use.

Methods & Results - The first part of the research is based primarily on literature. A state of the art of ADAS is presented, as well as an overview of ADAS related research projects. Several ADAS systems, such as Adaptive Cruise Control (ACC), Lane Departure Warning (LDW)and Intelligent Speed Assistance (ISA) are already popular among car manufacturers, or are being developed.

To try and integrate a selection of these systems into a single integrated ADAS concept, a design approach has been defined. The approach splits the research into two main parts. The first part covers the design of an integrated ADAS system. The second part covers the design of interface concepts for the ADAS system.

System Concept

The first part, the design of an ADAS system started with the investigation of user and stakeholder requirements. It was found that drivers accept ADAS systems, as long as they keep a certain amount of control. To comply to these requirements, the system uses so called *system states.* Every system state offers a certain amount of control, leaving the choice with the driver.

To define which drive tasks were to be supported, a system analysis of current ADAS systems has been made. Functions of these systems have been integrated into new multi-purpose functions and components. The results offers the support of the future driver in both longitudinal and lateral direction, by combining functions of current systems like cruise control, lane monitoring and control, obstacle avoidance and speed assistance. Improving safety is the primary goal of the system. Other characteristics are its flexibility and adaptability in use, and sustainable component selection.

Interface Concept

In the second part of the research, an interface framework was designed. Interactions between the driver and system have been investigated and used to define information flows. Next, input and output channels have been defined, indicating which information is presented to the user (output for a particular system state) and which information is used as input.

For the resulting interface framework four concepts have been designed, differing in feasibility and 'fanciness'. These concepts were named *Classic, Adaptive, Futuristic* and *Road Assistant*, referring to their key features.

Conclusions & Recommendations - The research ended with evaluations of both the system concept and the interface concepts. As for the system concept, further research regarding law, workload management and sensor integration is required. For the interface design, the 'Adaptive interface' and the 'Road Assistant' concepts turn out to be most favourable for further development, based on system and interface evaluations.

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Project Introduction

The Dutch Society for Nature and Environment (SNE) initially proposed a challenge for the three Dutch technical universities to design a sustainable mobility concept for 2020. This proposal was reshaped into a design challenge for 3TU, which is an umbrella organisation for the universities of Delft, Eindhoven and Twente.

Conditions of the challenge include

- The car will remain a major form of transportation in 2020
- The sustainable society affects the car
- The infrastructure won't change drastically

3TU formed a group of students and counsellors, with the working title “Nexus”. This project group employs students to develop individual parts of the final mobility concept. For this group, the primary part of the mobility concept is the car, which is to become sustainable, silent, clean, safe and space efficient.

Assignment

The Nexus group uses a vision-driven design approach. A vision of the future is used to make design-related decisions. This vision includes social, economical and sustainability aspects. Taking a stand within this vision should result in a coherent and well thought-out resulting concept, containing the following *principles.*

- Structure
- Body
- Drivetrain
- Suspension
- **User Interface**
- **Active safety**
- Passive safety
- Framework

The University of Delft (TuD) focusses on the body and framework principles. This includes interior and exterior design, the definition of a user group, branding, concept framework, etcetera. The University of Eindhoven (TuE) is primarily working on the drivetrain and suspension of the car. For the University of Twente (UT) the main principles are user interface and active safety.

Project Approach

The goal of this research is to explore the implementation and development of so called Advanced Driver Assistance Systems[1] for the Car of the Future. Design oriented research is needed to find out which ADAS exist, and how they can be implemented in the concept car. The research will be divided into three phases.

1. The first phase includes a market analysis to give an impression of the available ADAS. Furthermore, the requirements and preferences of participants and users must be acquired by conducting stakeholders- and user analysis. The result of phase 1 will be an overview of available ADAS and a list of requirements and preferences of stakeholders and end-users.
2. During phase 2, combinations of systems will be designed and presented. When required, new ADAS solutions can be developed. Concepts will be presented to stakeholders using drawings and 3d models.
3. The concepts will be evaluated based on existing evaluation methods, and by using the system requirements defined during the research.

1 See Chapter 1 for a definition of ADAS

Report Structure

The three phases of this research are reported in this design report. The following chapters are used to present the research findings and developments.

- Chapter 1 includes a literature research report and an overview of available ADAS, prototypes and relevant research projects.
- Chapter 2 investigates the issues related to the development of an ADAS concept. It concludes with a proposal design approach.
- Chapter 3 describes the actual development of an integrated ADAS concept on system level, resulting in a system specification.
- Chapter 4 continues the system development, focussing on the user interface. In this chapter the interface concepts are presented.
- Chapter 5 concludes with the evaluation of the concepts, resulting in a set of conclusions and recommendations.

The conclusions of this research are meant for further use in the Nexus project.

1. Introduction to ADAS

A first introduction to ADAS. What is it, and why would we use it? A market analysis will give an overview of existing products and their functionality. Next, a look at research projects and field-test reports will give an idea of current ADAS developments.

1.1 In-car Electronics

Since its introduction, the concept of the car hasn't changed a lot. A car still consists of four wheels, an engine, propulsion and an interior. Obviously technology has improved since the first production car, but the basics of the invention are still the same. Until a few years ago this was also true for the interface of a car, usually a steering wheel, control pedals and a dashboard. Recent developments show that this is changing significantly. An increase of in-car electronics is found.

The car radio is an example of in-car electronics, the GPS navigation kit is a more recent one. Adding these systems serves different goals. Car radio was meant to entertain the driver and passengers, GPS navigation is meant as a navigational aid, and could be considered a comfort system. Generally, in-car electronics can be categorised into either one of three categories[2].

- *Information systems* provide traffic or situational information, in order to help the driver navigate or generally use his car. Examples are navigation systems and traffic information receivers.
- *Entertainment systems* provide entertainment with video, music or other multimedia or office applications. For example, the car radio and modern in-car DVD players.
- *Safety systems* enhance the safety of driver and passengers, either by actively supporting the driving task, or passively (in the background) supporting the car itself. Examples are ABS and ESP (background) and driver assistance systems like cruise control.

Interactions between two or more categories occur. For example, a car radio can be used as entertainment, but may also provide the driver with traffic information. The interactions between categories should be an important consideration during the further design and research on Advanced Driver Assistance Systems. The interface in particular should provide the user with means to safely use all three categories.

This research will primarily focus on the safety systems. In-car active safety systems are generally called Advanced Driver Assistance Systems, or ADAS. ADAS are in turn part of a technology called Intelligent Transportation Systems, or ITS. A clear definition of ADAS is stated as follows.

ADAS: Advanced Driver Assistance Systems have a direct supporting interaction with the driver or the driver task. Their way of support may vary from informative to controlling. ADAS operate from inside the car, but may be connected to external sources.

Why ADAS?

As said above, ADAS supports the driver performing driving tasks. As a result, the use of these systems may increase traffic safety, traffic efficiency and improve the sustainability of the vehicle. Another aspect, comfort, can also be improved by the use of ADAS, however, the focus and goal of ADAS development is usually safety improvement.

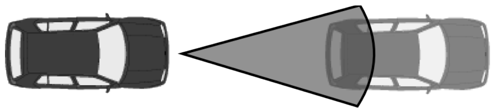
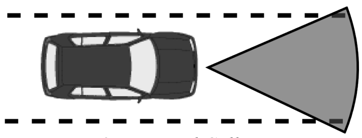
The implementation of ADAS (or intelligent transportation systems in general) may lead to a fatality decrease of 40%[3]. It's pointed out that new systems should be well designed and thoroughly tested before introduction.

The main goal of ADAS within this project is to improve future traffic safety. Although sustainability is influenced by the use of ADAS, it's too marginal to be used as a main objective. Nevertheless, sustainability effects, environmental factors and traffic efficiency will be taken into account during the research.

2 B.H. Kantowitz et al, 1999
3 B. van Kampen et al, 2005

1.2 ADAS Technology Overview

To give an impression of what ADAS means to end users, an overview of existing ADAS technology is presented. For convenience, they've been divided into subcategories. This short overview of existing ADAS technology only highlights the more 'common' types of ADAS. Other sources are available for a more complete list of available technology, see references[4],[5].

ADAS			Description
Longitudinal	ACC	Adaptive Cruise Control	ACC is becoming a more and more common accessory in modern cars. Basically, this technology keeps a safe distance between the driver's car and vehicles ahead. The driver can adjust the distance, and the system makes sure it's maintained, using throttle and brake control. Most ACC systems have influence on the driving task (they control brake and throttle), but still allow user take-overs.  *Fig 1: Adaptive Cruise Control*
	FCW	Forward Collision Warning	Like the ACC, this system detects vehicles in front of the driver's car. Obviously, it can be integrated with ACC. However, current systems still have problems distinguishing cars from trees, bridges from road signs, etc.  *Fig 2: Forward Collision Warning*
	ISA	Intelligent Speed Assistance	ISA influences the speed at which a car is driving. The maximum speed can be pre-set, or acquired from GPS data. Interfacing with the driver is done via the acceleration pedal, or by using visual or audio warnings.

4 L. Berghout, E. Versteegt et al, 2003
5 Stardust D1, August 2001

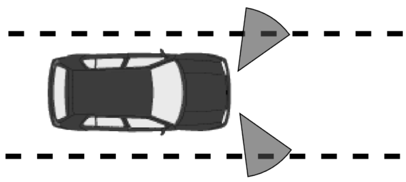
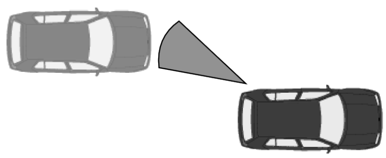
ADAS			***Description***
Lateral Support	LDW	Lane Departure Warning	The main task of Lane Departure Warning is to make sure a car is driving safely between road marks (i.e. in a lane). LDW uses cameras and computer systems to detect and process roadsides and lane markings, and warn the driver if necessary. Acceptance of LDW is expected to be a problem because control of the car is given to the computer, and chances of false alarms are still present.
	LKS	Lane Keeping System	An extended version of the LDW system is the Lane Keeping System. Instead of warning the driver about the unintended lane departure, LKS intervenes with the driving task by using steering wheel actuators. LKS can completely take over the steering task of the driver.  *Fig 3: Lane Keeping System*
	LCA	Lane Change Assistance	LCA is a collection of technologies taking care of blind spots and rear-view problems. It uses sensors to detect objects and vehicles which normally can't be seen by the driver because of obstructed view. Also, approaching vehicles from behind can be detected in time, and the driver can be informed of this.  *Fig 4: Lane Change Assistance*
Miscellaneous		Night Vision Systems	These systems provide the driver with an enhanced view of the outside world. It's meant to be used during bad weather or night time. Though already implemented in several car models, the system still has a problem with its interface: how to present the enhanced image to the user. Current solutions consist of displaying the image on a monitor on the dashboard.
		Parking Assistance	The Parking Assistance system looks like Lane Change Assistance, but is meant for low speed and short distance, for example when parking a car. Using sensors a car can measure available space, and show this information to the driver. Current systems have limited use because of the low range these sensors operate with. Future developments will let the system take over control of the car during parking, letting the car park itself.
		Fuel Economy Devices	With Fuel Economy Devices the fuel flow and usage can be monitored and analysed per car. A system can intervene by informing the driver about the fuel usage, or by actively intervening, using an active gas pedal or other active systems.

Table 1: Basic ADAS technology overview

1.3 Development Projects

Three major stakeholders play a part in the development of ADAS technology, namely the government, research institutes and car manufacturers. Every stakeholder has its own objective with developing ADAS. The government is trying to solve traffic and safety problems. Research institutes work on experimental and innovative technologies, and car manufacturers are looking for improvements of their current fleet. Luckily, the three stakeholders often form cooperative development projects with specialised topics such as law, safety and technology. A list of relevant projects and a short description is given below.

ADASE

In Europe, a key project in ADAS development was ADASE (ADAS Europe). It's an umbrella organisation for about 30 sub- projects, covering technology, legal issues, ergonomics and psychology aspects. Using workshops and meetings, they let projects network together, working at the following goals:

- Harmonising and communicating active safety functions,
- Identifying technological needs and focussing on essentials,
- Preparing architectures, roadmap and standards.

Relevant sub-projects of ADASE are the RESPONSE projects. With RESPONSE, market possibilities are investigated thoroughly, resulting in detailed reports.

RESPONSE 1 (1999) concluded with a report[6] about ADAS technical specifications, user requirements and legal aspects. It concluded that there are no problems with introducing ADAS, as long as there's an option for the driver to take over control from the system. RESPONSE 2 (2005) elaborates on these results. With all aspects covered, a “Code of Practice” was written, meant to help with the design of ADAS.

The results of the ADASE project can be used to define a marketing strategy, and provide several guidelines for ADAS/ADAS HMI[7] design. Though useful, more recent projects should be investigated to determine the actuality of the ADASE project.

eSafety

The 2001 White Paper "European Transport Policy for 2010: Time to Decide" sets out the ambitious target of reducing the number of road fatalities with 50 percent by 2010. This requires a rapid increase in the efforts of all safety stakeholders. To support these actions, the European Commission officially launched the *e*Safety initiative in April 2002.

“eSafety brings together the European Commission, industry, public authorities and other stakeholders to accelerate the development, deployment and use of eSafety systems - Intelligent Vehicle Safety Systems - that use information and communication technologies in intelligent solutions, in order to increase road safety and reduce the number of accidents on Europe's roads.”[8]

Within this project, several workgroups are active in different areas. The Human-Machine Interface group[9] is most interesting for this research, as it's aiming at the design of HMI for Intelligent Vehicle Systems. At the moment, the result of this workgroup is a European statement of principles on Human Machine Interface, containing general design guidelines[10].

AIDE

The Adaptive Integrated Driver-vehicle Interface (AIDE) project is specifically working on the HMI aspects of ADAS implementation. Both ADAS and IVIS (In Vehicle Information Systems) are recognised as potential life savers. Furthermore, nomad devices[11] are expected to become more popular in cars. Their goal is to design an interface that safely integrates nomad devices, ADAS and IVIS. Several workgroups are defined, of which “Design and Development of an Adaptive Integrated Driver-vehicle Interface” is most relevant for this research. So far, results include scenario sketches, workshops and guideline-overviews. Because this project is still active, most reports are confidential and not

6 S. Becker, T. Johanning et al, RESPONSE, D4.2, v. 2.0, 1999
7 HMI: Human Machine Interaction
8 Quoted from the eSafety website
9 A workgroup of the eSafety project
10 See Chapter 2, paragraph 2
11 Portable personal devices such as a PDA, a mobile phone

accessible for this research.

Communicar

In the COMUNICAR project[12], an attempt has been made to develop a HMI for an in-car multimedia system. It was one of the first systems to integrate multiple in-car applications, from GPS navigation systems to other ADAS. The project recognised the potential mental overload, and found a solution by intelligently scheduling the information presented on screen. Information is presented when needed and when the traffic situation is safe enough.

Results from this approach can be used to design an improved version of this “information prioritising solution”. Also, time-taking usability tests taken during the research should be taken into consideration. Furthermore, practical knowledge of building in-car (software) prototypes is relevant during the prototyping phase of this research.

ADVISORS

The goals of the ADVISORS Project[13] in 2003 included (among others) to determine potentially successful ADAS, and test implementations of these systems by setting up pilot projects. The final report states that systems like ACC and ISA have the biggest potential. For each system, extensive risk and acceptance research has been done, which can be used in this research as well.

Furthermore, implementation strategies are discussed to determine how the ADAS should be inserted into the market. System integration and standardisation are found to be necessary for successful marketing. This is a responsibility for car manufacturers. Interesting remarks are also made with respect to positive government intervention.

1.4 Current ADAS Applications

This paragraph presents examples of current ADAS applications, as well as ADAS field test results. The examples form just a small selection.

Adaptive Cruise Control

ACC is found to be on of the most successful ADAS systems at the moment. It was one of the first systems to be built in frequently with modern luxury production cars, and becomes more and more popular among less expensive classes of cars as well.

- Mercedes S550: “Stop & Go” ACC
- Lexus LS430/460
- BMW 3,5 and 7 series
- Honda Accord ADAS
- Nissan Primera

Lane Departure Warning

LDW systems are less common among normal cars, but are quite often found in modern trucks and large vehicles. LDW decreases the chance of roll-over accidents, which most frequently happen with these kind of cars. Last years more and more luxury passenger cars are equipped with LDW systems.

- Nissan Infiniti FX and M45
- Honda Accord ADAS
- Citroen C4 and C5 infra-red LDW
- MAN Guard System
- Daimler-Chrysler Spurassistent
- DAF SafeTRAC system

12 “Summary of COMMUNICAR”, 2004
13 “ADVISORS final report”, 2003

Another ADAS technology that is implemented in large vehicles and trucks is the ISA system.

ACC Field Test

A field test with ACC was taken by the TU Delft in the Netherlands[14]. They test-drove a Nissan Primara equipped with ACC. Their findings were according to expectations, and generally not very positive. It's found that current ACC systems lack certain crucial functions, especially during overtaking situations. Problems mentioned with road curvature have been solved by more modern ACC systems.

The interaction with non-assisted vehicles is mentioned as one of the major problems of ACC (or ADAS' general) market introduction.

LDW Field Test

In Lelystad, the Netherlands[15], a large scale test with LDW systems was held. The objectives of this test were to determine the traffic flow and safety effects of LDW systems, and to let the public know about the existence of ADAS and LDW in particular. The LDW systems were installed in a fleet of buses and trucks.

General results are positive. The acceptance of ADAS and LDW is reasonably high, as test subject indicate to have used LDW 75 percent of their driving time on main roads. The effects of LDW on safety are found to be significant. LDW may cause a decrease in truck involved accidents of nine percent.

The test concludes with positive prospects, though it's noted that full implementation of LDW will take several years.

ISA Field Test

In Sweden, a large-scale experiment with the 'supportive' variant[16] was held. When the driver exceeds local speed limits, the gas pedal would resist with more pressure. However, the driver could overrule ISA by pressing down the gas pedal with more power. The experiment showed a decrease in speed, and a decrease in travelling time. The users reported they were driving safer (or at least feeling so) and smoother. On the other hand, they found driving to become less fun, and had a feeling of being watched all the time.

In Tilburg, the Netherlands, experiments with a mandatory implementation of ISA shows similar results[17]. ISA is recognised as a traffic safety improvement, however, there's a more negative attitude towards mandatory solutions compared to informing or or assisting.

General conclusion of the trials is that to achieve acceptance, the ISA should be of an advisory kind, and most effective in urban areas with maximum speeds of 30 to 50 km/h.

Other Systems

This overview does not mention driving assistance systems like ABS (Anti Blocking System) or ESP (Electronic Stability Program). The reason for this is that these systems are presumed 'standard' in the 2020 future, and they don't have a direct interaction with the driver.

14 H.M. Jagtman et al, 2003
15 Dutch Ministry Traffic and Water management, August 2001
16 http://www.isa.vv.se/cgi-bin2/dynamic.cgi?page=39&lang=en
17 J.H. Kraay, 2002

1.5 Conclusions

Summary

Advanced Driver Assistance Systems have been introduced, as well as the meaning of ADAS within this project. The safety effects of ADAS are expected to be significant, but ADAS may also offer comfort and sustainability improvements.

A literature based overview of existing ADAS was made. The overview shows a variety of systems, divided by their functionality. It's found that the main categories are longitudinal and lateral support. For longitudinal support, systems like Adaptive Cruise Control, Forward Collision Warning and Intelligent Speed Assistance are available. Lane Departure Warning, Lane Change Assistance and Lane Keeping Systems provide lateral support.

Several of these ADAS systems, like ACC, ISA and LDW, have already found their way into both passenger and transport vehicles. This indicates the great potential of the systems mentioned above. Therefore they should be considered for implementation within this project.

Several projects are working on research and implementation of ADAS in the current and future market. In Europe, RESPONSE and eSafety play an important role. Funded by the EU, eSafety covers several sub-projects, of which AIDE is most interesting for this research. These and other project reports will be used during the design/concept phase of this research.

Prototypes of ADAS and field test results have been discussed. It becomes clear that the future of ADAS is bright, but certain development and implementation aspects need further investigation. Acceptance is a major issue often referred to in projects and field test results.

Interpretation

The chapter provides two main conclusions.

Firstly, the fact that ADAS systems like ACC, LDW and ISA are already being used in production cars indicates that they also have a high potential for this project. Though other systems should also be considered, ACC, LDW and ISA deserve priority at least.

Secondly, the problematic development and implementation aspects, such as acceptance, need to be investigated further. By looking at these problems more thoroughly, they can be taken into account during the design stage.

The next chapter will use these conclusions to define a development approach for the system concept.

2. Design Approach

The goal of this chapter is to define a development approach for the design of an ADAS system concept. The first step is to further investigate the research area, including development aspects mentioned in Chapter 1. After looking at these aspects, an appropriate development approach can be defined.

2.1 Research Area

The main goal of this research is to investigate which ADAS systems may be used in the Car of the Future in 2020. As shown in Chapter 1, several ADAS systems are available or being developed. Based on these results, it's decided to design a system that combines functionalities of several ADAS systems. After designing this underlying system a user interface has to be designed.

The research area therefore consists of two major parts, namely the design of the underlying system, and the design of the user interface. For future reference, the underlying system will be called '*system concept*', the user interface will be referred to as '*interface concept'*.

An approach is needed to define how the system and the interface will be developed. In preparation to this approach, known development problems regarding the system concept and the interface concepts need to be investigated.

2.2 Known Problems

For the system concept, some problems have already been mentioned in Chapter 1, and will be dealt with more thoroughly here. For the interface concepts, problems are generally caused by lack of proper guidelines.

Problems Regarding the System

Chapter 1 already mentioned the introduction and acceptance aspects. The following list includes all major problematic aspects of ADAS development.

1. Introduction / Acceptance
2. Negative behavioural changes
3. Workload / driving task effects

1. ADAS Introduction & Acceptance

The success of Adaptive Cruise Control proves there's a market for ADAS products. However, users should be approached with care and patience, according to literature[18]. In 2001, the RESPONSE project concluded[19];

"[…] the market introduction of ADAS shall be evaluated as not problematic as long as the driver is in a position to control and override the systems. A change in scenario occurs when this is not the case. This significant fact may inhibit the market introduction of ADAS."

Research undertaken for the Highway Agency (GB) in 2001confirms this conclusion[20] . The report describes a general positive attitude towards in-car electronics, particularly the information systems. Automated control systems are found to be less popular. It also noted a difference of acceptance between men and women. Men tend to reject the system to take over control, while women (as well as elderly people and people not interested in new technology) accept control being taken away. This research did not focus on specific types of ADAS, but made a division into information systems, driver assistance systems and fully automated highway systems.

A more recent survey among internet users went more into specific ADAS, and confirms the findings mentioned above[21]. Also, the RESPONSE 2 final report[22] states that for successful market introduction, the focus should first be on safety oriented ADAS which have proven their effectiveness.

18 Brookhuis et al, 2001
19 S. Becker, T. Johanning et al, RESPONSE, D4.2, v. 2.0, 1999
20 Chalmers, 2001
21 van Driel et al, 2005
22 E. Donner, H. Schollinski et al, RESPONSE 2 Final report D1, 2004

2. Negative Behavioural Changes

Presuming ADAS will eventually be accepted by the public, possible negative changes in driver behaviour are expected. These changes are studied and mentioned frequently in several research reports. The following factors have been found to cause negative driving effects[23].

- *Context Factors* - One factor that influences the behaviour of the driver is the user environment. This includes the road, signs and other vehicles. For example, the decision to activate ISA appears to depend on surrounding vehicles; if everyone drives too fast, a driver will not activate ISA. Furthermore, if the activation of an ADAS significantly changes the behaviour of the vehicle, the driver is likely not to use it. Another context factor consist of other 'non-assisted' vehicles. Both positive and negative changes are found in the interaction between assisted and non-assisted drivers.
- *Individual Factors* - Driver behaviour also depends on the driver's personality and character. The personal driving style of an individual influences the acceptance of a system and the way of interacting with it. Usually styles are described like 'slow and by-the-book' and 'fast and furious'. For example, fast drivers turned out to drive faster with ACC in comparison with slow drivers with ACC.
- *Learning Time* - The driver has to adapt to the system, and learn how to use it. During this learning period the driving behaviour changes, as the driver has to experience how and when the system works. It's found to be important to inform the driver about the system's limits and capabilities to prevent over-reliance.

3. Workload / Driving Task Effects

Workload describes the amount of mental stress a driver experiences while performing his driver task. For example, workload may increase when crossing a busy intersection or when entering a highway. Workload is relatively low while cruising a low-traffic highway with constant speed. Performing multiple tasks at the same time tends to increase workload.

A theory describing the causes and effects of multitasking by humans is Wickens' Multiple Resource Theory. The attention and performance of the human brain is divided into separate specific parts, each part handling for example visual tasks or verbal tasks. According to the theory, workload can be reduced by offering information in three different states (early or late processing), modalities (auditory or visual) or codes (spatial or verbal). Multiple tasks can be performed without decreasing quality, as long as they are offered for example in a combination of visual and verbal tasks. In case of the driver, a secondary task like talking to an on-board computer can be performed while maintaining safe longitudinal distance and lateral position.

Considering that ADAS is only a small segment of the future in-car electronics (information and entertainment systems being the other ones), the average workload for future drivers may increase due to increasing amounts of information.

To solve workload related problems, research and development of so called workload managers is carried out. A workload manager can assess both external and internal relevant factors, such as the outside traffic, and the user workload. With this workload estimation, the system can prioritise information and safely present it to the user.

Several systems are already in use, or in an advanced stage of development. Examples are the Motorola Driver Advocate System[24] and the Delphi Driver Workload Manager[25]. It's found that several methods of workload measurement are used.

- External situation assessment
- Driver Physical Condition
- Driver's motions (eyes and hands)
- Driver's voice

There's no clear evidence as to which method works best.

23 K. Brookhuis, 2001
24 http://prwire.com/cgi-bin/stories.pl?ACCT=104&STORY=/www/story/01-05-2004/0002083138&EDATE=
25 http://www.delphi.com/news/solutions/monthly/ms54500-09082005

Problems Regarding the Interface

The design of a user interface relies heavily on the underlying system. This system provides the interface with a challenge, namely to let the user cooperate with or use the system. The interaction between user and system involves different fields of science, which makes interface design a challenge. In order to assist the interface design, several guidelines are available.

Guidelines may be defined by governments, scientific institutes or manufacturers. Their contents may range from general guidelines to specific prescriptions for a certain product.

Several sets of guidelines have been found and investigated for use within this research. By analysing these guidelines it can be decided whether or not to use them, and where in the design process they should be used, thus preventing common interface design flaws.

European Statement of Principles

The European Statement of Principles on the Design of Human Machine Interaction[26] is a EU-wide set of guidelines composed by experts, supporting the eSafety[27] project. As the name implies, the principles stated in this document are to be used as guidelines, not strict regulations. Several chapters cover most aspects of HMI design, from installation and design to usage and safety. Most of the guidelines are too generic to use directly during the design stage.

However, they could help pointing out areas of attention otherwise forgotten. For this research, most relevant chapters are chapter 3 through 5, covering “Information presentation principles”, “Principles on interaction with displays and controls” and “System behaviour principles” respectively. The guidelines apply to in-car information systems, which means they can't be applied to ADAS without further investigation.

EsoP Revision

The eSafety HMI workgroup also noticed the generic character of the EsoP, and proposed several important changes. On the whole, changes make the guidelines more specific by adding ISO regulations, and by addressing guidelines to specific stakeholders. The revision proposal document repeats the importance of differentiating between 'normal' information systems like navigational aids and ADAS. For the research in hand, (revised) guidelines from the EsoP can be used but should be checked for relevance with respect to ADAS.

US Statement of Principles

In the United States, a similar statement of principles is available[28]. The statement includes roughly the same chapters and topics as the EsoP, but contains more specifications. Though interesting to compare, it's decided to stick to the European revised statement. The revised European statement contains almost the same guidelines, with similar specifications.

General Interface Guidelines

Besides the mentioned guidelines, guidelines regarding automotive interface or general human machine interfaces are available. These guidelines contain more specified guidelines regarding the use of colour, shape and buttons compared to the other guidelines. A summary of such HMI/UI guidelines is presented in Appendix 4.

The further use of these guidelines will be discussed in the next paragraph.

26 EsoP, 2001
27 See Chapter 1
28 Alliance of Automobile Manufacturers, Report v 2.0, April 2002

2.3 Design Consequences

After describing the known problems with system and concept design, it should be decided how to prevent these problems from occurring.

ADAS Introduction & Acceptance

The first problem, regarding introduction and acceptance, has no direct consequences. As the projects aims at 2020, problems with introduction are beyond the scope of this research. It's presumed that most introductory problems as well as acceptance problems occur during the first few years of ADAS implementation. The analysis of this problem does point out another important aspect of ADAS. The way in which ADAS intervenes with the driving task turns out to play an important role in getting people to use the system. It's found that most people aren't willing to hand over control completely, with the exception of emergency situations. This aspect should be taken in account during system design.

Negative Behavioural Changes

The second problem, regarding negative behavioural changes, can be dealt with by deriving system design requirements from the problem description. For example, the problem description states that over-reliance may cause unsafe use of the system. A derived requirement would be to let the system always show its functional limits. The following list shows which requirements have been derived from the problem description.

- The ADAS system should not change the behaviour of the vehicle significantly, unless necessary
- The ADAS system should cooperate with non-assisted vehicles
- The ADAS system should intelligently adapt to the driver's character, within safety limits

These requirements should be incorporated in the general system requirements, which will be defined in a later stage of the design.

Workload/ Driving Task Effects

The problem considering workload and driving task is very relevant. Current research usually discusses a situation where there's a primary task (i.e. driving) combined with secondary tasks like using an in-car phone, or operating in-car computers[29]. The general conclusion of this literature is that multitasking doesn't promote safety. So the way ADAS is implemented affects the driver workload. In contrary to phones and navigation systems, ADAS shouldn't be implemented as an 'additional system' but rather as a background primary safety system. This prevents ADAS from taking up even more driver attention, as ADAS becomes part of the driving task.

Though playing a background role, the ADAS system should be visually present and available for input and output. This way the driver may also decide to let ADAS take a more controlling role, leaving time available for secondary systems. For example, when the phone rings, and the driver decides to answer it ADAS may take over lateral vehicle control to increase safety.

Interface Consequences

The presented interface guidelines differ in their applicability for this research.

The revised EsoP contains a valuable list of aspects that may otherwise be overlooked during the design. However, using this list in the early stage of design is useless, as there is no clear vision of what the system should do exactly. Therefore it's decided to use the revised EsoP as a set of evaluation aspects. By evaluating early stage concepts, forgotten aspects can be added, while other aspects may be improved.

The general interface guidelines regarding the use of colours, shapes and different modalities will be used after global interface concepts have been designed. At that stage it's clear which concept is going to use which modality, and which interface guidelines apply. As the concepts evolve, the guidelines can be used to further detail the design of displays, sound messages, etcetera.

So on the whole, the guidelines will be used in the later stage of development, where they may serve as design evaluation methods, and assist in further designing concepts.

29 P. Green, 2004

2.4 Design Approach

Now that the research area and the problematic aspects of ADAS design have been discussed, a design approach can be defined. The results of the previous paragraphs will be considered during the phrasing of this design approach.

As said, the research area contains two major parts, the system design and the interface design. The design approach however, will combine these two aspects in a single approach. As a basis of this approach, an existing method called the RESPONSE Checklist is used.

RESPONSE Checklist

The RESPONSE Checklist[30] is meant to be used in the early design stage, and aims to design with a user-centred approach. The checklist contains an A-part, which should lead to a detailed system specification. In this section, a standard design approach is described, from user analysis to system requirements. Part B of the checklist consists of a set of questions, meant to evaluate the resulting system.

Part A

The list describes a standard systematic design approach, starting with user definition and requirements (I/II), to system functions (III/V) and specifications (VI/XII). The following table presents all the covered aspects of the RESPONSE Checklist, part A.

I. System Users	VII. Compliance to Standards and Traffic Law
II. Encountered User Need	VIII. Situational Boundaries
III. Supported Task	IX. System Failures
IV. Functional Description	X. Product Information
V. Level of Automation	XI. Maintenance
VI. Human Machine Interface	XII. System Price

Table 2: Part A of the Response Checklist

Because of time restrictions and lack of relevance, certain aspects can be omitted. Only items in bold type will be taken into account, because of the following reasons.

The first four steps (I/IV) are necessary to define at least a basic system, which is required to reach the goal of this research. This includes the definition of users, their needs, as well as the task and functions the system is supposed to carry out.

The relevance of the level of automation (V) was already mentioned in the previous paragraph, and should be taken into the design approach. However, it's found unnecessary to point out 'Level of Automation' as a separate design aspect. Therefore it's decided that this aspect should be added to the 'Functional Description'.

The Human Machine Interface design (VI) concerns the design of the interface, and obviously very important for this research.

The other aspects, (VII/XII) are less important, as they do not significantly affect the main goal of this research, which is to design an ADAS interface. Their influence is too marginal, so available time will be spent on the more important aspects.

30 M. Kopf, P. Allen et al, RESPONSE Checklist, 1999

Part B

After filling out Part A of the checklist, a system specification is at hand. The (theoretical) effects of this specification can be evaluated. The list provides a collection of 'evaluation concepts', by means of which the system should be evaluated. As with part A, certain evaluation concepts can be omitted due to time restrictions or relevance[31].

1. Perceptibility	9. Driving Economy
2. Comprehensibility	10. Workload/Fatigue
3. Learnability	11. Vigilance
4. Predictability	12. Error Robustness
5. Controllability	13. Emotional Issues
6. Behavioural Change	14. Trust
7. Microscopic Traffic Safety	15. Responsibility
8. Macroscopic Traffic Effects	16. Driving Efficiency

Table 3 - Part B of the Response Checklist

A selection of relevant evaluation concepts can be used to find relevant questions in Part B of the checklist. This is done using a matrix system with questions vertical, and evaluation concepts horizontal. This method is used and described in Chapter 5, where the resulting ADAS concept is evaluated with the help of the checklist part B.

31 This will be explained in the system evaluation presented in Chapter 5

Design Approach

The selected aspects of the Checklist part A are used to set up the final design approach. It's decided to divide the design approach into three phases.

The first phase covers the user analysis, where users and user needs are defined. The 'System Users' and 'Encountered User Need' aspects of the Checklist are implemented here.

The next phase uses the results of phase 1 to decide which systems are needed to fulfil the needs of users. This phase includes aspects 'Supported Task', 'Functional Description' and 'Level of Automation' of the Checklist.

Phase 3 concerns the development and design of a user interface.

Phase 4 concludes the approach with an evaluation of both the system concept and the interface concept. Part B of the Checklist can be used for this purpose. Also, the guidelines mentioned in 2.3 can be applied in this stage of the design.

1. User Analysis

I. System Users

II. Encountered User Need

2. Systems Definition

III. Supported Task

IV. Functional Description

3. Interface Design

VI. Human Machine Interface

4. System s Evaluation

This approach will be applied in the following chapters. The following diagram graphically describes the design approach, and will be used to indicate which phase of the design approach is being discussed. The objected goal of each phase is presented below the black arrows.

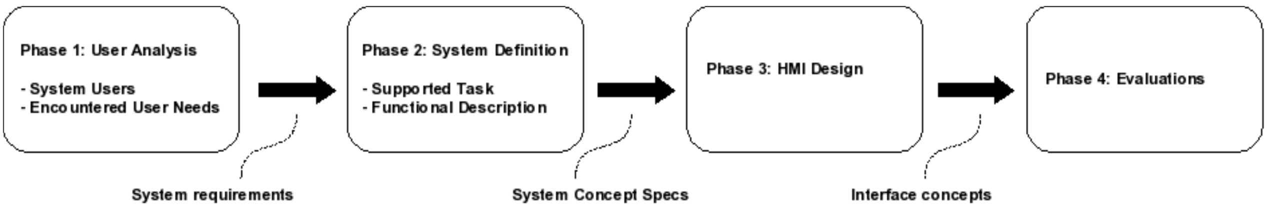


Fig 5: Graphical presentation of the design approach

2.5 Conclusions

The goal of this chapter was to define a design approach. The first step towards an approach was to define a research area, indicating the goal of the approach. It's been found necessary to design both a global *system concept* and an *interface concept*. The system concept is required for the proper design of an interface.

For the system concept, problems regarding the following are expected.

- Problems with introduction and acceptance, which are considered to be less relevant for the 2020 future of this project. However, the fact that 'level of automation' influences the acceptance of an ADAS system is pointed out as important.
- Negative Behavioural Changes are expected to appear after the introduction of ADAS. These changes have been analysed, and will be taken into account later on.
- Workload and driving task related problems; It's concluded that the role of ADAS in future cars should be so that ADAS takes a background safety role, not requiring active driver attention. A so called *"workload manager"* should be further developed to control the workload of the Car of the Future.

For interface design, it was found that problems may be prevented by designing according to the appropriate guidelines. Several guidelines have been discussed, and it's decided to use them during a later stage of the design, to assist in evaluating the concepts.

The problems regarding the system concept, as listed above, have their consequences on the design and the design approach.

- The 'level of automation' issue was made part of the 'Functional Description' in the design approach. This means that the system concept requires a function that fulfils the driver's requirements regarding the level of automation.
- The 'negative behavioural changes' issue was translated into a set of preliminary system requirements.
  - The ADAS system should not change the behaviour of the vehicle significantly, unless necessary
  - The ADAS system should cooperate with non-assisted vehicles
  - The ADAS system should intelligently adapt to the driver's character, within safety limits
- The workload management problem is to be solved by integrating a workload manager into the system. Also, the role of ADAS within the vehicle has been defined in such a way that ADAS won't negatively influence the driving task.

After the discussion of these problems, a design approach for a global ADAS concept is proposed. For the approach the RESPONE checklist has been found fit for this purpose. Though some items have been left out, the main route of the checklist will be used in this project.

1. User Analysis
2. Systems Definition
3. Interface Design
4. Systems Evaluation

The next chapter will deal with phase 1 and 2 of this approach. The interface design and systems evaluation will be discussed in later chapters.

3. System Concept

This chapter deals with the first two phases of the design approach, the 'User Analysis´ and 'System Definition'. The user analysis involves the definition of users and their needs. This results in a set of system requirements.

The system requirements are used in the next phase, the 'System Definition'. In this phase, the requirements are used to determine which part of the driving task is to be supported by the system concept. A functional description will then define which functions are needed to perform that task, and which components may carry out those functions.

Phase 1 and 2 are presented in the diagram below, along with their objected results, indicated below the black arrows.

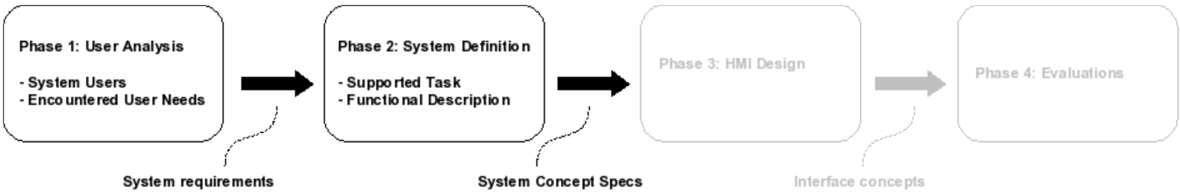


Fig 6: Phase 1 and Phase 2 of the design approach

3.1 User Analysis

The goal of the user analysis is to determine who the future system users are, and which requirements they have regarding the use of the system. The next paragraph will define the future user, and determine their needs. The 'Encountered User Needs' will translate the user needs into the objected system requirements.

System Users

Users are normally defined by concrete parameters such as income, age and sex. Based on these parameters user requirements are phrased. The Car of the Future project however, does not directly define a target group or users. Instead, a vision driven design approach is used. The Car of the Future vision contains assumptions and expectations with respect to the society, economy and mobility of 2020. So, an alternative approach is used to find the requirements.

Instead of looking for concrete user parameters, sources will be used to describe user *characteristics.* User characteristics will result in requirements and finally system specifications. The most relevant sources are literature (as used in chapter 1), the stakeholders opinions and the Nexus project vision. The following paragraphs will use these sources to extract concrete requirements .

Source I: Literature

In literature the following characteristics and requirements were already mentioned.

1. Users give priority to safety oriented ADAS[32]
2. Users are not willing to give away full control to ADAS[33]
3. Mobility users will include more older people[34]
4. Mobility users will include more females compared to present situation[35]

Table 4: User requirements and characteristics based on literature

32 See “Known Problems”, regarding “ADAS Introduction and Acceptance” on page 15
33 See “Known Problems”, regarding “ADAS Introduction and Acceptance” on page 15
34 See “Known Problems”, regarding “ADAS Introduction and Acceptance” on page 15
35 “Traffic & Water Management, 'Traveller of the Future' ”

These concluding requirements are the result of current research, and apply to a 'general public'. The objected user group of the Car of the Future is part of the general public, so these characteristics can be added to the total user image. Other findings from literature turn out to correspond to the ones found in the Nexus vision.

Source II: Nexus Vision

The vision of the Nexus project group is a wide perspective view on the 2020 future. It not only describes future mobility, but also links it to economy and society. The vision is to fit in a domain defined by the following restrictions.

- Time frame: 2020
- Initial location: Netherlands, Europe
- Using (adapted) current infrastructure
- Aiming at a sustainable solution

People in 2020 will use more means of communications in their social network. Due to modern communication, geographical boundaries will more or less disappear. More communication leads to bigger social networks. As 'personal contact' is still considered the highest form of interaction, people are expected to become more mobile as well as more individually oriented.

Both governments and consumers will recognise the shortage of resources. Sustainability is expected to become more (economically) attractive. An important shift from 'owning' to 'using' is foreseen. Other economic developments include the increasing use of external labour. In Europe, an increase of 'dedicated jobs' will be the result. People need to show their skills and abilities in order to be noticed. The Car of the Future is expected to help getting noticed. Another result is the need for people to be flexible and adaptable.

The car of the future is described as 'icon'. This means it should make distance irrelevant by absorbing the driver's attention. The car should also be an 'extended home', reflecting the user's abilities, skills, demands, etc. Social and economic aspects have changed the way people look at cars, and the car of the future should adapt to this change.

From these rather vague vision statements several user characteristics can be extracted. The following selection is considered relevant for the ADAS concept.

1. Users want to communicate
2. Users want to be mobile
3. Users become more individual
4. Users are interested in sustainability
5. Users are flexible and adaptable
6. Users want their car to be a reflection of themselves

Table 5: User requirements and characteristics based on the Nexus vision

Source III: Stakeholders

The Car of the Future project is affected by many stakeholders. Each stakeholder has its own preferences and requirements, priorities and influence. Several needs can be fulfilled by ADAS solutions. These needs are Safety, Comfort, Efficiency and Emotional Value, or combinations of those. Listing stakeholders and their needs will determine the 'character' of the concept. The following table lists all stakeholders, and their position with respect to ADAS.

The first column indicates the status of a stakeholder, divided into A, B and C-categories. Important and/or direct stakeholders are category A, irrelevant stakeholders are category C. The government, a B-category stakeholder, is most relevant during the introduction phase of ADAS. As this indirectly affects the 2020 future, this stakeholder is found relevant enough to be taken in to account.

	Stakeholder	Position
A	User	Users are willing to use the ADAS system. Safety is considered a priority reason for this, but shifts to comfort are expected as well, as safety becomes more and more 'standard'.
A	Non-user	Non users drive conventional cars, and are not willing or not able to use ADAS. This *could* have a negative effect on safety, and positive effects on emotional value, as there's always a need to distinguish among either users or non-users.
A	Nexus	Nexus' main concern is that the ADAS fits within their vision. Therefore it should have a positive appeal on the users emotional values.
A	SNE	SNE's main concern is sustainability. ADAS must have a positive effect on sustainability. Also, by positively affecting emotional values, marketing aspects for the car in general can be improved.
B	Government	During ADAS introduction, the government is expected to have positive influence on safety aspects. This results in positive influence on comfort, caused by shifting needs from safety to comfort.
C	Car manufacturers	Car manufacturers are only relevant during the production stage of this concept. The design process should take production aspects in account, but this does not affect any of the aspects mentioned directly.
C	Car salesmen	Car sales men do not affect the aspects directly, as they are expected to sell (or lease, according to the Nexus vision) whatever there's available/needed at the market.
A	Technology R&D	Technology R&D influences the character of the concept, because they provide the needed technology. Current developments tend to support safety. Comfort is also covered, but not by ADAS technology.

Table 6: Stakeholders and their position

The following table gives an overview of relevant stakeholders and their positive or negative influence on the concept character aspects.

Stakeholder	Safety	Comfort	Efficiency	Emotional Value
User	++	+		
Non-user	-	-		+
Nexus		+		++
SNE			++	+
Government	++	+		
Technology R&D	++	+		

Table 7: Stakeholders and their influences

It's shown that safety is a priority requirement, required by both users and government. Efficiency is only required by SNE, but should deserve more attention during the design phase, as SNE is a key stakeholder in this project.

Encountered User Needs

In the previous paragraph the characteristics of future users have been used to determine their needs and requirements.

Safety was more than once mentioned as an important aspect of ADAS. This requirement was also emphasised by the literature discussed in chapters 1 and 2.

The Nexus vision is treated as an important supplier of needs, so the needs for adaptability, flexibility and sustainability will also be taken in to account. Requirements like 'individuality' are harder to implement, nevertheless they should be remembered.

The following table presents the resulting set of requirements, to which the system concept is supposed to comply. In addition to the requirements derived from user needs, the table also includes the requirements proposed in chapter 2.

Requirement	***Requirement specification***
Provide Safety	The system should enhance the safety of the vehicle, within the limits of the project
	The system should not change the behaviour of the vehicle significantly, unless necessary
	The system should cooperate with non-assisted vehicles
	The system should support communications between users and vehicles
Provide Control	The system should let the user control ADAS influence
	The system should be adaptable by the user
Support Usability	The system should intelligently adapt to the driver's character, within safety limits
	The system should support drivers of all ages, within legal limits
	The system should support information and entertainment systems
	The system should support sustainability

Table 8: The system requirements, based on user needs

It should be noted that this table of requirements lists requirements for the global system. Some of these requirements apply to the *system concept*, while others apply to the *interface concept*.

This concludes the user analysis. It's been investigated who the future users of the system will be, and what their needs and requirements regarding ADAS are. The list of requirements can assist with the further definition of the system.

The following paragraph discusses the possibilities of the system concept, investigating which requirements can be fulfilled by the system concept. After this paragraph a reflection of requirements will be presented, giving feedback on how the system concept tries to fulfil requirements.

3.2 System Definition

As stated in the design approach., the system definition includes two aspects.

First, the ***'supported task'*** is to be investigated. This involves describing how the system should support the driver with his driving task. Needs and requirements, as presented in the user analysis, are used to determine which tasks should be supported, and when.

After defining this supporting task, the required systems need to be found, which is the goal of the ***functional description***.

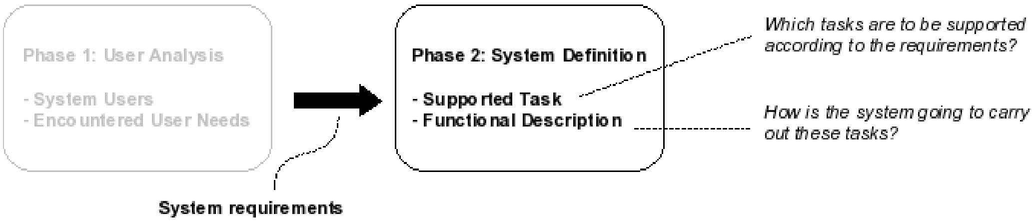


Fig 7: Phase 2, describing the system definition

Supported Task

One of the system requirements is to provide safety. Theoretically, stuffing the vehicle with control-computers may maximise traffic safety. However, this doesn't comply with the requirement of limited driving interference. There's a tension between fully automating a vehicle, and leaving control with the driver.

An aspect that adds to this tension is the variety of potential users. As stated above, the system should be usable for drivers of all ages. Users may vary from housewives to young businessmen. A proposed solution to this problem is to make the system adapt itself, based on the driver's characteristics. A certain amount of intelligence is required to achieve this. The system should be able to assess the driving capabilities and preferences of the driver, or should be able to get used to them. With that knowledge of the driver, the system can provide a specific way of support fitting the driver's needs.

For example, someone may generally drive perfectly by the rules, but has a tendency to keep insufficient distance to cars in front. The system should notice this and inform or assist the driver. After a while, the support and information should decrease, in order to see whether the driver has learnt from it or not. If not, the system will regain support.

Overall, this means the system provides intelligent and adaptive, yet passive task support. At no point should the driver feel too much controlled or watched. The system should assist and support when necessary or preferred.

If the driver activates an autonomous function of the system, such as car following or lane keeping, the driver should constantly be informed about the fact that this system is working. Whether or not the driver is informed about the actions of the system depends on preferences, but at least the activation of the system should be indicated. Also, in case of problems, required intervention or deactivation the driver must be informed about this.

To implement this dynamic task support in the ADAS concept, it's decided to use so called system states.

System States

System states offer selected 'modes' of operations, each mode with its own characteristics. For this system, it's decided to use three main states, each one representing a certain amount of task support. The first state offers minimal support, and support increases as the level of state increases, as explained in the following state definitions.

State 1 - Informing

In state 1 the driver has complete vehicle control. The system will only *inform* the driver about unsafe situations, by warning and by giving safety advice. ADAS systems will only take over control in case of emergencies, like emergency brake situations, or when the driver is unable to respond.

State 2 – Assisting

In addition to the informing character of state 1, in state 2 the system *assists* the driver in driving more safely by correcting the steering wheel, throttle and brake systems. This state represents a midway between the current way of driving and autonomous driving.

State 3 – Controlling

This state is the autonomous driving state. Here the driver can let go the steering wheel and gas pedal, while lane keeping and throttle control systems take over. This state is only available under certain conditions. If it's not safe to drive autonomously, or even impossible, the system will indicate so.

Failure and Deactivation

The other two states are “Off” and “Failure”. In the “Off” state, the ADAS systems have been deactivated. This mode enables the driver to deactivate the entire system, or subsystems in case of failure or annoyance. For example, in urban environments certain ADAS may annoy the driver by causing too many false alarms.

The failure state is a system mode which can't be activated by the user, but is used whenever (critical) systems fail. The situation will be analysed and actions taken accordingly. The driver will be informed through interface output.

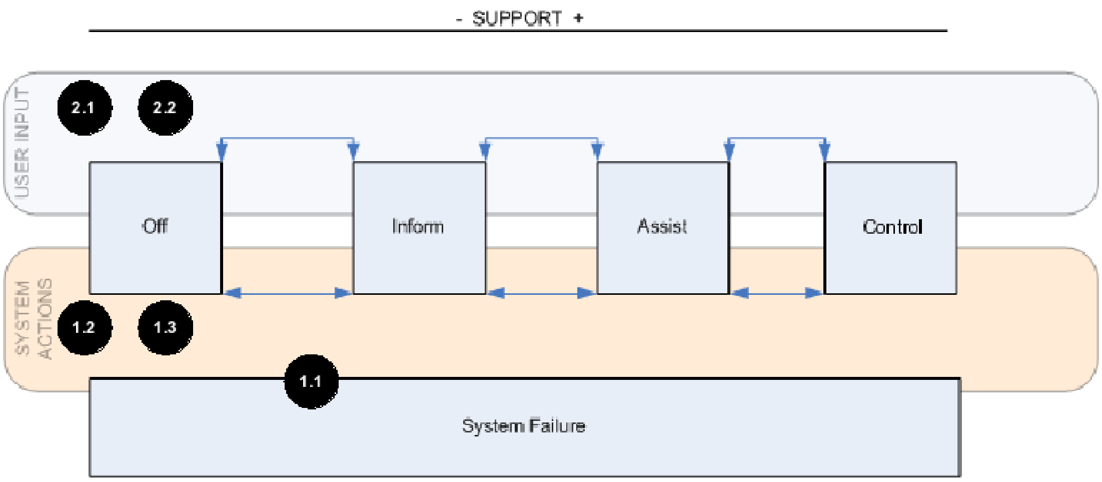


Fig 8: The system state diagram graphically presents the available states

State Transitions

Each state has a specific amount of active systems, providing a specific amount of support. As the state transition diagram shows (Fig. 4), transitions between the system states may either be caused by the system ('system actions') or by the user ('user input').

Transitions initiated by System

The system may initiate state transitions because of one of the following reasons.

1.1. *System failure* - If (essential) systems fail, the *failure state* should be accessed. In this mode the driver will be informed about malfunctions, and advised about what to do.

1.2. *Driver Attention problem* – Whenever the system detects a problem with driver attention, the amount of support increases, but only after asking the driver for confirmation. If a driver does not respond to a request, it's assumed necessary to intervene by increasing support. *(Shift to the left in the diagram)*

1.3. *Traffic Situation* – By using sensor input, the system can assess traffic situations, and determine whether it's needed to offer the driver additional support, for example, intersection support or cruise control. *(Shift to the left or right in the diagram)*

Transitions initiated by User

The driver may initiate state transitions because of one of the following reasons.

2.1 *Preferences* – If desired, the driver can hand over control to the system, leaving the driver with more time and attention for secondary tasks. Whether it's safe to take over control or not is up to the system to decide, based on traffic assessment. *(Shift to the left or right in the diagram)*

2.2 *General lack of driver attention* may cause the system to start taking over control, as defined in the system initiated state changes. *(Shift to the left in the diagram)*

The states can be used to further define the system character. They've been described graphically in the diagrams below. Horizontally, the amount of system control is presented, and vertically user attention. State 1 would be the default status, positioned in the lower left quadrant.

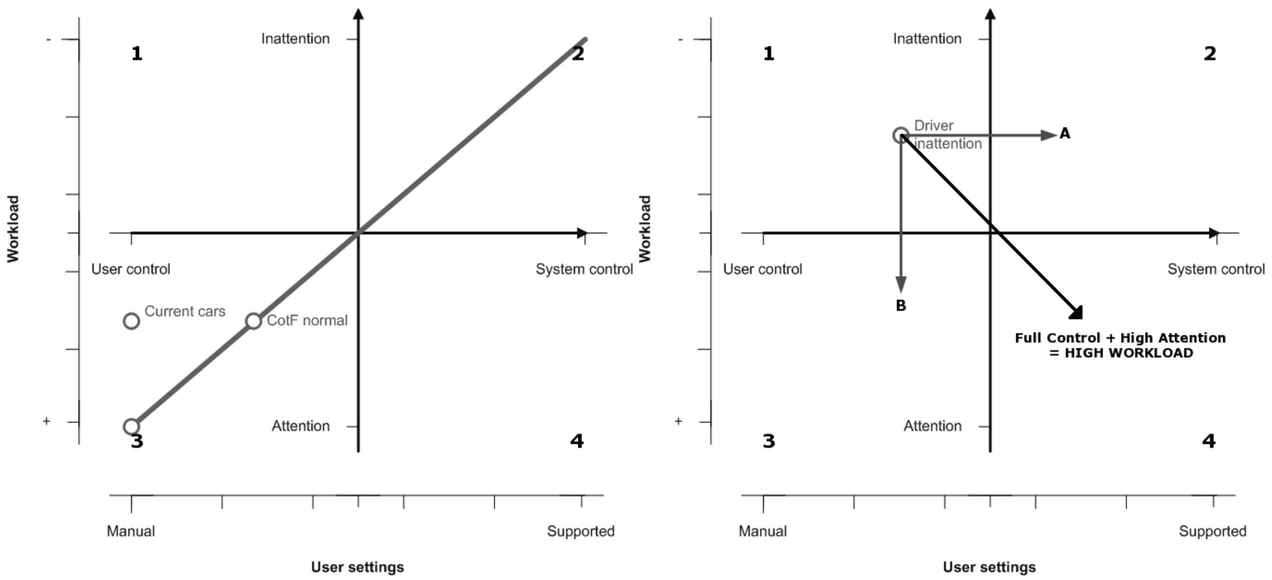


Fig 9: Graphical representations of system states (left) and state transitions (right)

The left diagram shows the system character of the Car of the Future in normal operation. The line indicates the preferred relation between driver attention and system support. If the driver is in control, system control should be minimal. With decreasing attention, system support should increase.

The right diagram shows an example of a state transition. At first, the attention of the driver is below usual value, while control is still in his hands (The circle in quadrant 1). The horizontal and vertical vectors indicate two available solutions. First, the system could take over control to regain safety (A). Second, user attention can be increased by following the vertical vector (B).

Choosing both solutions together , following the resultant vector, would end up in the fourth quadrant, which is not the best option as it may cause mental overload.

The definition of the system character and resulting system states provide additional system requirements. There's a need for both a driver assessment application and a traffic assessment application. The system needs to be able to see what the driver is doing, and assess the traffic situation.

Towards the Functional Description

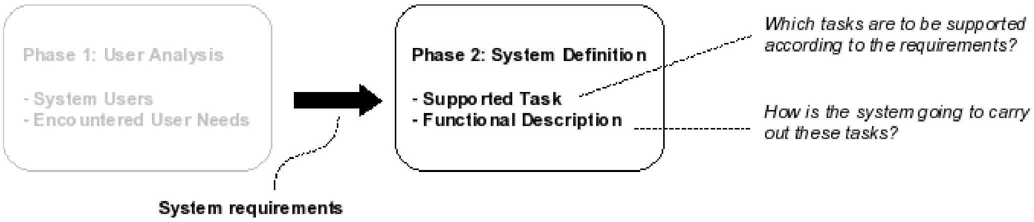


Fig 10: Phase 2, describing the system definition

The '*Supported Task*' paragraph found an answer to the question “Which tasks are to be supported according to the requirements”. According to the system requirements ,users want safety, while staying in control of the vehicle. This tension between safety and control was solved by introducing system states. System states offer layered amounts of safety and control, and are user selectable.

Now it's up to the '*Functional Description*' to find out which systems may be used to provide the required safety and control. This will be done in the next paragraph.

Functional Description

The goal of the functional description is to determine which ADAS systems may fulfil the requirements and allow the task support defined in the previous paragraphs. A first step towards reaching this goal is to determine which systems are available around 2020.

Available Systems

To assess the availability of ADAS systems in 2020, a roadmap is sketched. The roadmap indicates which technologies are available within a certain period of time. Certain factors may influence the way in which ADAS may develop over the next few years, as listed below.

- Introduction & Acceptance, method of implementation
- The merging of intelligent traffic with 'normal' traffic
- Law may prevent ADAS from operating optimally

The resulting roadmap is based on the findings from chapter 1 and 2 as well as other ADAS road maps[36, 37]. The use of literature should increase the feasibility of the roadmap. Still, the following assumptions have been used during the making of the roadmap.

- Introduction and acceptance problems are limited due to the step-by-step introduction of ADAS
- ADAS systems are implemented as visible applications[38]
- Law is assumed to be adapted in favour of ADAS

As part of the integration aspect of this project, the roadmap also covers developments of information and entertainment systems. This table shows a basic roadmap. An extended version is presented in Appendix 1.

Time frame	*ADAS*	*Information*	*Entertainment*
2006-2010	- Use of ACC and ISA increase - ISA obligated in urban areas - Introduction of LDW in production cars	- Navigation systems on PDA's - Traffic information over radio	- Car radio, CD players, capabilities for mp3 playback, connection to mobile devices
2010-2015	- ACC advances to ACC+, longitudinal support advances (FCW) - Communications are advancing - Law adapts to allow ACC+ - LDW and other lateral support systems advance and become common	- Integrated navigation systems with traffic information systems - Higher level of information exchange through new communication methods	- Internet connectivity, improved ADAS provides more opportunities for multimedia, like DVD's and others
2015-2020	- Longitudinal and lateral support integrate - Car -to-car and car-to-infrastructure communications - Law adapted to allow these applications - Combination of assisted and non-assisted cars	- Information and navigation systems are linked to car control systems to provide a more integrated system.	- Autonomous driving provides even more opportunities for multimedia

Table 9: A basic ADAS roadmap from 2006 to 2020

36 http://www.publications.parliament.uk/pa/cm200304/cmselect/cmtran/319/319we47.htm
37 D. Ehmanns & H. Spannheimer, RESPONSE "Roadmap", July 2004
38 Instead of being implemented as invisible applications, like ABS and ESP

The ADAS roadmap points out the expected available ADAS systems in 2020. These include longitudinal control and support systems like FCW, ISA and ACC, and lateral control systems like LDW, LKS and LCA. So which of these systems are to be used in the Car of the Future system concept?

Looking at the functional system requirements, it would be best to use all of the systems mentioned above in order to provide a maximum safety enhancement. In combination with the 'system states' this would provide an adaptable yet safe system to the user. However, restrictions should be taken in to account. The sustainability requirement may prevent certain systems from being used, as they decrease the sustainability aspects of the design because of high power usage.

Therefore the available systems need to be analysed to determine which task they fulfil, which functions they offer to do so, and what their component characteristics are.

System Analysis

A system analysis of ADAS and their components will give insights into their (sub) functionality and architecture. The analysis covers the following aspects.

1. A task analysis defines which part of the driving task is taken over by the ADAS. These tasks are divided into three main categories, being Stabilising, Manoeuvring and Navigating. This analysis helps to find the system functions.
2. A function analysis defines how the tasks (as mentioned above) are going to be executed by the system. A system may have one or more main functions, each one containing one or more sub functions.
3. A system outline shows all functions and sub functions of the system are drawn together in a diagram, indicating interactions between functions. The system outline gives an overview of the general working of the particular ADAS.
4. A component overview describes the actual realisation of system functions.

This analysis was carried out for all available systems, based on the roadmap outcomes, which are ACC, FCW, ISA, and lateral systems[39].

The main outcome of this series of analysis is a set of system functions. For every ADAS system, these functions can be used for either input, processing or output/reaction purposes. For example, an ACC system uses the functions listed in the second left column for input, processing and output.

	ADAS Systems and their functions				
	ACC	*LDW/LKS*	*ISA*	*FCW*	*LCA*
Input	Scan road Detect vehicles	Scan road Detect markings	Detect speed limit Detect current speed	Scan road Detect obstacles	Scan rear road Detect vehicles
Processing	Determine vehicle speed Determine local speed Calculate braking time Calculate following distance Acquire interface input	Predict path Detect deviations Calculate corrections Acquire interface input	Determine action Acquire interface input	Identify obstacles Determine action Acquire interface input	Determine risk Acquire interface input
Output	Provide interface output Apply brake Apply gear Apply throttle	Provide interface output Apply brake Alter steering	Provide interface output Apply brake Apply throttle	Provide interface output Apply brake Apply gear Apply throttle	Provide interface output Apply brake Apply steering

Table 10: An overview of ADAS systems and their functions

39 See Appendix 2

Several conclusions can be drawn from the table.

1. The system requires a connection to mechanical vehicle components. The throttle, gear, brake and steering wheel need to be controllable by the ADAS system. Also, systems like ISA require a connection to the speedometer.
2. Each ADAS system requires a user interface for both the input and the output of information. This is important to consider for the future interface design, as presented in chapter 4.
3. The system may use a single processing unit (CPU) to take care of all processing functions. A graphical processing unit is required for the processing of visual information.
4. An integration challenge can be found in the 'input' row of the table. The functions mentioned in this row are currently carried out by different sensors, so it's useful to see whether it's possible to use a single sensor for multiple purposes.

The first three conclusions result in clear concept requirements. They state that the concept should contain a CPU, a user interface and an interface to mechanical components. The fourth conclusion from the list will be clarified further below.

Sensor Selection

The upper row of the table indicates which functions are used as input for the ADAS systems. In order to design an integrated ADAS system, these functions need to be investigated for integration possibilities. The upper row shows that the forward 'scan road' function is used by four systems, namely ACC, FCW and LDW/LKS.

ACC	*LDW/LKS*	*ISA*	*FCW*	*LCA*
Scan road Detect vehicles	**Scan road** Detect markings	Detect speed limit Detect current speed	**Scan road** Detect obstacles	Scan rear road Detect vehicles

Table 11: Integrating system functions

Designing a new sensor that would fulfil the 'scan road' function for each of these ADAS systems is beyond the scope of this research. Therefore, existing and commonly used sensors have been investigated, as shown in the system analysis in Appendix 2.

It's concluded that the ACC and FCW systems can use the same forward looking 24 GHz radar. This radar will also provide backup for the LDW/LKS system, whose main sensor source will be a forward looking camera.

The LCA system has less integration possibilities, as it uses rear sensor systems instead of the forward looking radar and camera. Therefore it's decided that the LCA uses its own set of rear 24 GHz radar components. Furthermore, a communication device is needed for ISA to receive the local speed limit.

The following table summarises the applied sensors and their properties.

Component	*Capabilities*	*Power Consumption*	*Volume*
Forward 24 GHz radar	Max. 240m, 15° x 10° scanning field	+- 10 Watt	Data not available
Rear 24 GHz radar	Max. 15m, 30° scanning field	+- 3 Watt	60x45x30 mm³
Forward camera	Max. 30m, max 30° x -14° to 29° visual coverage	+- 7 Watt	200x100x50 mm³

Table 12: Sensor properties

Sensor Implementation

The implementation of the sensors results in two ways of task support. Firstly, there is longitudinal task support. Secondly, the system provides lateral task support. The new functions of the system concept have been correlated with these tasks so that the concept fulfils the tasks using functions as listed in the table below.

Longitudinal Functions		***Lateral Functions***	
Task	***Functions***	***Task***	***Functions***
Vehicle & Obstacle detection	Scan Road	Lane Tracking	Scan Road
Vehicle Tracking	Detect vehicle position Detect vehicle speed Detect vehicle distance Control Adjustments Warn HMI	Lane keeping/Warning	Detect markings Detect deviations Determine corrections Control Adjustments Warn HMI
Obstacle Avoidance	Detect obstacle position Warn HMI Control Adjustments	Rear Vehicle Detection	Scan read road Detect vehicle position Detect vehicle speed Control Adjustments Warn HMI
Speed Limit Detection	Detect speed limit Control Adjustments Warn HMI		

Table 13: Functionality of the system concept

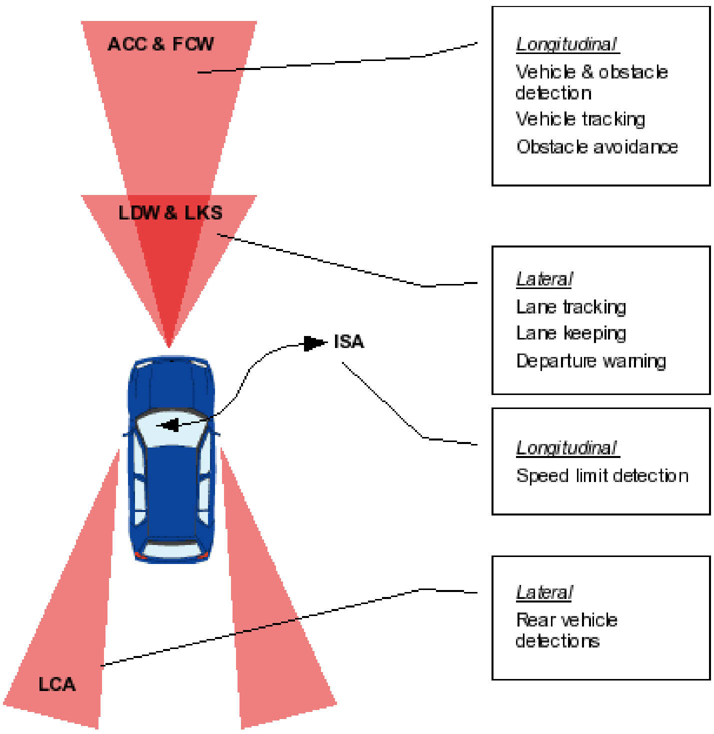


Fig 11: Graphical representation of the system functionality

3.3 System Concept

With the *functional description* concluded, it's possible to compose a final system concept. The functional description provides a set of conclusions that indicates which system components are required, besides the obvious sensors. These conclusions have been summarised and listed below.

1. The system requires a connection to mechanical vehicle components.
2. Each ADAS system requires a user interface for both input and output of information
3. The system may use a single processing unit (CPU) to take care of all the processing functions
4. The system uses a forward radar, forward camera, communication device and two rear radar systems as sensor devices[40]

Furthermore, Chapter 2 mentioned the need for a workload manager application, so this component should also be integrated with the system concept. The full design of a workload manager is beyond the scope of this research. However, a first step in the design of such a system has been included in Appendix 7.

Subsystems

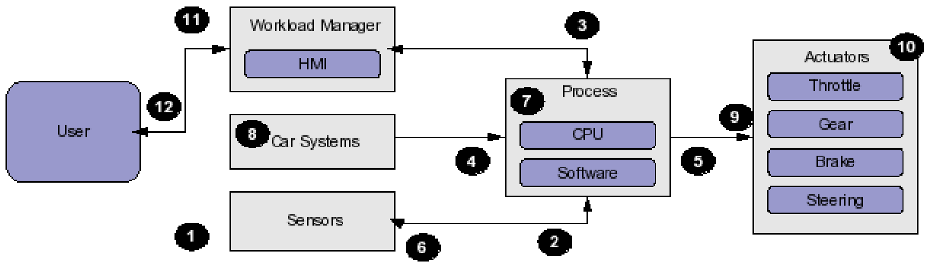
Based on these conclusions, several subsystems have been defined. The subsystems represent a group of components with a specific task or function. Besides the sensor subsystem, which has already been described in the functional description, the following subsystems are used.

- *Actuators* - Actuators directly control car components like steering, throttle and gear. For ADAS to operate, throttle, gear and steering should be controllable by those actuators[41]. Current engines are already fitted with computer control, and actuated steering shouldn't be a problem either.
- *CPU* - The CPU should be able to process constant real-time information, provided by sensors and car input devices. Furthermore, it may be necessary to use a specific graphical processing unit (GPU) for the forward looking camera device.
- *HMI/Workload Manager* - The workload manager needs to assess both the internal and external situation of the vehicle. The external situation can be received through the existing sensors, supported by car-to-car and car-to-infrastructure communications. The internal (workload) assessment can be done by using speech input or by watching the driver through a camera device.
- *Car Systems* - Car systems provide the ADAS concept with information about the engine, its status, fuel status, possible failures, vehicle speed, etcetera.

In practice, the driver won't directly interact with these functions. However, the *results* of these functions are very important for the driver. The results of the functions are for example the ability to track a preceding vehicle, or to automatically change lanes. In other words, these functions define the final functionality of the system concept, which are the safety supporting tasks[42].

The table on the next page shows the subsystem layout and their interacting functions.

40 Conclusion 4 has been altered, based on the results of the 'Sensor Selection' in the preceding paragraph
41 See “System Analysis” on page 32
42 See Table 13: Functionality of the system concept



Subsystem	***Functions***	***Sub Functions***
SENSORS	1. Receive sensor input	Receive forward radar image Receive forward camera image Receive speed limit Receive rear radar image
	2. Link to CPU	Send sensor input to CPU
CPU	3. Link to HMI	Receive input from HMI Send output to HMI
	4. Link to car systems	Receive input from car systems
	5. Link to actuators	Receive input from actuators Send output to actuators
	6. Link to sensors	Receive input from sensors
	7. Process	Process sensor input, car systems input, HMI input / output, actuators input/output, etcetera
CAR SYSTEMS	8. Provide input	Provide dynamics Provide engine status Provide fuel status Provide system status, etc.
ACTUATORS	9. Receive adjustments	Steering adjustments Throttle adjustments Gear changes Brake adjustments
	10. Actuate adjustments	Actuate steering Actuate throttle Actuate gear Actuate brake
WORKLOAD MANAGER/HMI	11. Receive user input	Receive vehicle controls Receive ADAS controls Receive other controls
	12. Provide user output	Provide ADAS output Provide vehicle systems output

Table 14: Subsystems and their appropriate functions and sub functions

Reflection of Requirements

The first paragraph of this chapter defined a list of requirements for the ADAS concept. After the detailed selection of systems and their properties, a short reflection of these requirements can be presented. The requirements have been listed in the table below, along with their implementation method in the system concept.

Requirement	Requirement specification	Implementation
Provide Safety	*The system should enhance the safety of the vehicle, within the limits of the project*	Longitudinal and lateral support functions
	The system should not change the behaviour of the vehicle significantly, unless necessary	The use of system states
	The system should cooperate with non-assisted vehicles	The system-concept is autonomous, operating independently from infrastructure
	The system should support communications between users and vehicles	The system uses a communication device for speed limit detection
Provide Control	*The system should let the user control ADAS influence*	HMI
	The system should be adaptable by the user	HMI
Support Usability	*The system should intelligently adapt to the driver's character, within safety limits*	System intelligence, HMI and workload manager
	The system should support drivers of all ages, within legal limits	HMI
	The system should support information and entertainment systems	HMI/Workload manager
	The system should support sustainability	The system uses several multifunctional components

Table 15: Requirements and implementations

The reflection of requirements shows how user requirements have been implemented in the system concept. The table also indicates which implementations are to be made through user interface design. These requirements should be taken into account in the next chapter.

3.4 Conclusions

This chapter describes the development of an integrated system concept for ADAS in 2020. It uses the design approach as described in Chapter 2.

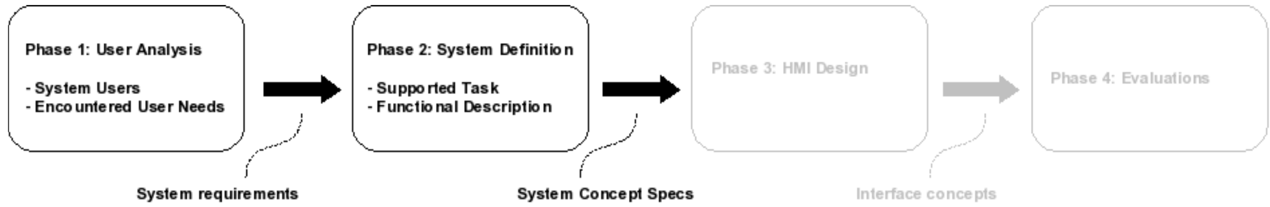


Fig 12: Phase 1 and 2 of the design approach

Phase 1 covered the *'user analysis'*. The goal of this phase is to acquire user needs to define system requirements. This was done using multiple sources, including the Nexus vision, literature and stakeholder analysis. The resulting requirements have been split in to functional requirements, usability requirements and package requirements.

The main functional requirement is that the system should improve safety. Usability requirements include the need for adaptability and system intelligence. Package requirements concern the sustainability and system integration aspect of the concept. These are the key requirements, other requirements have been listed in the table in paragraph 3.1.

The requirements that were defined in phase 1 are used in phase 2 (the *system definition)* to determine which part of the driving task is to be supported, and how to support it.

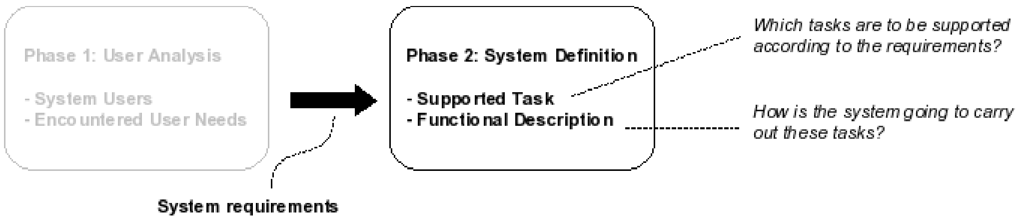


Fig 13: Phase 2, including 'supported task' and 'functional description'

It was found that the use of so called system states would result in a system that complies with the requirements. System states, drive-task support increasing with every next state, offer a flexible and adaptable system, which only support the driver if he wants to, or if necessary for traffic safety.

Next, the 'functional description' determined how the supported task was to be carried out. A first step towards a solution was the making of an ADAS roadmap. The roadmap indicated the expected availability of systems like ACC, FCW, ISA and LDW/LKS/LCA in the 2020 future.

These systems were analysed, determining their task support, functions and components. Their functions were put in a table, from which conclusions were drawn. These conclusions lead to the selection of components, which together formed the final ADAS system concept. The use of a forward looking camera, two radar systems and a communication device offers the user longitudinal control through ACC, FCW and ISA. Lateral control is provided by means of LDW, LCA and LKS.

Apart from the ADAS related components the system also uses a CPU, an interface for vehicle systems, an interface for vehicle actuators and a workload manager. The workload manager has been described more thoroughly because of the influence it has on the user interface.

The estimated power usage and physical properties of all these components are sufficiently low and small to justify the rather 'luxurious' collection of ADAS systems for a sustainable vehicle.

This chapter concludes phase 1 and phase 2 of the design approach. The result is a system concept, which consists of a set of specified components and their functionality. A user interface for this concept will be developed in phase 3, which is covered by the next chapter.

4. Interface Concept

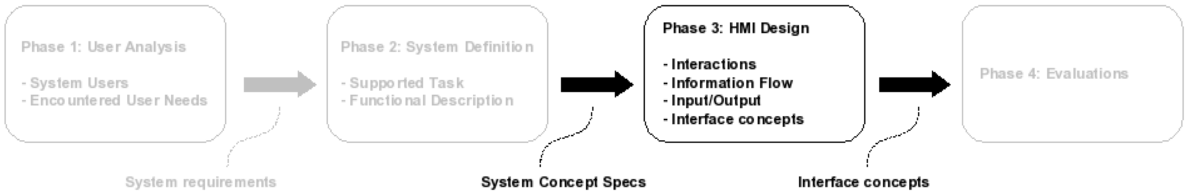


Fig 14: Phase 3 of the design process covers interactions, information flows, input/output and final concept design

The system concept specifications provide the starting point for the development of the interface concept. The goal of the interface design is to find a way to let the driver operate the system in a safe and effective way. The interaction between the driver and the vehicle will play a central role during the development of the interface.

Interactions between the user and the system (driver and vehicle) involve the input, processing and output of information flows. In order to design a safe and effective interface, all interaction aspects need to be investigated.

The first step is to further specify interactions within ADAS, using interaction diagrams. These diagrams will then be used to determine the information flows. In order to let the driver acquire and receive the information, input and output modalities also need to be investigated.

- *Paragraph 4.1 Define Interactions*
    - *Paragraph 4.2 Derive information flows*
    - *Paragraph 4.3 Derive input and output modalities*
- *Paragraph 4.4 Interface Concept design*

Combining the results of these investigations will result in a so called framework. The framework defines the underlying structure of the interface, for which external concepts can be designed. For this design, the HMI-specific requirements mentioned in Chapter 3 will be taken into account.

4.1 Interactions

As said in the introduction, interaction between the driver and the vehicle consists of the input, processing and output of information flows. Interactions are needed to perform the main driving task. The 'cruising' task for example involves observing preceding traffic, estimating following distance and speed, and applying the brake or throttle accordingly.

To further discuss ADAS related interactions, the interaction diagram shown below will be used. Each step of the interaction either requires or provides information. In normal circumstances, the driver will acquire information (observe, input), process it, and react accordingly (output).

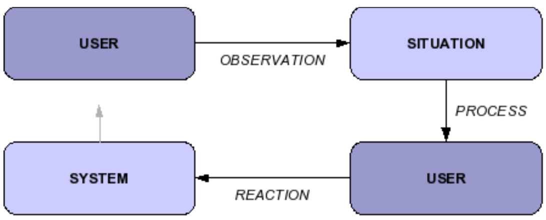


Fig 15: The extended system interaction diagram

Tasks & Interactions

After the definition of the interaction diagram, the next logical step would be to define the information flows of the interaction. However, the system states that are used in this concept cause some problems with that approach.

The effect of system state transitions on interactions is significant. Appendix 6 describes interaction diagrams for the three system states, in addition to the diagram presented above. Each state appears to require and provide different amounts of information, depending on *who's performing the task*; the driver or the system.

This effect is summarised in the table below. The table lists the available task functionality of the system concept, as presented in the previous chapter[43]. The four far right columns present a task allocation, based on system states. In brief, the table describes who's supposed to carry out a task in which state. This may be “User”, “Both” or “ADAS”. A combination of “User” and “ADAS” means that the user is backing up the task of ADAS.

Longitudinal Functions		***Task Allocation***			
Task	*Sub Tasks*	*Off*	*Inform*	*Assist*	*Control*
Vehicle & Obstacle detection	Scan Road	User	Both	Both	ADAS, User
Vehicle Tracking	Detect vehicle position Detect vehicle speed Detect vehicle distance Control Adjustments Warn HMI	User User User User	Both Both Both User ADAS	Both Both Both Both ADAS	ADAS, User ADAS, User ADAS, User ADAS, User ADAS
Obstacle Avoidance	Detect obstacle position Warn HMI Control Adjustments	User User User	Both ADAS User	Both ADAS Both	ADAS, User ADAS ADAS, User
Speed Limit Detection	Detect speed limit Control Adjustments Warn HMI	User User	Both User ADAS	Both Both ADAS	ADAS, User ADAS, User ADAS
Lateral Functions		***Task Allocation***			
Lane Tracking	Scan Road	User	Both	Both	ADAS, User
Lane keeping/Warning	Detect markings Detect deviations Determine corrections Control Adjustments Warn HMI	User User User User	Both Both Both User ADAS	Both Both Both Both ADAS	ADAS, User ADAS, User ADAS, User ADAS, User ADAS
Rear Vehicle Detection	Scan read road Detect vehicle position Detect vehicle speed Control Adjustments Warn HMI	User User User User	Both Both Both User ADAS	Both Both Both Both ADAS	ADAS, User ADAS, User ADAS, User ADAS, User ADAS

Table 16: The task allocation table

With ADAS inactive, the interactions between the driver and system are comparable to current vehicle interactions, as no task allocation has changed. More interesting are the informing and assistant modes, in which cooperation between the system and driver is needed.

The conclusion drawn from this table is that different amounts of information are needed for different system states. The table can also be used to determine which information should be presented, which will be done in the next paragraph.

43 See “System Functionality” in chapter 3

4.2 Information Flow

As concluded in the previous paragraph, the presentation of information changes as system states change. This paragraph will determine which information will be presented during a particular state. The task allocation table from the previous paragraph is used, resulting in the following overview.

Longitudinal Functions		***Presented Information***		
Task	*Sub Tasks*	*Inform*	*Assist*	*Control*
Vehicle & Obstacle detection	Scan Road	ADAS is active	ADAS is active	ADAS is active
Vehicle Tracking	Detect vehicle position Detect vehicle speed Detect vehicle distance Control Adjustments Warn HMI	Vehicle position and distance during unsafe situations	Vehicle position and distance during unsafe situations ADAS reaction	Vehicle position and distance during unsafe situations ADAS reaction
Obstacle Avoidance	Detect obstacle position Warn HMI Control Adjustments	Obstacle position and distance during unsafe situations	Obstacle position and distance during unsafe situations ADAS reaction	Obstacle position and distance during unsafe situations ADAS reaction
Speed Limit Detection	Detect speed limit Control Adjustments Warn HMI	Speed limit if exceeding	Speed limit if exceeding ADAS reaction	Keep speed below the speed limit
Lateral Functions		***Presented Information***		
Lane Tracking	Scan Road	ADAS is active	ADAS is active	ADAS is active
Lane keeping/Warning	Detect markings Detect deviations Determine corrections Control Adjustments Warn HMI	Warnings in case of lane departure	Warnings in case of lane departure ADAS reaction	ADAS is active Show anticipation
Rear Vehicle Detection	Scan read road Detect vehicle position Detect vehicle speed Control Adjustments Warn HMI	Warnings in case of unsafe lane changing	Warnings in case of unsafe lane changing ADAS reaction	Automatically change lanes

Table 17: Information divided by system states

The defined information flows can now be added to the interaction diagrams, as shown in Appendix 6. With these interaction diagrams, the interaction between the driver and the system concept has been described. Important findings are the following.

1. Different system states cause a changing need of both the amount and type of information. The information table shows how the information is to be distributed over the different system states.
2. The driver needs to be aware of the current system state, to prevent overestimation or underestimation of system functionalities. Therefore, the information table states that system activity should continually be indicated.
3. The driver needs to be able to influence the interactions, by altering system parameters.

The input channel is used by the driver to control the vehicle. This may either be directly, for example by pushing the brake, or indirectly, by telling the ADAS system to keep driving in the lane or to maintain a certain following distance. Furthermore, the interface should allow the driver to change settings of the ADAS system. For convenience, the input channel has been divided into two parts, namely the “Direct Controls” and the “Indirect Controls”. The table below presents a list of all controls and settings, and the parameters they affect.

Input		Parameter(s)
Direct Controls	Steering	Heading
	Throttle	Speed
	Brake	Speed
	Gear	Transfer ratio
Indirect Controls	System State Change	State 0/1/2/3
	Vehicle detection	On/Off
	Obstacle detection	On/Off
	Lane detection	On/Off
	Rear vehicle detection	On/Off
	Speed Limit detection	On/Off
	Lane keeping	Sensitivity, Tolerance
	Car tracking	Distance, Speed

Table 18: The list of input options

It's shown that the driver has the possibility to enable or disable several functions of the ADAS system, such as lane detection and obstacle detection. If the traffic situation is not suitable for the use of these systems, the driver or system may disable them.

The sensitivity and tolerance settings, as well as the following distance and speed are advanced settings. To comply to the adaptability system requirement, the interface should offer the user multiple layers of settings. More advanced settings like these should only appear if the (advanced) user asks for them.

Car tracking settings

The 'Distance' parameter sets the following distance, which is already common for current ACC systems. The range of this setting should be adaptable by the user, but should also be within safety limits. The parameter may be set in seconds (of following time) or meters (of following distance). The desired cruising speed should also be adjustable by the user. This speed can be checked with local speed limits, available through the ISA system.

Lane keeping settings

For lateral systems, the driver should be able to set the sensitivity and tolerance of the system. These parameters define how much the driver may deviate from the lane before a warning or intervention takes place, and how close a vehicle may approach from behind in case of lane changing.

4.3 Input/Output

This paragraph describes which input and output methods (or *modalities)* will be used in the interface concept. A lot of input and output modalities are available, including endless combinations between them.

Modality selection is influences by several factors.

- First, physical restrictions of the automotive interior apply. The modalities have to fit in to the Car of the Future cockpit.
- Second, the information that is sent through the modality limits the choice. For example, a simple LED can very well be used for on/off indication, but is less useful for the presentation of speed.
- Furthermore, sustainability should be considered. Fancy and futuristic modalities such as a touchscreen may be less favourable because of costs and/or power drain.

A problem with modality selection for automotive use is the fact that several input and output channels of the driver are already occupied by other tasks. For example, the driver spends most of his visual attention on the road, the traffic and the dashboard. It's therefore important for the interface to use available modalities. However, changing modalities all the time, or using several modalities for the same task would interfere with interface design principles, such as the principle of *coherence*[44].

To assist the selection of modalities, the so called *modality theory* was developed[45]. This theory tries to solve the 'information-mapping problem':

Given any particular set of information which needs to be exchanged between user and system during task performance in context, identify the input/output modalities which constitute an optimal solution to the representation and exchange of that information.

This problem is exactly the problem to be solved for this interface design. However, the modality theory does not yet offer a usable approach to the problem. A proposed approach includes the following steps.

1. Identification of information and tasks
2. Selective task analysis
3. Information representation
4. Information mapping
5. Trade-offs

The first three steps have already been covered in paragraphs 4.1 and 4.2. They generally concern the identification of tasks and their information flows. The fourth and fifth steps involve the selection and evaluation of modalities, based on a large matrix of combinations and their properties. The matrix can assist in answering generic questions like:

Available modalities are [good/not good] for a certain task/function

At this moment, such a matrix does not exist. The modality theory literature therefore recommends the use of empirical research to select modalities[46]. Relevant literature has been collected and summarised. The findings are as follows.

In current vehicles the driver receives most of the drive-task related information through the visual channel. Examples of drive-task related information are the observation of external traffic situations, or the monitoring of vehicle instruments. According to Wickens' Multiple Resource Theory[47], it would therefore be advisable to use other modalities for additional applications, such as navigational aids or ADAS systems. The same reason prevents the visual channel from being used for important warnings or messages. If presented visually, such information should be emphasised by auditory signals.[48]

44 Shneiderman's principles of HMI design, see http://www-static.cc.gatech.edu/classes/cs6751_97_winter/Topics/design-princ/
45 N.O. Bernsen, 1994
46 N.O. Bernsen, 1994
47 See Chapter 2, paragraph 1
48 M. Panou et al, 2005

For output, the most obvious choice would be an auditory modality, such as speech or tones. Auditory information has several specific properties in favour of in-vehicle use[49]. Firstly, auditory information is *omnidirectional*, so the information will reach the user regardless of his point of attention. Secondly, auditory information does not require visual or limb activity of the user. And finally, this modality has a high saliency, which means that the chance of the driver receiving and understanding the information is very high.

A drawback of the speech output modality is that the information lacks freedom of perceptual inspection. The driver can not decide when or how long to listen to the message. A common solution for this problem is the use of a repeat-button, which may also function as an interruption button. Also, the speech system may be linked to an awareness system (such as the workload manager) to produce output only when preferred by the driver.

In addition to the visual and auditory modalities, the haptic modality maybe used for input and output of information. For input, this modality has been used for years in the form of buttons, dials and switches. For output, this modality is relatively new. Examples of haptic output devices are force feedback steering wheels, vibrating seatbelts and vibrating seats. According to research[50], haptic signals may be used as supporting signals for visual or auditory warnings, or should be used for non-vital warnings.

Current automotive interior designs mainly use mechanical input modalities, such as knobs and switches. Besides these common input modalities the interface may also use auditory input methods. As the quality of speech recognition software increases, this method provides a good alternative to common input methods. The advantage of speech input is that the driver can keep his hands on the steering wheel.

Literature does not prescribe a particular modality to be the best choice for a certain situation. Survey results sometimes even contradict each other, but some conclusions are generally valid, as listed above. In conclusion, it's found that the visual channel is used for the main driving task. Therefore it is not available for high-priority warnings and information. Auditory signals and possible haptic signals maybe used to emphasise warnings and messages. For input, haptic devices are common. Speech input is a relatively new and probably safe auditory input method.

After this overview of interface modalities, it is up to the concept design to select particular devices. During the evaluation of these concepts, the literature results as described above can be used. To be able to compare the concepts with respect to input and output modalities, the following table has to be filled in for every concept.

INPUT/OUTPUT MODALITY SELECTION		***Visual***	***Auditory***	***Haptic***
Input	Direct			
	Indirect			
Output	Vehicle & Obstacle detection			
	Vehicle Tracking			
	Obstacle Avoidance			
	Speed Limit Detection			
	Lane Tracking			
	Lane keeping/Warning			
	Rear Vehicle Detection			

Table 19: Concept modality selection table

The table shows the required input and output fields, as defined in the preceding paragraphs. The three far right columns will be filled in with concept solutions. In case of multimodal solutions, a prioritisation will be indicated.

49 N. O. Bernsen, 2001
50 M. Panou et al, 2005

4.4 Interface Concepts

The preceding paragraphs of this chapter defined which information flows and interactions should be supported by the interface. To design interface concepts, the brainstorm method is used to collect ideas. These ideas can be combined to form complete concepts.

Boundary conditions

although the brainstorm should be 'open-minded', a few boundary conditions are appropriate. These boundary conditions have already been mentioned, in the form of HMI specific *system requirements*.

Requirement	*Requirement specification*	*Implementation*
Provide Safety	The system should enhance the safety of the vehicle, within limits of the project	The longitudinal and lateral support functions
	The system should not change the behaviour of the vehicle significantly, unless necessary	The use of system states
	The system should cooperate with non-assisted vehicles	The system-concept is autonomous, operating independently from infrastructure
	The system should support communications between users and vehicles	The system uses a communication device for speed limit detection
Provide Control	The system should let the user control ADAS influence	**HMI**
	The system should be adaptable by the user	**HMI**
Support Usability	The system should intelligently adapt to the driver's character, within safety limits	**System intelligence, HMI and workload manager**
	The system should support drivers of all ages, within legal limits	**HMI**
	The system should support information and entertainment systems	**HMI/Workload manager**
	The system should support sustainability	The system uses several multifunctional components

Table 20: System requirements

Besides the HMI specific requirements, the general requirements for example regarding sustainability should not be forgotten. The use of these requirements will make sure the interface concepts will comply to the project demands as well as research results, while also offering enough freedom to come up with new ideas.

Results

The collection of ideas resulted in four different concepts. These concepts mainly differ in their 'fanciness', ranging from a 'classic' concept to a very 'futuristic' concept. By presenting such a wide range of concepts, the Nexus project can select certain concepts that are expected to be successful within the project.

The four concepts will be presented by describing their characteristic properties. As this is only the first round of concept design, the level of detail will be low. The rough outline and heading of a concept should be enough for the Nexus project group to make a selection of.

The next four paragraphs will discuss the concepts more in-depth.

Concept 1 – Classic

The theme for this concept is “Classic”. To keep the interface familiar and acceptable, conventional indicators and other interface components have been used. The main part of the interface is located on the centre front instrument panel. The usual dials (oil, fuel, etc.) are accompanied by an *integrated safety indicator* and an *enhanced speedometer*,which will be explained later.

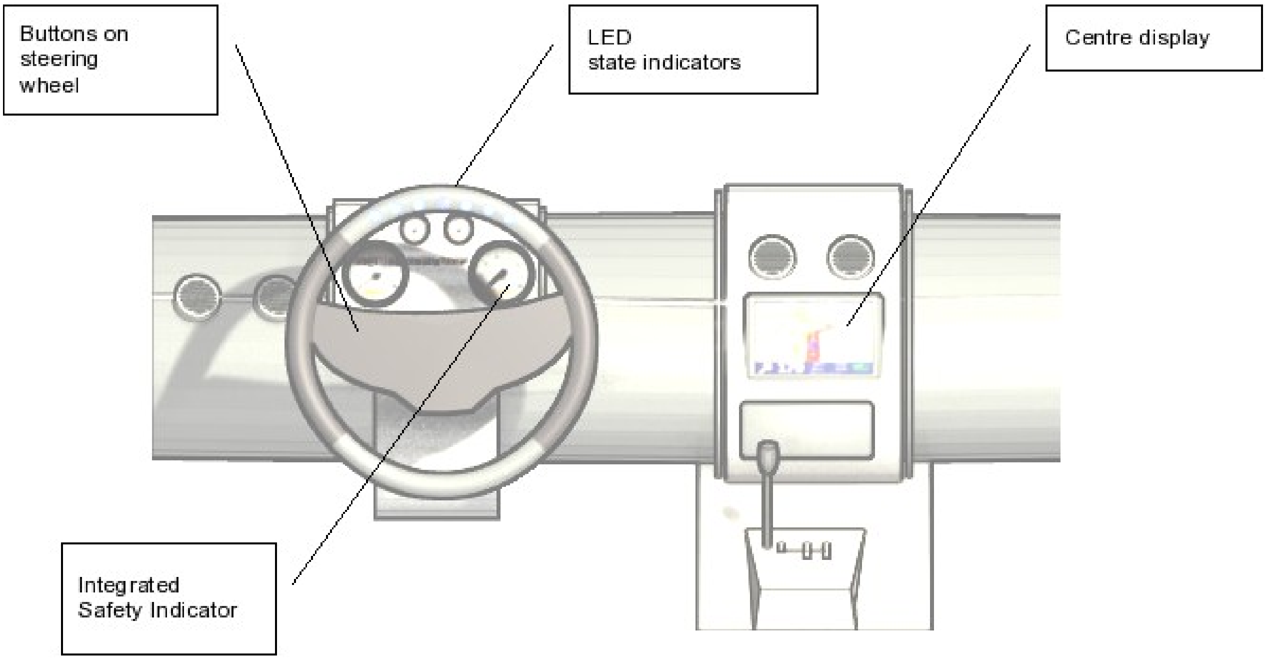


Fig 15: Overview of concept 1

System state is indicated by LEDs on the steering wheel and gear lever. When driving assisted or supported, the LEDs will indicate system activity by lighting up (constantly when in c*ontrolling state*, on activation when in *assisting state*). Changes in states are presented visually through LEDs and accompanied by auditory signals.

Input

The main input device for this concept is the steering wheel. The steering wheel offers a set of buttons to control menus on the centre console. Using this menu the user can alter advanced settings like following distance, sensor control and other preferences. Feedback of buttons is both visual (through actions on screen) and auditory (a sound signal when a button is pressed). It can be compared to steering wheels with integrated radio and cruise control buttons.

Enhanced Speedometer

The speedometer of this concept is enhanced using sensor data from the ADAS system. This way, the speedometer not only shows current local speed, but also the local speed limit, as well as advisory speeds based on traffic assessments.

Integrated Safety Indicator

The integrated safety indicator is a combination of a visual dial, similar to existing speedometers, and auditory feedback. The dial gives a rough first indication of danger, based on ADAS sensor data. The driver is given the opportunity to notice the danger indication and react on it. If no reaction is given, the indicator will use auditory feedback to indicate the danger and assist in returning to a safe situation.

The scale of the safety indicator ranges from safe to unsafe, with additional warning indicators in the unsafe area. In order to assess the safety of the traffic situation, sensor data are used. A statistical formula then calculates the real-time 'risk factor', based on the so called *time to collision (TTC)*[51].

TTC indicates the time to collision, if nothing changes in the current situation. So, with two vehicles following each other, a TTC will only exist (positively) if the speed of the following car is higher than that of the leading car. TTC can be calculated using the following formula[52].

$$TTC_i = \frac{[X_{(i-1)}(t) - X_i(t) - l_i]}{[V_i(t) - V_{(i-1)}(t)]}$$

X is the location of a vehicle (at t)

V is the speed of a vehicle (at t)

l is the length of a vehicle

i represents the vehicle for which the TTC is being calculated, i-1 is the lead vehicle

The required parameters, such as the locations of vehicles relatively to each other can be derived from longitudinal sensor input. For longitudinal situations such as cruising on a busy highway this method works fine. However, problems arise when looking at lateral situations.

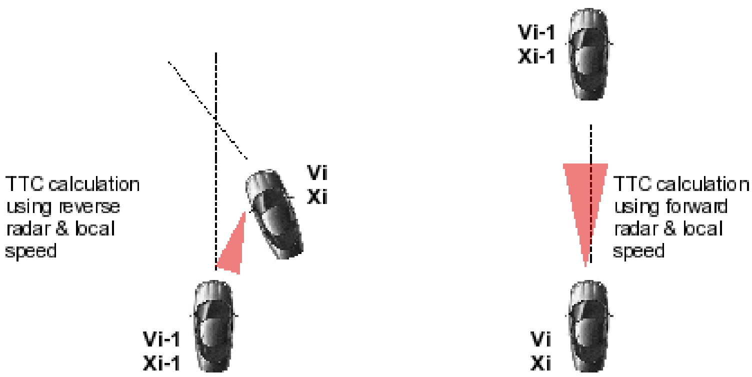


Fig 16: Real time TTC calculation in longitudinal and lateral situations

In lateral situations, TTC still applies, as shown in the left figure. A more predictive calculation is needed, using the values from rear radar sensors. The speed of the approaching vehicle (V_{i-1}) is important, as it highly influences the TTC calculation in such a situation. Also, the indicator shouldn't indicate danger every time a vehicle passes by, so a connection to the steering wheel may be useful, making sure only actual lateral danger is indicated.

System Integration

A drawback of this concept is the fact that it doesn't provide specific integration possibilities for information and entertainment systems. The lack of integration may be a drawback, but it does comply to the 'classic' and 'minimalistic' character of the concept. In case of a sustainable car, which doesn't need fancy multimedia, this concept may still be an attractive option.

51 K. Vogel, 2002
52 K. Vogel, 2002

Summarised, concept 1 offers a classic approach, with proven and existing technology. It fits the sustainable needs of the project, and offers additional safety to the driver. However, since the interface are designed for 2020, it may not be the most attractive solutions. Furthermore, the use of fixed dials and LEDs doesn't support system modularity or flexibility.

The input and output characteristics of this concept have been listed in the following table. The modality selection prioritisation is indicated by numbers. A '1' indicates highest priority.

INPUT/OUTPUT MODALITY SELECTION		***Visual***	***Auditory***	***Haptic***
Input	Direct			Steering, Brake, Throttle, Gear
	Indirect	2. Display on centre console	3. Auditory feedback	1. Buttons on steering wheel
Output	Vehicle & Obstacle detection	1. Integrated safety ind.	2. Auditory advice	
	Vehicle Tracking	1. LED indicators, 1. Integrated safety ind.	2. Auditory advice	
	Obstacle Avoidance	1. Integrated safety ind.	2. Auditory advice	
	Speed Limit Detection	1. Enhanced speedometer	2. Auditory advice	
	Lane Tracking	1. LED indicators	2. Auditory advice	
	Lane keeping/Warning	1. Integrated safety ind.	2. Auditory advice	
	Rear Vehicle Detection	1. Integrated safety ind.	2. Auditory advice	

Concept 2 – Adaptive Interface

The focus of this concept is on adaptability. The interface shows information depending on the system state, always providing both sufficient and efficient information. Adaptability can be achieved using software or hardware.

Input

Input for this concept is given through voice commands. Feedback on voice commands is given by auditory and visual cues. The steering wheel contains backup buttons for interface control, but voice commands should be the main source of input.

Adaptive software

Following the current trend of increasing use of displays instead of conventional vehicle instruments, the output of the software version is given through a digital display. On the display the usual dials and indicator can be shown, along with ADAS output. With system states changing to more supportive modes, the display will show more ADAS output, and minimise other systems.

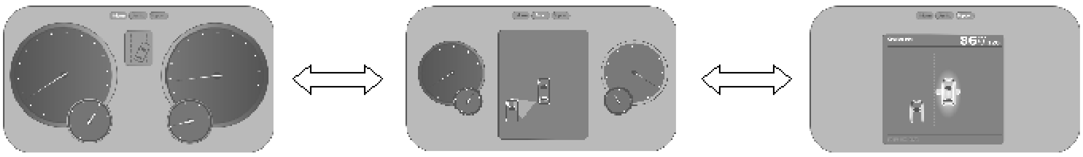


Fig 16: The software adaptive concept

Adaptive hardware

Using hardware, the dashboard can be altered according to system use. Dials and indicators can slide or rotate, in order to be visible or not. This way the user can get more 'in touch' with the system, and may better understand what's happening.

Grouping Information

The adaptive character of this concept introduces a possible problem with recognition and expectancy. Users may not always receive information from the same location. For example, when driving in the *informing state*, the vehicle speed is displayed large and in the centre-left part of the screen. After switching to a higher state of support, the speed maybe displayed smaller and in a different location.

Therefore it's necessary to define groups of information, as also recommended in several interface guidelines[53].

- Conventional vehicle dynamics; including speed, engine revolutions, fuel status.
- System failure indicators: warning lights and sounds for system failure, either vehicle or ADAS
- ADAS output: the visual display offers opportunities for ADAS output, as described below. In combination with buttons or voice control it may also be used as part of the input system for ADAS.
- Secondary system output: the display may also be used for secondary assistant applications like parking assistance and night-vision systems. The instrument cluster is not considered a suitable location for multimedia output.

Fig 17: The hardware adaptive concept

53 See Appendix 3

The hardware version should support grouping by placing information output devices on separate interior components. The software version can simply use a digital display to support this.

Output

Both concepts use a visual display to show which system state is active, and which ADAS systems are running. The following drawing shows the basic workings of such a display.

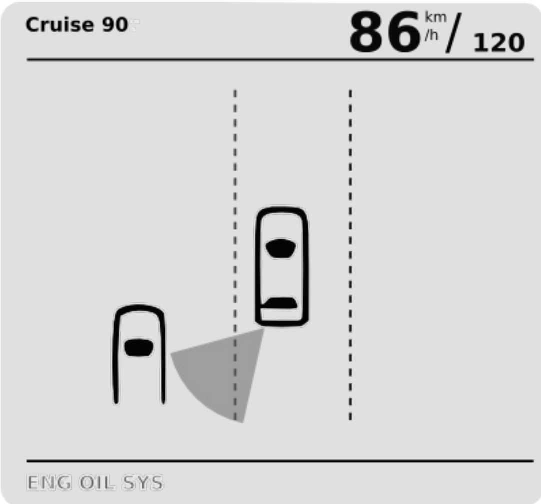


Fig 18: Concept ADAS display

The display uses a top-down perspective to indicate current vehicle and traffic conditions. Road markings can be used to show whether the lane keeping or lane departure (i.e. the lateral control and monitoring) functions are operating. If a system is active, for example the lane change assistance system as shown in the drawing, this can be indicated by highlighting the sensor area. Furthermore, a display like this offers integration possibilities with navigation and communication equipment.

INPUT/OUTPUT MODALITY SELECTION		***Visual***	***Auditory***	***Haptic***
Input	Direct			1. Steering, Brake, Throttle, Gear
	Indirect		1. Speech	2. Buttons on steering wheel
Output	Vehicle & Obstacle detection	1. ADAS display	2. Auditory support & advice	
	Vehicle Tracking	1. ADAS display	2. Auditory support & advice	
	Obstacle Avoidance	1. ADAS display	2. Auditory support & advice	
	Speed Limit Detection	1. ADAS display	2. Auditory support & advice	
	Lane Tracking	1. ADAS display	2. Auditory support & advice	
	Lane keeping/Warning	1. ADAS display	2. Auditory support & advice	
	Rear Vehicle Detection	1. ADAS display	2. Auditory support & advice	

Concept 3 – Futuristic

This concept uses relatively new and unproven technology[54] to provide the user with information. The main information output is shown on the windscreen, using an augmented reality display. On this display, the information is shown within the line of sight of the driver.

Input

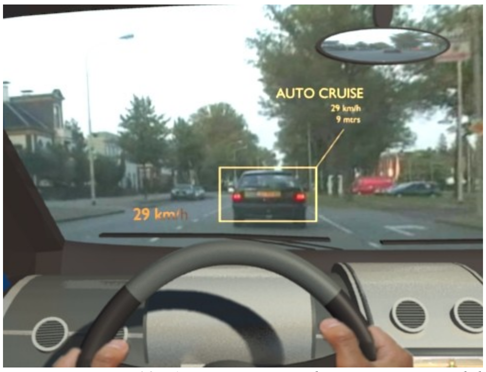


Fig 19: A HUD presented in a concept model

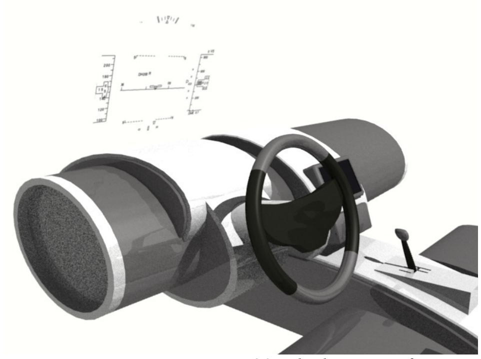


Fig 20: The location of a HUD

System input is given by voice commands only. A centre console touch-screen may be used as backup. With voice commands the user can control system parameters and preferences. Feedback is given through digitized speech output.

Output

Besides the speech output, most ADAS output is presented on the windshield display. The information changes according to system states. When driving manually, traditional information is shown, when driving in the *controlling state*, ADAS information is shown. The windshield display can be used to show path predictions, car tracking and obstacle highlighting. It also offers a platform for other car systems like navigational instruments.

INPUT/OUTPUT MODALITY SELECTION		***Visual***	***Auditory***	***Haptic***
Input	Direct			1. Steering, Brake, Throttle, Gear
	Indirect		1. Speech	
Output	Vehicle & Obstacle detection	1. On the HUD	2. Auditory support	
	Vehicle Tracking	1. On the HUD	2. Auditory support	
	Obstacle Avoidance	1. On the HUD	2. Auditory support	
	Speed Limit Detection	1. On the HUD	2. Auditory support	
	Lane Tracking	1. On the HUD	2. Auditory support	
	Lane keeping/Warning	1. On the HUD	2. Auditory support	
	Rear Vehicle Detection	1. On the HUD	2. Auditory support	

54 See Appendix 3.4

Concept 4 – Interactive Driver Assistant

The driver assistant is a physical or virtual appearance in the car, providing the driver with tips and advice on driving safety. Ideas for this concept include actual robots, computerised voices and virtual road buddies.

A physical form of driver assistant can also express certain traffic conditions or vehicle status. For example, a scanning movement of some kind can indicate system alertness.

With this concept focus is on interactions between the driver and the system, as well as with system intelligence. Intelligence should prevent the assistant from assisting too much, or it's unwanted.

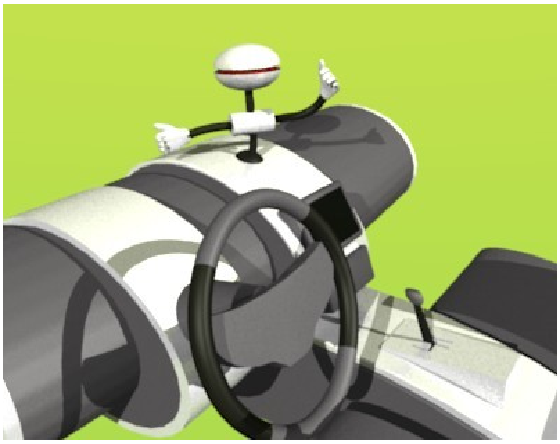


Fig 21: A robotic driver assistant concept

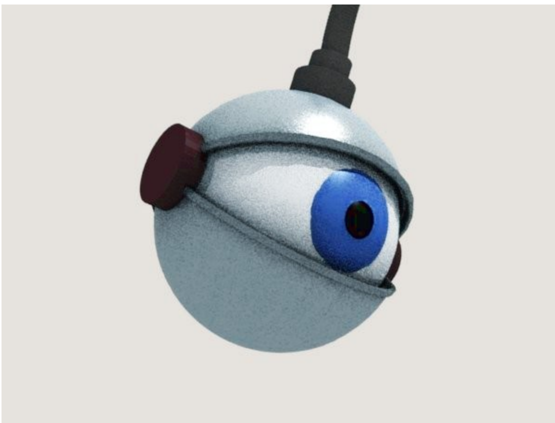


Fig 22: Another driver assistant concept

Input

The input method for this concept is voice control. By being able to communicate naturally with the car, a certain amount of trust and comfort can be created. The assistant will reply with voice answers. To control the system states, a physical robot could be aimed at a traffic situation. For example, aiming the face on the road would put the car in the *controlling mode*, aiming the face on the dashboard would put the car in assisting mode.

Output

System output is given through voice commands, visual cues and expressions of the assistant. These output channels may also be used by other car systems like information and navigational applications. The assistant should use expressions or movements to indicate alertness or inattention. The user should be able to trust the assistant to watch out if he wants him to do so.

Fig 23: Expressions of a driver assistant concept

System Integration

The assistant concept is also able to present information and entertainment to the driver. Not only is the assistant aware of the traffic safety situation, he should also know when to play music, and which music to play. A personal bond with the assistant may also increase trust between him and the driver.

INPUT/OUTPUT MODALITY SELECTION		Visual	Auditory	Haptic
Input	Direct			1. Steering, Brake, Throttle, Gear
	Indirect		1. Speech	2. Assistant Physics
Output	Vehicle & Obstacle detection	1. Assistant Expressions	1. Assistant speech	2. Assistant Physics
	Vehicle Tracking	1. Assistant Expressions	1. Assistant speech	2. Assistant Physics
	Obstacle Avoidance	1. Assistant Expressions	1. Assistant speech	2. Assistant Physics
	Speed Limit Detection	1. Assistant Expressions	1. Assistant speech	2. Assistant Physics
	Lane Tracking	1. Assistant Expressions	1. Assistant speech	2. Assistant Physics
	Lane keeping/Warning	1. Assistant Expressions	1. Assistant speech	2. Assistant Physics
	Rear Vehicle Detection	1. Assistant Expressions	1. Assistant speech	2. Assistant Physics

4.5 Conclusions

This chapter describes the design of user interface for the global system concept. The following aspects have been dealt with.

1. System/user interactions
2. System information flows
3. Input/output modalities
4. Interface concept design

Interactions between the user and the system have been defined for every system state. Interactions differ for every system state. The information, divided into observation, processing and reaction parts, changes with every state transition.

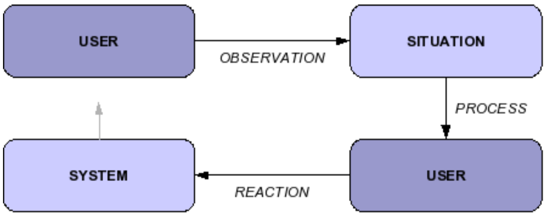


Fig 17: The basic interaction layout

It's found that most interesting interactions occur in the *assisting state*, and to some extent in the *controlling state*. In these states, the user and system have to cooperate to drive the vehicle. An inventory of information based on states was made, defining which information should be available at which moment. The system interactions and task allocation tables were used to support the selection.

The defined information flows have been divided into input and output. For this input and output, *modalities* were to be selected. Using the *modality theory* and a small literature overview, conclusions were drawn, and an input/output table for the interface concepts was set up. Together with the interaction diagrams and the information flows, this table provides an interface framework for which concepts can be designed.

Four ideas ranging from classic to futuristic, and with different levels of feasibility and sustainability have been described.

1. Classic – A conventional instrument cluster is used, on which a so called “integrated safety indicator” is located. The indicator will show whether a situation is safe or not, and what to do about it.
2. Adaptive – This concept uses hardware or software to adapt the interface according to a situation, thus always providing efficient yet sufficient information.
3. Futuristic – The windscreen of the vehicle is used to project imagery, showing vehicle and ADAS information within the line of sight of the user.
4. Road Assistant – A robotic or virtual road assistant will assist the driver with the driving task, navigation, and entertainment.

These concepts are to be evaluated in the next chapter, in order to make a first concept selection and further develop the remaining ideas.

5. Evaluations & Recommendations

The concepts as presented need to be further developed before they are able to be used in large-scale usability tests or even field tests. Therefore, this chapter will deal with an evaluation of both the global ADAS concept and the interface solutions, resulting in recommendations for further development.

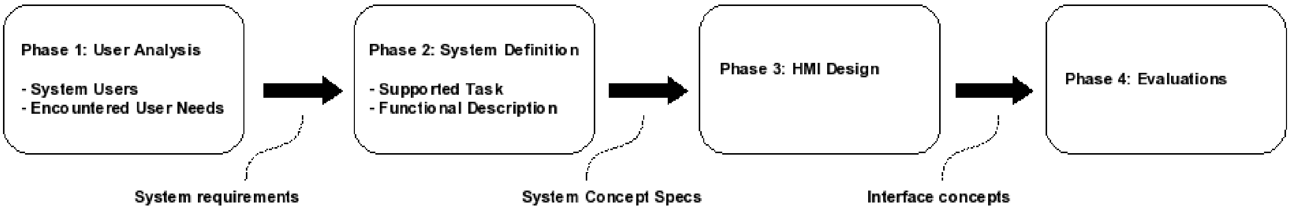


Fig 18: Evaluations, phase 4 of the design process

For the Systems Evaluation a review of development aspects is used. This method evaluates the global system concept. For the interface evaluation the Response Checklist part B is used. With this evaluation concepts will be evaluated individually.

5.1 System Evaluation

Development Aspects

The development aspects as described in chapter 2 are used. In chapter 2 three potential problem areas of ADAS systems have been discussed.

1. Introduction & Acceptance
2. Negative behavioural changes
3. Workload & driving task effects

So how does the presented ADAS concept handle these potential problems?

Introduction & Acceptance

The system uses technology that should be available in 2020, based on the ADAS roadmap. The roadmap reserves about 15 years of development time and for users to get acquainted with the new technology. However, some factors may affect the success of this roadmap. For example, if the government does not support the introduction of ADAS, it's impossible for further ADAS developments to succeed as law needs to be adapted to this new technology.

As said in literature, acceptance shouldn't be problematic as long as the system offers the user to remain in control if he/she prefers to do so. The system concept as presented offers this functionality by using different system states. Acceptance also depends on trust. Therefore ADAS systems should be tested thoroughly before market introduction. A negative first experience may cause the general public to reject ADAS.

Negative Behavioural Changes

It's hard to evaluate this aspect without conducting a long-term usability or field test. However, it can be said that both 'Individual Factors' and 'Learning Time' are covered by the systems intelligence. This intelligence causes the system to get to know the user, and adapt accordingly. This causes optimized interactions and consequently safer driving.

For this to succeed it is vital that the artificial intelligence as well as the human-machine interaction of the system is further investigated.

Workload & Driving Task Effects

The integration of a workload management system should prevent mental overload. A problem with such a solution is the lack of modularity of it. In the Car of the Future the user may add or remove parts and components, like PDAs, phones, etcetera. The workload manager should be designed to be adaptable, so that it adapts to every car configuration.

If successful, the system concept offers a lot of time space for secondary driving tasks, or even non-driving related tasks like work or leisure. The workload manager is capable of combining ADAS systems with these other applications.

Design Method

The design process that was used to develop the ADAS concept turned out to be positive. The RESPONSE Checklist part A is found suitable for global system development by pointing out important development aspects, as well as offering the possibility to fine-tune the list.

The following issues are worth mentioning.

– The result of the fine-tuning is that some important aspects have been left out because of time restrictions. These aspects need to be investigated in further research. The aspects include “Compliance to standards and traffic law” and “System Price”.

– The function analysis of ADAS systems to sub-function level resulted in a set of requirements for a potential new kind of integrated sensor. Further investigation of this subject may lead to the development of such a device, saving energy and space in future ADAS systems.

– While working on the interface framework it was found that the global system concept needed to be updated constantly. For future use of the ADAS checklist part A, a close integration between the global design and the HMI development is recommended.

5.2 Interface Evaluation

RESPONSE Checklist

The first method of evaluation for the interface will be the RESPONSE Checklist, Part B, as mentioned in chapter 2. Part B consists of a list of questions, with specific questions about HMI, system design, system use, etcetera. Each question affects a so called 'evaluation concept'. For example, a question about the use of the HMI may affect the evaluation concepts “Trust” and “Acceptance”.

The HMI chapter of the Checklist part B is used. A complete evaluation is presented in Appendix 8. The matrix below shows the total result of each evaluation aspect. Every aspect is awarded with 1 to 3 points, where 3 points indicate maximum positive effects on an evaluation concept.

Concept	***Predictability***	***Controllability***	***Traffic Safety***	***Responsibility***	***Misuse Potential***	***Driving Efficiency***	***Workload***	***Error Robustness***	***Trust***	***Perceptibility***	***Acceptance***
1. Classic	4/6	3/3	6/9	15/21	1/3	3/3	6/6	7/9	7/9	2/6	2/3
2. Adaptable interface	6/6	3/3	9/9	17/21	2/3	3/3	5/6	9/9	8/9	4/6	2/3
3. Futuristic	3/6	3/3	9/9	16/21	2/3	3/3	6/6	9/9	9/9	6/6	3/3
4. Road Assistant	5/6	3/3	8/9	15/21	3/3	2/3	5/6	9/9	9/9	5/6	3/3

Table 21: Results of the Checklist part B system evaluation

It should be noted that filling out the evaluation questions is not a pure scientific or objective task. The evaluation compares relatively feasible technology (concepts 1 and 2) to more futuristic technology (concepts 3 and 4). Also, questions often refer to detailed design aspects, such as menu design or use of speech messages. At this stage, design concepts haven't reached that level of specification yet.

Therefore, the numerical result of this evaluation (concept 3 scores highest) should not be interpreted as a victory for this concept. However, answering the questions does provide the designer with previously underestimated or forgotten design aspects. These aspects are listed below for each concept.

Concept 1

On the whole, concept 1 is evaluated as somewhat negative. The most interesting benefits of this concept are the use of familiar output methods which results in high acceptance and easy adaptation to new technology.

However, significant limitations to the concept have been found.

Firstly, negative behavioural changes may be caused by misinterpretation of the longitudinal safety indicator. Instead of merely indicating 'safe' or 'not safe', the interface should also support the driver (up to a certain level) by presenting messages that may be helpful.

Another problem with the interface is the use of steering-wheel buttons. There's a chance of accidentally pressing these buttons while driving, which may result in hazardous situations. To prevent this, button placement should prevent accidental pressing, either by not placing them on the steering-wheel, or by inactivating them when the steering-wheel is in use.

Finally, the amount of feedback of this interface is very minimal. The LED system that's used to indicate system activity should be improved to prevent misinterpretation. It should be made clear to the driver whether the system is actively driving, or asking for input.

Concept 2

No major concerns with this concept were found. The interface is expected to be accepted quite easily because of the familiar technology.

Possible problems are expected with driver attention. As the interface is located below the line of sight of the driver, it may be hard for a small display to get enough attention in case of emergency. Therefore it's necessary for the visual cues to be supported by auditory signals.

Concept 3

Concept 3 turns out to be quite positive. The use of a display within the line of sight of the driver may increase safety by preventing the driver from looking down too often. Information displayed on the HUD has a good chance of being noticed, and can be interpreted quickly.

A major drawback of this concept is the use of new technology. although HUDs appear in production cars more and more often it's still an unproven technology in the automotive industry. However, taking into account the future aspects of this design project this may not be a big issue.

Concept 4

As with concept 3, this concept may have problems with acceptance. It's unclear whether the robot or software assistant will cooperate safely and effectively with the driver. However, human-machine robotics and artificial intelligence is an active field of science.

European Statement of Principles

The second method to evaluate the interface concepts is to use the European Statement of Principles regarding automotive HMI design. Appendix 8 contains an overview with all the principles and their relation with the interface concept.

Although the principles check-up did not result in as much feedback as expected, the following issues were found interesting enough to be mentioned.

Principle 1.4 - "The system does not present information to the driver which results in potentially hazardous behaviour by the driver or other road users"

Concept 1 may potentially cause negative behavioural changes because it doesn't always indicate what's going wrong exactly. This is a major drawback of the concept, and should be considered for re-design. The other concepts use explicit warnings and assistance to inform the user.

Principle 2.2 - "No part of the system should obstruct the driver's view of the road scene"

This guideline is relevant for several concepts. First, concept 3 uses a windshield display. This solution is not yet allowed in certain countries, partly because of this guideline. Though HUDs are becoming more common, research should further investigate the benefits of these displays.

Furthermore, concept 4 may have a problem, as it uses a physical appearance to assist the user. This 'robot' shouldn't obstruct the field of vision, but at the same time must be noticed in case of emergencies.

Principle 2.5 - "Visual displays should be designed and installed to avoid glare and reflections"

Only concept 3 may have major problems with glare and reflections. Further development of head-up displays and other transparent display technology may come with solutions.

Principle 4.3 - "System controls should be designed such that they can be operated without adverse impact on the primary driving controls"

Only concept 1 may have problems with this guideline, as it uses controls fitted on the steering wheel. Concepts 2 to 4 mainly use voice control.

5.3 Recommendations & Future Research

System Concept

The system concept presented in this research is used as a basis for further interface design, and should not be used as a final system design. However, as it has been designed with support of literature and research results, the concept describes a well-thought out and reasonable system.

Furthermore, the research was primarily safety oriented, possibly causing the comfort factors and attractive aspects to diminish. It's assumed however that by striving for safety the other factors will be dealt with as well.

On the whole, the system concept fulfils the requirements of both stakeholders and pre-defined evaluation methods. More detailed designing is necessary before actual implementation in to the Car of the Future. The evaluation of the system concept provides us with the following recommendations for future research.

- Further research on both general and traffic law is required
- System price factors are to be investigated
- The workload manager design needs to be extended
- The design of a new integrated sensor may be required/preferable for a sustainable Car of the Future

Interface Concepts

The four interface concepts have been evaluated as well. As it's the first generation of concepts, a lot of potential problems and improvements have been found thanks to evaluations. These results should be used to further develop the concepts, and finally make a smaller selection to further evaluate and improve.

For each concepts it's benefits and drawbacks are summarised below.

Concept	*Benefits*	*Drawbacks*
1. Classic	Familiar interface components Cheap interface components Low implementation costs	Unattractive, not futuristic Not adaptable/flexible Not modular or upgradable High maintenance costs No integration with other in-car systems
2. Adaptive	Futuristic, attractive Familiar interface components Cheap interface components Adaptable and flexible Integrates with other in-car systems Low maintenance costs	High implementation costs Possibly disorientating
3. Futuristic	Futuristic, attractive Adaptable and flexible Possibly safer Lower workload Integrates with other in-car systems	Expensive components Unproven technology High implementation/maintenance costs Practical restrictions
4. Road Assistant	Futuristic, attractive Trustworthy Adaptable and flexible Lower workload Integrates with other in-car systems	Expensive components Unproven technology High implementation/maintenance costs Practical restrictions

Table 22: Summary of benefits and drawbacks of interface concepts

Development Recommendations

Based on this research it would be advisable to further investigate possibilities of the “Adaptive Interface”, concept 2. Current research and technology support the use of adaptive interfaces, and car manufacturers are already increasing the use of digital displays in their vehicles.

The use of the digital version is advised, as it offers optimal integration opportunities with other in-car applications like navigation and multimedia systems. Also, it leaves quite a lot of design freedom with the interior designers, as long as space is reserved for a digital display, roughly the size of current instrument clusters.

However, taking in account the futuristic character of the project, it may be more interesting to further investigate the “Road Assistant” , concept 4. The use of a human-like assistant may be the key to gain trust among drivers, to let them rely on the system to support them.

Further research could look at human-robotics interactions (HRI) and robotic expressions. Current restrictions, such as traffic and general law and interface guidelines regarding distracting and obstructing components, should be kept in mind. The interface evaluation results can be used to do so.

5.4 Conclusions

The chapter covers the evaluation of both the global system concept and the four interface concepts.

Evaluation of the system concept is done using the development problems stated in chapter 2, being “Introduction & acceptance”, “Negative behavioural changes” and “Workload & driver task effects”. It turns out that the system concept has fitting solutions for these problems. However, as it is only a concept design, the further development of artificial intelligence and a workload management component are pointed out as future requirements.

The interfaces have been evaluated using the HMI section of the RESPONSE Checklist part B, as well as by evaluating design principles from the EsoP. Results of these evaluations indicate that the concepts need further development. Concept 2 turns out to be most feasible based on these results, while concept 4 is also recommended for further research, based on project preferences.

A summary of benefits and drawbacks of each concept has been made, along with recommendations for the further developing of both concepts 2 and 4.

Abbreviations

ABS	Anti Blocking System
ADAS	Advanced Driver Assistance System
ACC	Adaptive Cruise Control / Advanced Cruise Control
AID	Augmented Information Display
AIDE	Adaptive Interface Design
ADASE	Advanced Driver Assistance Europe
CC	Cruise Control
CPU	Central Processing Unit
ESP	Electronic Stability Program
HDD	Head-Down Display
HMI	Human Machine Interface
HUD	Head-Up Display
IVS	Intelligent Vehicle Systems
IVIS	Intelligent Vehicle Information Systems
ITS	Intelligent Traffic Systems
ISA	Intelligent Speed Adaptation / Intelligent Speed Assistance
LCA	Lane Change Assistant
LKS	Lane Keeping System
LDW	Lane Departure Warning
LDWa	Lane Departure Warning Assistant
SNE	Society for Nature and Environment
STD	State Transition Diagram
TuD	University of Delft
TuE	University of Eindhoven
UI	User Interface
UT	University of Twente

References

Papers

1. B. van Arem & C.J.G. van Driel, *Integrated driver assistance from the driver's perspective – Results from a user needs survey*, CE&M Research Report, August 2005
2. N. O. Bernsen & L. Dybkjaer, *Exploring Natural Interaction in the Car*, University of Southern Denmark, Denmark, December 2001
3. N.O. Bernsen, *Modality Theory in support of Multimodal Interface Design*, Centre for Cognitive Science, Roskilde University, March 1994
4. G. Burnet, *A road-based evaluation of a HUD for presenting navigational information*, School of Computer Science and IT, Nottingham, UK, june 2003
5. P. Blythe & A. Curtis, *Advanced Driver Assistance Systems: Gimmick or Reality,* Paper presentation, 2004
6. L.G. Braimaister, *Mobiele computers in personenauto's en mogelijke effecten op de verkeersveiligheid*, Stichting Wetenschappelijk Onderzoek Verkeersveiligheid SWOV, 2002
7. K. Brookhuis et al, *Behavioural impacts of ADAS – An overview*, Groningen, the Netherlands, 2001
8. L. Campbell, D. Hoffmeister et al, *Comprehension Testing of Active Safety Symbols*, SAE International, 2004
9. I.J. Chalmers, *User attitudes to automated highway systems*, The Highways Agency, United Kingdom, April 2001
10. B. Elzen, F. Geels et al, *Sociotechnical Scenarios (STSc) - A new Methodology to Explore Technological Transitions*, Final Report for PRET project, University of Twente: Centre for Studies of Science, Technology and Society, Enschede, March 2002
11. M. Fitzgerald, *Lane Departure Warning Boosts Anti-Rollover Protection*, Automotive DesignLine, March 4, 2005
12. P. Green, *Driver Distraction, Telematics Design, and Workload Managers: Safety Issues and Solutions*, University of Michigan Transportation Research Institute, SAE Paper Number 2004-21-0022, 2004
13. P. Green & H. Cai, *Character Heights for Vehicle Displays as Predicted by 22 Equations*, SID Vehicle Display 2005 Symposium, Human Factors, Paper number 2.2, 2005
14. C. Ho & S. Chung, *A compact 24 Ghz Radar Sensor for vehicle sideway-looking applications*, National Chia-Tung University, Hsinchu, Taiwan, 2005
15. H.M. Jagtman & E. Wiersma, *Driving with adaptive cruise control in the real world,* Safety Science Group, Faculty of Technology, Policy and Management, Delft University of Technology,The Netherlands, February 2003
16. B. Kantowitz & M. Moyer, *Integration of driver in-vehicle its information*, Report for FHWA, March 1999
17. Kanevsky, Churchill et al, *Safety Driver Manager*, IBM Research Report,IBM Research Division Thomas J. Watson Research Center, Yorktown Heights, NY , 2004
18. R. Kovordányi, *When will ADAS be User-Adaptive? The Case of Adaptive Cruise Control*, Cognitive Systems Engineering Lab., Linköpings Universitet, Sweden, 2003
19. F. Kücükay & J. Bergholz, *Driver Assistant Systems*, Institute of Automotive Engineering, TU Braunschweig, 2004
20. J.H. Kraay, *The Netherlands traffic & transport plan; road safety with a special focus on speed behaviour*, Ministry of Transport, the Netherlands, ICTCT workshop Nagoya, 2002
21. J. Lee, B. Caven et al, *Speech-based Interaction with In-vehicle Computers: The Effect of Speech-based E-mail on Drivers' Attention to the Roadway*, Cognitive Systems Laboratory University of Iowa, Department of Industrial Engineering, June 2000

22. Lewin, T, *Adaptive cruise control: Who's in charge? Europe wrestles with safety benefits vs. driver control*, Automotive News / May 8, 2006
23. R. Mende, M. Behrens et al, *A 24 GHz ACC Radar Sensor*, Smart microwave sensors GmbH, Germany, 2005
24. P. Morsink, C. Cseh et al, *Preliminary Design of an application for communication based longitudinal control in the CARTALK2000 Project*, TNO Automotive, Delft, September 2002
25. J. Najjar, J. Ockerman et al, *User Interface Design Guidelines for Speech Recognition Applications*, Georgia Tech Research Institute, Atlanta, United States, 1998
26. M. Panou et al, *Towards an integrated in-vehicle HMI for ADAS and its application for lateral collision warnings*, 1st FERSI Scientific Road Safety Research Conference, September 2005
27. S. Peterson, *Collimation in Transparent Projection Screens for Panoramic Augmented Reality Environments*, Linköping University, Sweden
28. T. Ranney, J. Harbluk et al, *Effects of voice technology on test track driving performance: Implications for Driver Distraction*, Transportation research Centre
29. M. van Russelt, *Head Up Display – From high-tech jet fighters to your car windshield*, Glass Processing Days 2005
30. F. Tango and Roberto Montanan, *In-Car Machine-Human Interaction - How the new vehicle technologies which respond to the vehicles needs could match with the user-centered approach and contribute to shape a user-centered design approach*, University of Modena & Reggio Emilia, Italy, 2004
31. L. Tijerina, E. Parmer et al, *Driver Workload assessment of route guidance system destination entry while driving: A test track study*, Transportation Research Centre
32. O. Tsimhoni, D. Smith et al, *Address Entry While Driving: Speech Recognition Versus a Touch-Screen Keyboard*, HUMAN FACTORS, Vol. 46, No. 4, Winter 2004, pp. 600–610.
33. K. Vogel, *A comparison of headway and time to collision as safety indicators*, Swedish National Road and Transport Research Institute, S-581 95 Linkäping, Sweden, February 13, 2002
34. C. Wood, K. Torkkola et al, *Using Driver's Speech to Detect Cognitive Workload*, SPECOM'2004: 9th ConferenceSpeech and ComputerSt. Petersburg, Russia, September 2004
35. P. Wouters & J. Bos, *Traffic accident reduction by monitoring driver behaviour with in-car data recorders*, In: Accident Analyses and 24 Prevention, 32(5): 643-650, 2000
36. Y. Zhangy, Y.i Owechkoz et al, *Driver Cognitive Workload Estimation: A Data-driven Perspective*, Electrical & Controls Integration Lab, General Motors Cooperation, October 2004

Reports

Ministries & Organisations

1. "Towards Sustainable Town development: A Research on Deployment of Urban Sustainable Transport Systems", Deliverable 1, Stardust project, August 2001
2. "ISA-UK Intelligent Speed Adaptation, Implications of Travel Patterns for ISA", University of Leeds and MIRA ltd, may 2003
3. "LUND – Results of the ISA trial", Swedish National Road Administration, September 2002
4. "Reiziger in de Toekomst", Project Road to the Future, Dutch Ministry Traffic and Water management, June 2005
5. "LDWA Field operational test, Dutch Ministry Traffic and Water management, August 2001'
6. "Innovatie voor mobiliteit", Dutch Ministry Traffic and Water management
7. "Nota Mobiliteit", Dutch Ministry Traffic and Water management
8. "Recommendation of the Commission of the European Communities to the Member States and Industry on Safe and efficient in-vehicle information and communication systems: a European statement of Principles on Human Machine Interface", European Commission, December 1999
9. "Statement of Principles, Criteria and Verification Procedures on Driver Interactions with Advanced In-Vehicle Information and Communication Systems", Alliance of Automobile Manufacturers, Driver Focus-Telematics Working Group, Report v 2.0, April 2002
10. "European Statement of Principles", European Commission, 2005
11. "Auto's om veilig mee thuis te komen", SWOV and RAI vereniging, December 2nd, 2005
12. "Pro.Pilot: ADAS; Enhancement of Comfort and Safety", Siemens VDO powerpoint presentation, February 2006
13. Y. Noy, *Human Factors Issues Related to Driver Distraction From in-vehicle systems*, Powerpoint presentation for Ergonomics Division, Transport Canada

International Projects

AIDE

http://www.aide-eu.org

1. “Literature review of behavioural effects”, deliverable 1.2.1, 21-09-2004
2. “Recommendations from the HMI-eSafety group”, Revision of EsoP, HMI-eSafety group, 2005

ADASE

http://www.adase2.net

3. S. Becker, T. Johanning et al, “The Integrated Approach of User, System, and Legal Perspective: Final Report on Recommendations for Testing and Market Introduction of ADAS”, RESPONSE, D4.2, v. 2.0, September 1999
4. M. Kopf, P. Allen et al, “Checklist for Theoratical Assessment of ADAS: Methods, Results and Assessment of Applicability”, RESPONSE, Deliverable 4.2, September 1999
5. L. Berghout, E. Versteegt et al, “Advanced driver assistance systems; Results of the State of the Art of ADASE-II”, Deliverable D2A, v2.1, December 2003
6. D. Ehmanns & H. Spannheimer, Response “Roadmap”, Deliverable D2D, v 1.0, July 2004
7. E. Donner, H. Schollinski et al, “ADAS Market Introduction Scenarios and Proper Realisation“, RESPONSE2, Deliverable D1, January 2004

ADVISORS

http://www.advisors.iao.fraunhofer.de

8. “Action for advanced Driver assistance and Vehicle control systems Implementation, Standardisation, Optimum use of the Road network and Safety”, Final Public Report, 2003
9. “Inventory of ADAS and User Needs Update 2002”, Deliverable 1.2, v12.3, November 2002

COMMUNICAR

10. “COMUNICAR: designing a multimedia, context-aware human-machine interface for cars”, Communicar Report (Summary), Department of Electronics and Biophysical Engineering, University of Genova, Via Opera Pia, Italy, December 2004

Internet Sources

Automotive Technology

1. http://euler.fd.cvut.cz/research/rs2/files/mitsubishi/9838.html, *last visited 21-08 2006*
2. http://uk.cars.yahoo.com/car-reviews/car-and-driving/honda-accord-adas-1004962.html, *last visited 21-08 2006*
3. http://www.bmwworld.com/technology/acc.htm, *last visited 21-08 2006*
4. http://www.thecarconnection.com/Vehicle_Reviews/Sports_Convertibles/2006_Lexus_IS_250_IS_350.S184.A8929.html, *last visited 21-08 2006*
5. http://www.is-350.com, *last visited 21-08 2006*
6. http://www.autospies.com/article/index.asp?articleId=6235&categoryId=21, *last visited 21-08 2006*

Head-Up Display technology

7. http://www.qa-talk.com/news/cog/cog114.html, *last visited 21-08 2006*
8. http://www.i-car.com/html_pages/about_icar/current_events_news/advantage/-advantage_online_archives/2005/061305.shtml, *last visited 21-08 2006*
9. http://www.canadiandriver.com/articles/jk/021016.htm, *last visited 21-08 2006*

ADAS Technology

(A)CC software

10. http://www.cs.cmu.edu/~ModProb/CC.html, *last visited 21-08 2006*
11. http://www.nhtsa.dot.gov/people/injury/research/pub/ACAS/ACAS-fieldtest/3_system_integration.htm, *last visited 21-08 2006*
12. http://www.mbusa.com/models/features/specs/instrumentation.do?modelCode=S600V&class=07_S, *last visited 21-08 2006*
13. http://delphi.com/manufacturers/auto/safesecure/warning/stopgo/, *last visited 21-08 2006*

Lane Departure Warning technology

14. http://www.citroen.com/CWW/en-US/TECHNOLOGIES/SECURITY/AFIL/, *last visited 21-08 2006*
15. http://www.rws-avv.nl/servlet/page?_pageid=121&_dad=portal30&_schema=PORTAL30&p_folder_id=5397,5457,5762, *last visited 21-08 2006*
16. http://www.valeo.com/automotive-supplier/Jahia/pid/889, *last visited 21-08 2006*
17. http://www.conti-online.com/generator/www/de/en/cas/cas/themes/products/-electronic_brake_and_safety_systems/driver_assistance_systems/lane_keeping_en.html, *last visited 21-08 2006*
18. http://www.automotivedesignline.com/howto/60405845, *last visited 21-08 2006*

Interface Guidelines & Human Factors

19. http://ntl.bts.gov/DOCS/atis/ - Human Factors design guidelines for IVIS, *last visited 21-08 2006*
20. http://www.fhwa.dot.gov/tfhrc/safety/pubs/95153/index.html – Human Factors design guidelines for ATIS, *last visited 21-08 2006*

Afterword

This assignment concludes the Bachelor part of my Industrial Design study. The field of science it covers, that of ADAS, ITS and automotive in general turned out to be an interesting and enormous one. So while working on this research the focus shifted from pure interface design to both system design and interface design. As a result, both designs are less in-depth than initially objected.

Despite the lack of in-depth design, the shifted focus did enforce me to use a more broader set of methods and techniques, including those of Systems Engineering, Ergonomics and general design courses. I'm quite pleased with the result, though sometimes it looks more like a collection of knowledge, conclusions and repetition of sources. In my opinion, the final concepts certainly contain new ideas, but need to be further developed before being implemented in the Car of the Future.

The cooperation with students and partners from the Car of the Future project was not entirely as expected, but interesting nevertheless. The different design approaches universities used sometimes caused communication problems, but never lead to a crisis. On the whole, the Nexus group and our meetings were often (but not always) inspiring and useful for my individual assignment. Therefore I'd like to thank Jacco, Niels, Gilbert, Martin, Jeroen and Gertjan.

I'd also like to thank Hans Tragter for support from the Industrial Design department during my bachelor assignment. For the topic-related support I'd like to thank the faculty of Civil Engineering. Their literature sources and general assistance was of great value for this research. I would especially like to thank Frans Tillema and Kasper van Zuilekom from the VVR group for helping me out with the report and research.

And last but not least I'd like to thank Gertjan and Marjan for pre-reading the report. Their comments were of great use for the final result[55].

55 Don't blame them for spelling errors on this page, as it was written afterwards

ADAS for the Car of the Future

Interface Concepts for Advanced Driver Assistant Systems
in a Sustainable Mobility Concept of 2020

Appendices

April/June 2006
Bachelor Assignment of J.P. Thalen

Faculty of Engineering Technology / Industrial Design
University of Twente

Table of contents

Appendix 1 – ADAS Roadmap

ACC is considered to form a base for longitudinal control of a vehicle. With the current state of the art, cars can maintain safe speed and following distance, and 'stop & go' functions are being implemented as well. ACC will become common with the next few years, growing trust and acceptance amongst the public. Combined with advancing technology, more and more features can be added to or combined with longitudinal control.

1. Forward collision warning and detection (FCW) could increase safety by detecting and even avoid potential collisions with static objects or other traffic. This feature will be a relatively passive one, as the user has no active interaction with it. The system will be operating continuously, the only output being a possible emergency brake or evasive manoeuvre.
2. Intelligent speed assistance systems, as mentioned in Appendix I can be combined with ACC. This way ACC will only drive within the speed limits of a specific location. When the limits change, ACC automatically adapts the car's speed accordingly.
3. Systems like infra-red camera's can enhance the general performance of ADAS detection components during all weather conditions. Current ACC systems still suffer from decreasing performance during the night or in foggy weather.

Besides longitudinal control, lateral control systems also advance. Lane departure warning is just a first step, preparing people for lane keeping systems. With lane keeping, users can take their hands off the wheel and let the car follow lanes automatically. Combined with longitudinal control provided by advanced ACC, one could drive autonomously in appropriate situations. Lane keeping systems can be combined with:

1. Lane changing assistance. Sensors monitor the surroundings of the vehicle, checking for upcoming traffic before changing lanes.

Another important addition to the car of the future are car-to-car and possibly car-to-infrastructure communications. With this technology, car's can communicate, exchange information about the car status, trip destination, etcetera. Cars will become smarter as they know more about themselves and their environment. A brainstorm of possible applications of car-to-car communication, combined with the future ADAS mentioned above.

1. When cars can 'see' each other, and know each other's destinations, they can form platoons of cars following the same route. This offers several advantages, one of them being a more efficient traffic flow[1]. Platooning requires advanced ADAS, as car's need to be able to follow each other. Longitudinal as well as lateral control should be in hands of ADAS.
2. Cars can find so called 'fuel efficient partners'. Know the frontal surface of other cars, an optimal partner can be picked out to follow. This may save fuel and time. A critical factor for this system is the need for a minimal distance between two cars. It may be used in combination with platooning.
3. Cars can warn each other about traffic jams, so alternative routes can be configured to avoid the traffic jam. And once in a traffic jam, more efficient car distributions might be possible based on destination, priority, etcetera. This does not heavily depend on advanced ADAS, but could be more of an advisory system.
4. Certain social advantages can be pointed out. For example, a driver could be informed about the environmental or economical efficiency of other traffic, creating a competition to become the most efficient one. Also, people can keep track of each other on the road, or see where and why co-workers are delayed for an appointment. Privacy issues should be taken in to account with this application.

This bright looking future for ADAS obviously still depends on factors like government, law, social acceptance and technological improvements, but all in all, it's not unthinkable to be realised by 2020. For this project, a decision has to made as to which systems to use, which systems to assume feasible, etcetera.

1 See http://www.verkeerskunde.nl/moxie/actueel/nieuws/mens-blijft-slimme-cruise.shtml

Appendix 2 – ADAS System Analysis

2.1 Adaptive Cruise Control

Supporting Task

Task	*Sub Tasks*	
Stabilisation	Longitudinal	Throttle Control Brake Control Gear Control
Manoeuvring	External	Traffic situation – Vehicles Position – Speed

Function Analysis

Main Function	*Sub Function*
Monitor & maintain longitudinal position	Scan road Detect vehicles Determine vehicle speed Determine local speed Calculate braking time Calculate following distance
Interact with driver	Provide output Acquire input
Intervene	Apply brake Apply gear Apply throttle

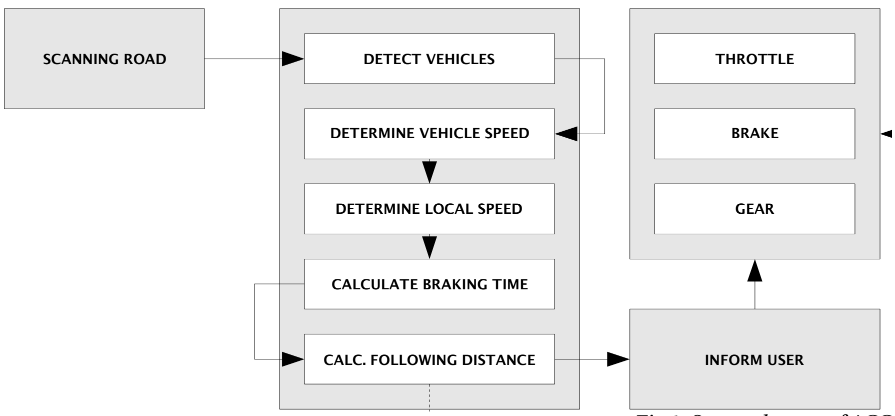


Fig 1: System layout of ACC

System Components

Function	*Component(s)*
Scanning Road	Radar / Camera / Lidar
Detect Vehicles Determine Vehicle Speed Calculate Braking Time Calculate Following Distance	Central Processing Unit Central Processing Unit Central Processing Unit Central Processing Unit
Input/Output	User Interface
Apply Brake Apply Gear Apply Throttle	Engine and brake control system Engine and brake control system Engine and brake control system
Determine Local Speed	Interface To Speedometer

Component Specifications

Sensor type	*Volume*	*Usage*	*Pros*	*Cons*
Lidar	105 x 105 x 76,5 mm, 410 gr [2]		Low cost. Accurate	Weather dependant
Camera		+- 7 Watt	Low cost, integration with lateral systems	Weather dependant, lower accuracy
77 Ghz Radar	2 x (89 mm x 105 mm x 27 mm)[3]		High accuracy, all weather	High cost, small field of vision[4], ghost measurements
24 Ghz Radar	60 mm x 45 mm x 30 mm[3]	3 Watt[5]	High accuracy, all weather, less expensive c.t. 77 Ghz, wide field of vision[6,1] low range	Ghost measurements

2 http://www.hella.com/produktion/HellaCOM/WebSite/MiscContent/Download/AutoIndustry/Electronics/TI_ADAS_GB_TT_07.pdf
3 http://www.hella.com/produktion/HellaCOM/WebSite/MiscContent/Download/AutoIndustry/Electronics/TI_ADAS_GB_TT_07.pdf
4 http://www.cs.berkeley.edu/~bfeldman/Research/PDF's/AVEC2002.pdf
5 T. Ho & S. Chung, “A compact 24 Ghz Radar Sensor for vehicle sideway-looking applications”
6 http://www.smartmicro.de/A_24GHz_ACC_Radar_Sensor.pdf

2.2 Lane Departure Warning/Lane Keeping

Supporting Task

Task	Sub Tasks	
Stabilisation	Lateral	Steering Wheel Brake Control
Manoeuvring	External	Position – Heading

Function Analysis

Main Function	Sub Function
Monitor & maintain lateral position	Scan road Detect road markings Predict path Detect deviations Calculate required corrections
Interact with driver	Provide output Acquire input
Intervene	Apply brake Apply steering wheel

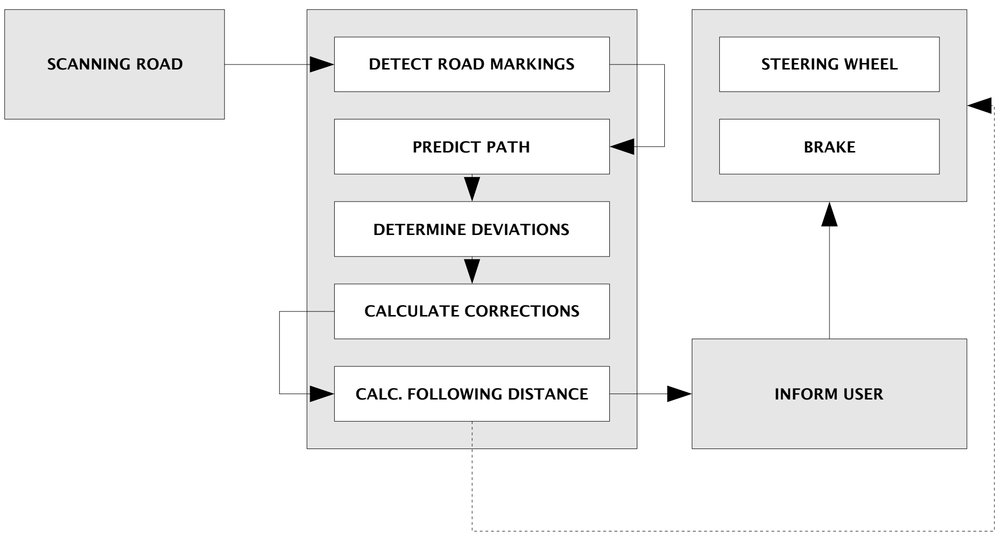


Fig 2: System layout of LDW

System Components

Function	*Component(s)*
Scanning Road	Camera, Infra-red sensor, Radar
Detect road markings Predict path Determine deviations Calculate corrections	Central Processing Unit Central Processing Unit Central Processing Unit Central Processing Unit
Input/output	User Interface
Apply Brake Apply steering wheel	Engine and brake control system Engine and brake control system

Component Specifications

Sensor type	*Volume*	*Usage*	*Pros*	*Cons*
77 Ghz Radar	2 x (89 mm x 105 mm x 27 mm)[7]		High accuracy, all weather	High cost, small field of vision[8], ghost measurements
24 Ghz Radar	60 mm x 45 mm x 30 mm³	3 Watt[9]	High accuracy, all weather, less expensive c.t. 77 Ghz, wide field of vision[10]	Ghost measurements
Camera		+- 7 Watt	Low cost, high accuracy, efficient	Weather dependant
Infra-red			Low cost, high accuracy	Not predictive

7 http://www.hella.com/produktion/HellaCOM/WebSite/MiscContent/Download/AutoIndustry/Electronics/TI_ADAS_GB_TT_07.pdf
8 http://www.cs.berkeley.edu/~bfeldman/Research/PDF's/AVEC2002.pdf
9 T. Ho & S. Chung, "A compact 24 Ghz Radar Sensor for vehicle sideway-looking applications"
10 http://www.smartmicro.de/A_24GHz_ACC_Radar_Sensor.pdf

2.3 Forward Collision Warning

Supporting Task

Task	*Sub Tasks*	
Stabilisation	Longitudinal	Throttle Control Brake Control Gear Control
Manoeuvring	External	Traffic situation - Obstacles

Function Analysis

Main Function	*Sub Function*
Monitor longitudinal safety	Detect obstacles Identify obstacle
Interact with driver	Provide output Acquire input
Intervene	Apply brake Apply throttle Apply gear

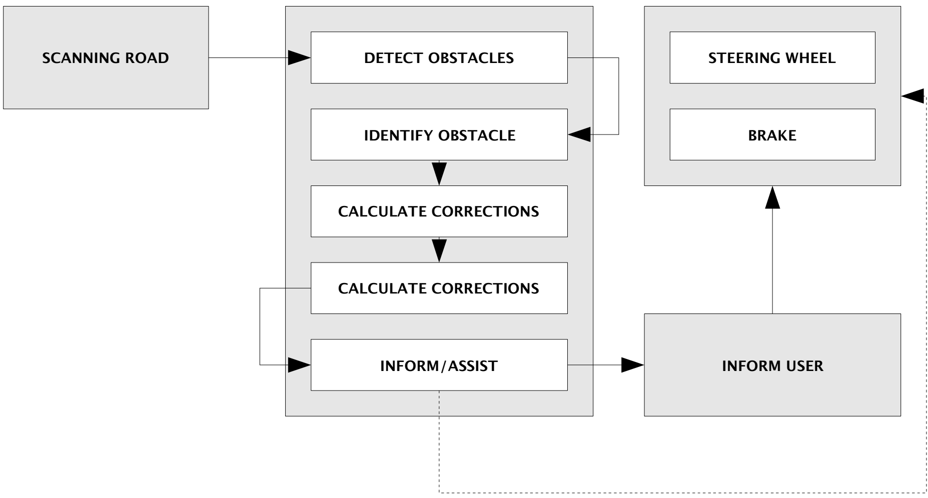


Fig 3: System layout of FCW

System Components

Function	Component(s)
Detect obstacles	Camera, Radar
Identify obstacle	Graphics, Central Processing Unit
Input/output	User Interface
Apply Brake Apply steering wheel Apply gear	Engine and brake control system Engine and brake control system Engine and brake control system

Component Specifications

Sensor type	Volume	Usage	Pros	Cons
77 Ghz Radar	2 x (89 mm x 105 mm x 27 mm)[11]		High accuracy, all weather	High cost, small field of vision[12], ghost measurements
24 Ghz Radar	60 mm x 45 mm x 30 mm³	3 Watt[13]	High accuracy, all weather, less expensive c.t. 77 Ghz, wide field of vision[14]	Ghost measurements
Camera		+- 7 Watt	Low cost, high accuracy, efficient	Weather dependant

11 http://www.hella.com/produktion/HellaCOM/WebSite/MiscContent/Download/AutoIndustry/Electronics/TI_ADAS_GB_TT_07.pdf
12 http://www.cs.berkeley.edu/~bfeldman/Research/PDF's/AVEC2002.pdf
13 T. Ho & S. Chung, "A compact 24 Ghz Radar Sensor for vehicle sideway-looking applications"
14 http://www.smartmicro.de/A_24GHz_ACC_Radar_Sensor.pdf

2.4 Intelligent Speed Adaptation

Supporting Task

Task	*Sub Tasks*	
Stabilisation	Longitudinal	Throttle Control Brake Control Gear Control
Manoeuvring	External	Position – Speed
	Internal	Vehicle status Traffic rules (speed)

Function Analysis

Main Function	*Sub Function*
Monitor and maintain speed	Determine current speed Determine speed limit
Interact with driver	Provide output Acquire input
Intervene	Apply brake Apply throttle Apply gear

System Components

Function	*Component(s)*
Determine current speed	Car systems output (speedometer)
Determine speed limit	Communication devices, car-to-infrastructure
Input/output	User Interface
Apply Brake Apply steering wheel Apply gear	Engine and brake control system Engine and brake control system Engine and brake control system

Appendix 3 – Technical Analysis

3.1 Adaptive Cruise Control

Adaptive Cruise Control (ACC) is an elaboration on the conventional cruise control. Usually, cruise control systems maintain a user-set speed. At any time a user can intervene by applying throttle or brake pedal. The system will deactivate and the user regains control. Some systems let the user intervene, and take over control after the user takes his foot of the pedal.

ACC adds intelligence to this system, by giving it sensors. These sensors monitor the road and traffic in front of the vehicle, detecting cars and obstacles. With ACC, when the car approaches another car that is driving slower, the system will decrease speed to maintain a safe following distance. As soon as the car in front disappears (by increasing speed, changing lanes or leaving the highway) the ACC increases speed to the pre-set value.

Whenever the system has to brake with more force than a specified maximum amount (differs per system, manufacturer), the system will inform the user by audio or visual cue, and deactivates. From here the user is back in control of speed.

A next step in ACC is the implementation of “Stop & Go” functionality. This enables the car to come to a full stop, for example while driving in a traffic jam. A problem with Stop & Go technology is to find suitable (short range) sensors and the required (safe) amount of braking force needed to fully stop the vehicle.

Technology

For ACC, the most important part of system technology is the traffic sensor. With current systems the RADAR is most often used. RADAR sends out radio waves, and calculates distances by counting the time of flight of each radio wave. A RADAR detection beam used in cars is usually about 150 meters long, and 3 to 4 degrees wide to each side of the car. These waves operate in any weather conditions. This makes RADAR a reliable sensor technology for ACC systems. Reliability comes with a price, as RADAR is also the most expensive technology.

Alternatively, some systems use laser, infra-red or camera systems to create an image of the traffic situation in front of the vehicle. An obvious advantage is the ability to distinguish relevant traffic from tin cans and other obstacles. A drawback is weather influence: fog and snow can decrease sensor visibility.

Applications

ACC is often referred to as the first step of ADAS introduction. The mass implementation of the system confirms this. Several car manufacturers offer ACC as a standard or extra option with their production cars.

For example, Mercedes is offering “Stop & Go” ACC in their 2007 S550 cars[15]. This system uses a combination of RADAR and infra-red to determine distances and movements of traffic or obstacles[16]. Other examples include the Lexus LS430/460 and the BMW 3,5 and 7 series. Other car companies also implement ACC, even in more medium priced cars like the Volkswagen Passat (2006).

User Interface

The user interface of these systems is generally located in the dashboard, somewhere between the speedometers. A car icon represents the user, and additional text, numbers and icons indicate system activity, other traffic, etc. Most interfaces indicate at least the ACC status (on/off), pre-set speed, car following speed and car-to-car distance.

Fig 4: ACC user interface integrated in dashboard

15 See http://www.gayot.com/lifestyle/automobile/reviews/2006/mercedes_benz_s_class_page2.html
16 http://www.conti-online.com/generator/www/de/en/cas/cas/themes/products/electronic_brake_and_safety_systems/driver_assistance_systems/radar_and_infrared_technology_en.html

3.2 Lane Departure Warning

Lane Departure Warning (LDW) systems monitor the lateral position of the car with respect to the road. A sensor detects lane markings on the road, and checks the position of the vehicle. If a car tends to drift to the left or right by accident, for example when the driver is tuning a radio, the system will notice the driver. This notification differs per system, from visual and audio cues to vibrating seats or steering wheels.

LDW is being used by large vehicles (long distance trucks in the United States) already, and is slowly penetrating consumer car markets as well. LDW is just a first step though. Successors are already being developed in the form of Lane Keeping System (LKS) and Lane Change Assistant (LCA) or Lane Departure Assistant(LDA)[17].

LKS is a combination of LDW and active steering controls. Using the sensors of LDW, the steering wheel is corrected by a computer, keeping the car in lane. This way a car can (theoretically) be controlled autonomously. LDA is a less autonomous application. It supports the driver while changing lanes by 'looking backwards' and warning for traffic in blind spots.

Technology

Most LDW systems use CCD or CMOS camera's to get a digital image of the traffic situation in front of the vehicle. Using an image processor, the current lane and possible deviations can be calculated. Use of camera's offer the advantage of seeing the road up to 25 meters ahead.

An alternative method, using infra-red sensors doesn't offer this feature. Infra-red sensors are located directly under the front bumper, aimed at the road. They detect road markings as soon as the front of the car crosses them.

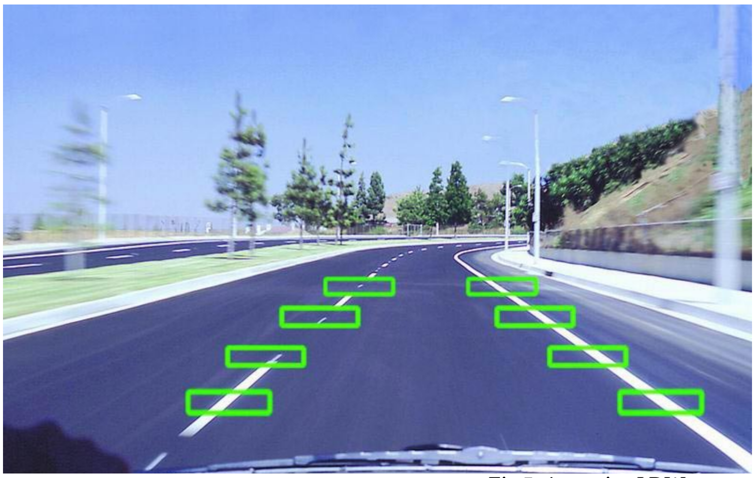


Fig 5: An active LDW system

Applications

The Delphi ForeWarn LDW system is an example of an LDW system using camera's[18]. Nissan offers the Infiniti FX and M45 equipped with such systems. They are however limited to operate only on speeds above 45 mph, as the system can't effectively predict lane changes when driving slower.

Citroen C4 and C5 models are equipped with infra-red based LDW systems[19].

LDW is seen as a great safety improving solution, as accidental lane departure is a major cause of accidents[20]. However, taking over the steering wheel control is currently considered to much automation[21].

17 See http://www.conti-online.com/generator/www/de/en/cas/cas/themes/products/electronic_brake_and_safety_systems/driver_assistance_systems/lane_keeping_en.html
18 See http://delphi.com/manufacturers/auto/safesecure/warning/warning/
19 See http://www.citroen.nl/CWH/nl-NL/Corporate/Modellen/Techniek+en+Innovatie/Lane+Departure+Warning+System.htm
20 See http://www.ivsource.net/modules.php?name=IV_Archives&file=article&sid=28
21 See http://www.automotivedesignline.com/howto/60405845

3.3 Intelligent Speed Adaptation

Compared to ACC and LDW, Intelligent Speed Adaptation, or Assistant (ISA) is a relatively easy concept. With ISA, a vehicle receives information about local speed limitations based on it's location on a digital map, using GPS. Knowing the speed limits, ISA can inform the driver about it, advise or even adapt speed accordingly.

ISA has been used in buses and trucks for years, and is slowly finding it's way into passenger cars. A main concern with ISA is the acceptance of the public. People find it hard to accept a computer is controlling their speed. So, the rate of control is an important aspect of ISA implementation. Several research projects investigated the possible options.

Technology

Technology used with ISA is fairly straightforward. The only requirement for the system is to be aware of the local maximum speed, and the speed of the car. Two solutions are used, one being GPS, the other being roadside transponders[22]. With GPS, there's a benefit in that infrastructure doesn't need changes. Using the GPS based position and a digital map the maximum speed can be determined. Roadside transponders provide the car with information about local speeds.

Eventually, an autonomous version of ISA is planned. The Autonomous Speed Assistant can determine desired maximum speeds based on map input, road status and weather conditions.

Trials

In Sweden, a large-scale experiment with the 'supportive' variant[23]. When the driver exceeds local speed limits, the gas pedal would resist with more pressure. However, the driver could overrule ISA by pressing down the gas pedal with more power. The experiment showed a decrease in speed, and a decrease in travelling time. The users reported they were driving safer (or at least feeling so) and smoother. On the other hand, they found driving to become less fun, and had a feeling of being watched all the time.

In Tilburg, the Netherlands, experiments with a mandatory implementation of ISA shows similar results[24]. ISA is recognised as a traffic safety improvement, however, there's a more negative attitude towards mandatory solutions compared to informing or assisting.

General conclusion of the trials are that to achieve acceptance, the ISA should be of an advisory kind, and most effective in urban area's with maximum speeds of 30 to 50 km/h.

User Interface

With ISA the user interface determines a great deal of acceptance. Whether the system should enforce safe speeds or just inform the user has a great influence on acceptance. The research mentioned above shows a preference for non-mandatory systems.

22 See http://www.isa.vv.se/index.en.htm
23 See http://www.isa.vv.se/cgi-bin2/dynamic.cgi?page=39&lang=en
24 Kraay, J.H, “THE NETHERLANDS TRAFFIC & TRANSPORT PLAN; ROAD SAFETY WITH A SPECIAL FOCUS ON SPEED BEHAVIOUR”, Ministry of Transport, the Netherlands

3.4 HEAD-UP DISPLAYS

Originally designed for fighter aircraft, Head-Up Displays (HUDs) are currently being introduced to production cars. A HUD projects information on a invisible (transparent) display in front of the user. The result is a combined view of environment and information.

Fig 6: A BMW Head-Up Display

Issues

Though the superimposed display of information within the line of sight of the driver may keep the driver from looking down or to the right, there are still some safety concerns with HUDs in cars.

First of all, the direct comparison with fighter pilots isn't applicable, as fighter pilots are intensely trained to use the HUD. For people who don't drive a lot, a HUD may display too much information, or distract from important external traffic situations. However, according to a HUD field-test[25], obstruction of sight is not a major problem with these displays.

Second, some usability issues exist. People wearing bi-focal glasses had to lower and raise their head in order to accurately read the display, resulting in strained muscles. Furthermore, people didn't like the fact that they had to keep their head fixed in a virtual box to use the HUD. Assuming a more relaxed position would result in problems reading the display.

Finally, current HUD technology is quite expensive. Most HUDs use some kind of LED light to beam an image trough a set of mirrors, ending up on the windscreen. This windscreen also requires special production methods, including a wedge shaped plastic between two layers of glass, in order to correct the displayed image.

Conclusion

Concluding, it can be said that HUDs have a fair chance of succeeding in the automotive industry. However, several issues have to be dealt with.

- More research regarding distraction and vision obstruction
- HUDs should be user-adaptable to prevent relatively simple usability problems
- Technology should become more cost-efficient

25 G. Burnet, “A road-based evaluation of a HUD for presenting navigational information”, School of Computer Science and IT, Nottingham, UK, june 2003

Appendix 4 – Automotive Interface Guidelines

4.1 Visual Displays

Physical

Information shown on a in-car visual display is most readable when the display is in the line of sight of the driver. It should be placed as close to the vertical centre as possible, and with a maximum viewing angle of 30 degrees. Physical requirements are therefore that the display should not be interfered by glare under these circumstances[26].

Distance between the driver and the display is not important, as long as the display doesn't obstruct the line of sight of the driver. Fonts and symbology should be able to adapt to the user distance. Grouping similar or co-relevant information increases recognition and interpretation of the information.

Colours

The use of colours may enhance readability of visual information. The following guidelines ensure optimal effects of colour use.

- Avoid reliance on colour coding of critical information
- Too many colours create more information density and an increase in search time.
- Colours from extreme ends of the colour spectrum (i.e., red and blue) should not be put next to each other
- Use familiar colour coding
- Colour codes should be used consistently
- Colour alone should not be relied on to discriminate between items
- Coloured symbols should differ from their coloured backgrounds by a minimum of 100ΔE (CIE Yu'v') distances
- Highly saturated blue (i.e., approximately 450 nanometres) should be avoided

Text

Text messages can support or replace symbology. The selection of text, fonts and messages is free as long as the text is readable within a certain time frame. For on-screen characters, the following guidelines[27] are used.

- Provide adequate symbol space-to-height ratios so that 95 percent of drivers can comfortably and quickly read the ATIS symbology 95 percent of the time.
- To the extent possible, provide wider spacing (up to a 0.25:1 ratio) as the criticality of the display information increases (e.g., hazard warnings).
- To the extent possible, provide wider spacing (up to a 0.25:1 ratio) as the number of alternate cues to legibility (e.g., consistent position, colour) decreases.
- To the extent possible, provide wider spacing (up to a 0.25:1 ratio) for dynamic symbology (e.g., next turn) than for static symbology (e.g., legends).

26 http://www.fhwa.dot.gov/tfhrc/safety/pubs/95153/sec5/sec5_03_02.html
27 http://ntl.bts.gov/DOCS/atis/ch03/body_ch03_07.html

Text message guidelines:[28]

- Text messages presented when the vehicle is in motion should be no longer than 4 information units, in order to minimize the eyes-off-road time.
- Many text messages are best presented while the vehicle is stationary. In these cases, 6-8 information units are optimal.

4.2 Auditory Interaction

General[29]

Speech recognition can be used in situations where the user's other input channels are not available. A car driver may be an example of such a user. Important factors are the surroundings of the user (i.e. background noise) and the user should be alone and stationary. Furthermore, the speech software should be intelligent so that it can get to learn the users' voice in the relevant environment.

Input Guidelines

- Keep small the number of words in the speech recognition vocabulary
- Keep short each speech input
- Use speech inputs that sound distinctly different from each other
- Provide immediate feedback for every speech input
- Make error correction intuitive
- Don’t use speech to position objects
- Use a command-based user interface
- Allow users to quickly and easily turn off and on the speech recognizer

Output Guidelines[30]

- Messages that require an urgent action should be a single word or a short sentence with the fewest number of syllables possible. Drivers should be able to understand the message immediately.
- Messages that are not urgent or for which a response may be delayed can be a maximum of 7 units of information in the fewest number of words possible. If the information cannot be presented in a short sentence, the most important information should be presented at the beginning and/or the end of the message.
- Offer a possibility to repeat output
- Offer visual support for auditory output

Hardware Requirements

- Use a highly directional, noise-cancelling microphone
- Consider using headphones or an earphone (versus a speaker) for auditory feedback
- Use full duplex audio (combine input and output channels)
- Consider providing a back-up input technique to speech

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28 http://ntl.bts.gov/DOCS/atis/ch03/ch03_14.html
29 **J. Najjar, J. Ockerman et al**, “User Interface Design Guidelines for Speech Recognition Applications”, Georgia Tech Research Institute, Atlanta, United States, 1998
30 See http://ntl.bts.gov/DOCS/atis/ch03/body_ch03_13.html

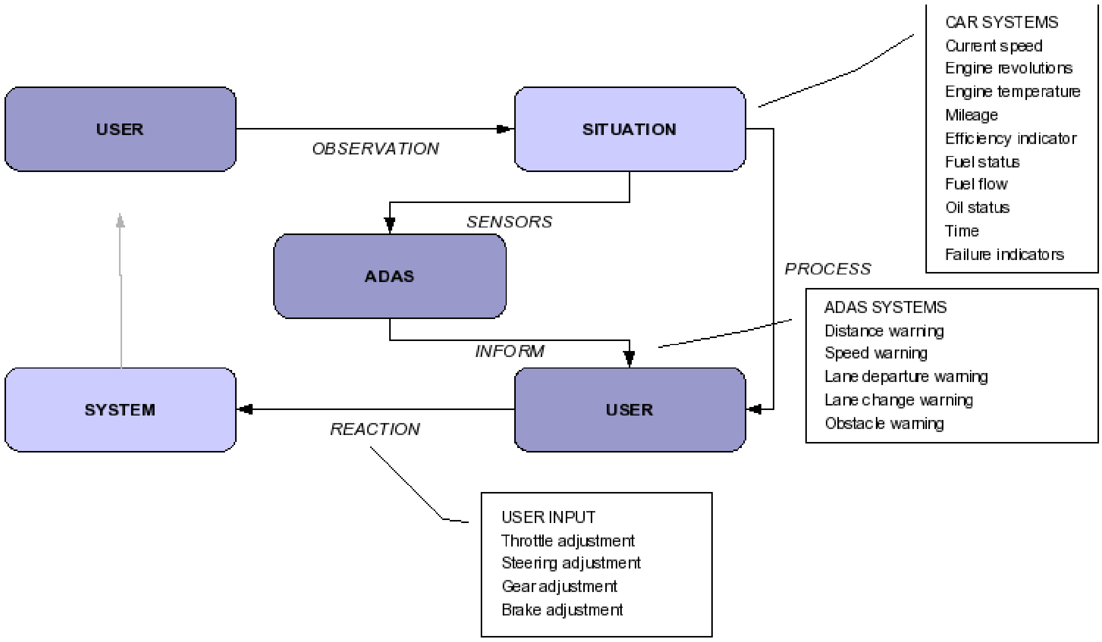
Appendix 5 - Driving Task Analysis

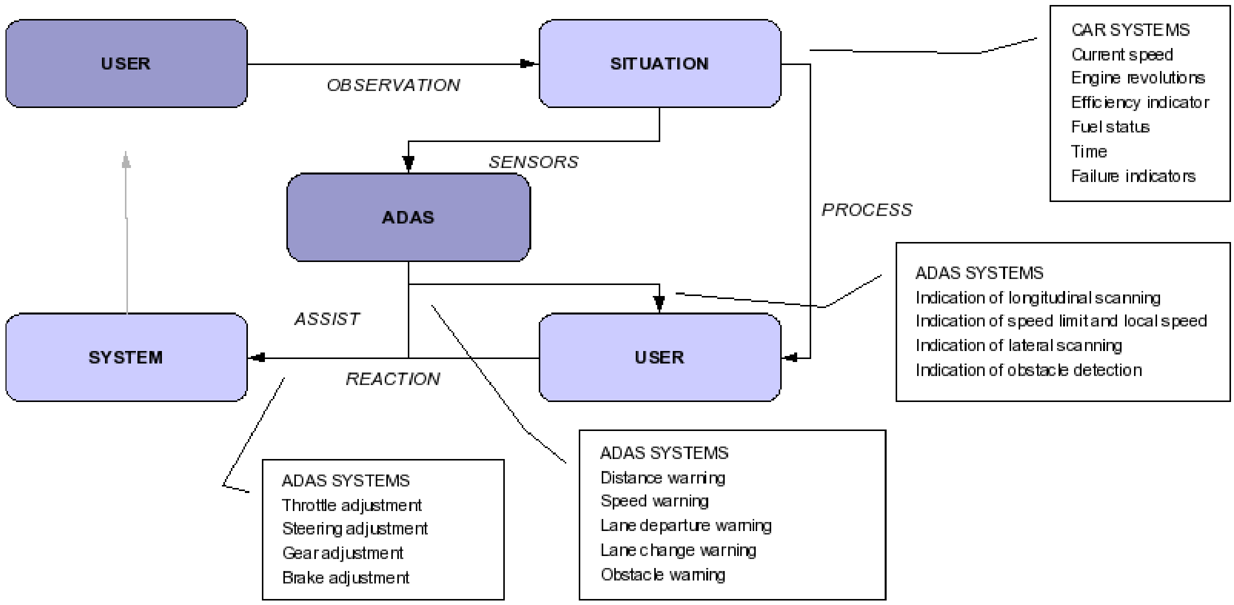
To specify which tasks are supported by the ADAS, a task analysis of the 'normal' driving task is made. This is done by describing all tasks a user has to execute in order to drive, or perform a specific action. The task analysis contains primary and secondary tasks.

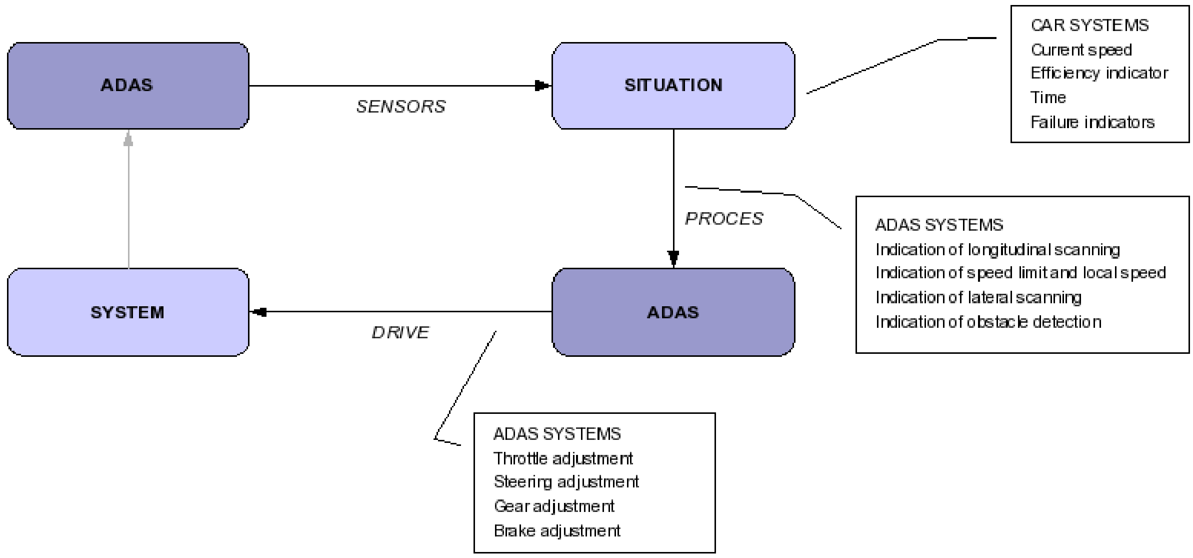
Each task may also contain subtasks, which are required to fulfil the main task. For this analysis, only (primary) driving tasks are listed. Secondary tasks like controlling a window or radio are not relevant here.

- 1.1 Stabilisation
  - 1.1.1 Longitudinal
    - 1.1.1.1 Throttle control
    - 1.1.1.2 Brake control
    - 1.1.1.3 Gear control
  - 1.2.1 Lateral
    - 1.2.1.1 Steering wheel
    - 1.2.1.2 Brake control
- 1.2 Manoeuvring
  - 1.2.1 Internal
    - 1.2.1.1 Vehicle status
    - 1.2.2.2 Traffic Rules
  - 1.2.2 External
    - 1.2.2.1 Traffic situation
      - A. Vehicles
      - B. Obstacles
      - C. Pedestrians
    - 1.2.2.2 Road signs
    - 1.2.2.3 Position
      - A. Speed
      - B. Heading
- 1.3 Navigating
  - 1.3.1 Route planning
  - 1.3.2 Route following

Appendix 6 – Interaction Diagrams






ADAS
SENSORS
SITUATION
CAR SYSTEMS
Current speed
Efficiency indicator
Time
Failure indicators
PROCES
ADAS SYSTEMS
Indication of longitudinal scanning
Indication of speed limit and local speed
Indication of lateral scanning
Indication of obstacle detection
SYSTEM
DRIVE
ADAS
ADAS SYSTEMS
Throttle adjustment
Steering adjustment
Gear adjustment
Brake adjustment

Appendix 7 - Workload Manager

The workload manager is presented as a shell surrounding the user interface (HMI). This indicates the importance of a workload manager, it's therefore described more thoroughly below.

The main task Workload Manager subsystem is to make sure that the workload of the driver is within safety limits. The workload of the driver, as described in Chapter 2, is affected by both the internal and external situation of the vehicle.

Busy or increasing traffic enforces the driver to pay more attention to the external situation in order to remain within safety limits. This increases the workload, as more visual attention is addressed by traffic. Inside the car workload may increase due to an increase of information, either from the ADAS systems, a phone, the car radio or passenger.

In order for the Workload Manager to operate, it needs to be able to assess both the internal and external situation of the vehicle. For the external situation available sensors are the forward camera and the two radar systems. Also, the communication device may be used to assess long-distance traffic, thus predicting increasing workload. For the inside situation, several methods are being investigated, as stated in Chapter 2.

After assessing the situation, the Workload Manager should be able to decide whether the workload is acceptable or not, and what to do about it. The global functionality of the described workload manager is presented in the diagram below.

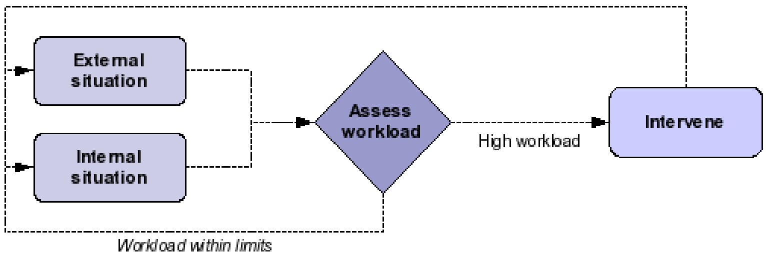


Fig 7: Basic layout of the workload manager

External Situation Assessment

To assess the external situation of the vehicle, several sources are available.

- The forward looking camera – Using image processing software it may be possible to determine traffic density and environmental circumstances like the weather and road status.
- The Radar systems may be used to backup the camera recognition, and to assess short-range traffic density
- Communication – By communicating with other ADAS enabled vehicles it's possible to make a long-range assessment of traffic conditions. Communication with road-side systems or satellite systems can be used to determine current location, which may indicate something about known safety risks.

The workload manager should use the assessment of the external situation to determine how much driver attention is needed to safely operate the vehicle. The systems' CPU may be used for calculations, which may result in a percentage or score, indicating the required attention. The workload manager now needs to assess the internal situation in order to compare the two variables and make a decision accordingly.

Internal Situation Assessment

For the assessment of the internal situation, the system may use one of the following methods.

- Driver Physical Condition – This measurement requires temperature and vital signs sensors for heart rate, blood pressure, etc.
- Driver's motions – The way a driver operates the vehicle may indicate increasing or decreasing awareness. For accurate measurements, it would also need a vehicle black box in order to compare current driver motions with a personal 'driving character'.

- Driver's voice – Experiments are being held which investigate the usability of the driver's voice to determine the level of awareness. This measurements requires a high quality microphone.
- In-vehicle systems – The Workload Manager could be aware of where the driver's attention is by monitoring all in-vehicle systems, including the radio, the navigation system and the phone.

Using one or more of these methods, a score or 'awareness-percentage' can be calculated for the internal situation. The workload manager should then compare the internal and external values, and decide what to do.

Processing & Intervention

The assessment of both the internal and external situation need to be updated constantly. The workload manager should have a real-time situation assessment, possibly extended by information trough external communication. If the workload manager detects an increasing workload and an increasing demand of attention, a few possibilities are available to return to the safe situation.

- According to the traffic situation, offer the driver to engage more supporting systems. This may be achieved by sending a signal to the user interface, indicating a need for increasing support.
- Temporarily disengage secondary in-vehicle systems. During busy traffic, the workload manager may prevent calls from coming in, or disable the in-vehicle multimedia systems.
- If the external situation requires attention, and the driver is not aware of this, a signal could be sent to the user interface in order to alert the driver. In case the driver doesn't respond in time, the workload manager could engage control systems like LKS and ACC.

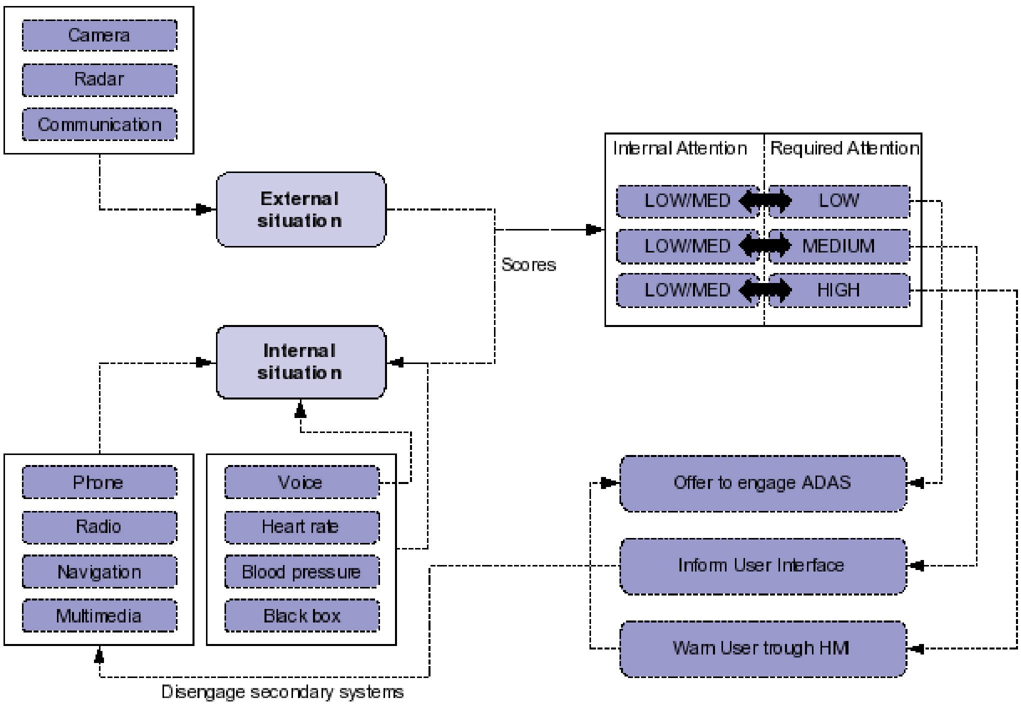


Fig 8: The functions of the workload manager in a subsystem diagram

The diagram shows how the internal and external situations are evaluated, and which actions may be taken to achieve a safe situation. If the internal situation (i.e. the driver awareness) is high, the system should simply continue monitoring without further actions. This is not shown in this diagram. Choosing the driver awareness sensors heavily depends on the interface concept. For example, if the interface concept uses speech recognition, the microphone may also be used for the awareness measurements.

It should be noted that the Workload Manager as presented is just a basic concept of such a system. Further research is required to determine which methods provide best results regarding situation assessment and intervention.

Appendix 8 – Interface Evaluation

8.1 RESPONSE Checklist Part B

For evaluation of the interface concepts, the HMI section of the RESPONSE Checklist part B is used. Each table contains a question with respect to the HMI. The question is discussed with respect to each concept, and awarded a score between 1 (negative influence on the topic) and 3 (positive influence on the topic).

1. Do the system reactions correspond to the previous experiences and expectations derived from driving or using related systems (Expectation conformity)?		***Predictability***
Concept 1	Yes, as this concept uses classical and familiar instrumentations. The longitudinal safety indicator operates very similar to a common speedometer or revolutions indicator.	3
Concept 2	Yes, as this concept uses either classic dials (the hardware version) or software dials (software version) which are more and more used in current production cars. The top-down view as used in the integrated ADAS display is often seen in current computer applications and navigational systems.	3
Concept 3	No, the display of information within the driver's field of vision is not often used today. However, an increase in automotive HUDs as seen today may cause HUDs to be common in 2020. The use of voice commands is assumed known by 2020.	2
Concept 4	No, the interaction with machines as proposed in the concept is not often used today, and not foreseen for the near future. Quite some technological advanced are needed in order for machines to naturally interact with humans.	1

2. Does the driver get a clear feedback on the selection of different system modes/system states?		***Predictability***
Concept 1	Not really. The system state is indicated by LEDs on the steering wheel and gear lever. Confusion may arise while driving in assisted mode, in which case LEDs will light up when the system is active, but only then.	1
Concept 2	Yes, a visual indicator to indicate system state (off, inform, assist, support) is used in the visual display.	3
Concept 3	Yes, a visual indicator to indicate system state (off, inform, assist, support) is projected on the windscreen	3
Concept 4	Possibly. The driver assistant can indicate system state by location, placement, movements or expressions. However the effectiveness should be investigated.	2

3. Can critical situations arise if the user (driver) wants to activate the system and the system is not available?		***Controllability, Traffic Safety, Responsibility***		
Concept 1	No. If the system is not available it will indicate so, and the traditional vehicle control devices are available for use.	3	3	3
Concept 2	No. If the system is not available it will indicate so, and the traditional vehicle control devices are available for use.	3	3	3
Concept 3	No. If the system is not available it will indicate so, and the traditional vehicle control devices are available for use.	3	3	3
Concept 4	No. If the system is not available it will indicate so, and the traditional vehicle control devices are available for use.	3	3	3

4. Is the user informed if a detectable system error occurs?		***Traffic Safety, Responsibility***	
Concept 1	Yes, by the use of auditory cues	2	2
Concept 2	Yes, by the use of visual and auditory cues	3	2
Concept 3	Yes, by the use of visual (in line of sight) and auditory cues	3	2
Concept 4	Yes, by the use of visual and auditory humanised feedback	3	2

5. Are system messages, which are relevant for the driving task, display in time with respect to the situation?		***Responsibility***
Concept 1	Yes, -+	1
Concept 2	Yes, +	2
Concept 3	Yes, ++	3
Concept 4	Yes, -+	2

6. Is it possible to adjust system parameters to traffic and environmental conditions?		***Responsibility***
Concept 1	Yes, but not likely while driving	1
Concept 2	Yes, by voice commands and visual display	3
Concept 3	Yes, by voice commands	2
Concept 4	Yes, by voice commands	2

7. Does the product information deal with a possible need for special skills? Does it point out that the system is unsuitable for certain groups of users?		***Responsibility, Misuse Potential***	
Concept 1	No special skills	3	1
Concept 2	Native language voice commands, no special skills	2	2
Concept 3	The use of HUDs may cause problems with people wearing bi-focal glasses	2	3
Concept 4	Native language voice commands, no special skills	2	2

8. Are there realistic possibilities to adjust type approval rules or laws?		***Responsibility***
Concept 1	General ADAS acceptance	3
Concept 2	General ADAS acceptance	3
Concept 3	HUD acceptance, ADAS	2
Concept 4	General ADAS acceptance	3

9. Have there any methods been applied to avoid design errors (ISO9000, safety and risk estimation, check-lists)?		***Responsibility***
Concept 1	RESPONSE Checklist for system design, EsoP,AAM Guidelines, general HMI/human factors	2
Concept 2	RESPONSE Checklist for system design, EsoP,AAM Guidelines, general HMI/human factors	2
Concept 3	RESPONSE Checklist for system design, EsoP,AAM Guidelines, general HMI/human factors, concept is not in accordance with current guidelines. (HUDs are not allowed everywhere yet)	1
Concept 4	RESPONSE Checklist for system design, EsoP,AAM Guidelines, general HMI/human factors	2

10. Has the system a negative impact on driving efficiency?		***Driving Efficiency***
Concept 1	Not expected	3
Concept 2	Not expected	3
Concept 3	Windscreen display may consume more power than traditional displays	2
Concept 4	Not expected	3

11. Are there traffic situations where the driver's sensory channels are overloaded due to system specific HMI layout?		***Workload,***	***Error Robustness***
Concept 1	Not expected	3	2
Concept 2	While in assisted mode, both ADAS and classic output is presented, which may cause visual overload	2	2
Concept 3	While in supported mode, the HUD may visually overloading the user	2	2
Concept 4	Not expected	3	2

12. Are all HMI-procedures interruptible by the driver once initiated?		***Workload***
Concept 1	Trough controls in the steering wheel & actuator input	3
Concept 2	Trough voice commands & actuator input	3
Concept 3	Trough voice commands & actuator input	3
Concept 4	Trough voice commands & actuator input	3

13. Is it possible that action slips occur during the operation of the system?		***Error Robustness***
Concept 1	Yes, buttons on the steering wheel may be accidentally pressed	1
Concept 2	Yes, trough voice command error	2
Concept 3	Yes, trough voice command error	2
Concept 4	Yes, trough voice command error	2

14. In case of an incorrect input: Can the desired result be achieved with no or small correction effort?		***Error Robustness***
Concept 1	Yes, by using buttons	3
Concept 2	Yes, by using voice commands	3
Concept 3	Yes, by using voice commands	3
Concept 4	Yes, by using voice commands	3

15. Are physical constraints implemented to prevent incorrect operation?		***Error Robustness***
Concept 1	No, though needed	1
Concept 2	No, no need to do so	2
Concept 3	No, no need to do so	2
Concept 4	No, no need to do so	2

16. Does the warning system alert the user only to genuine hazards that have not already been recognised by him/her?		***Trust***
Concept 1	Yes, the system first waits for the user to act, until finally intervening	3
Concept 2	Yes, the system first waits for the user to act, until finally intervening	3
Concept 3	Yes, the system first waits for the user to act, until finally intervening	3
Concept 4	Yes, the system first waits for the user to act, until finally intervening	3

17. Is the presentation of warnings appropriate to the criticality of the hazard?		***Trust***
Concept 1	Somewhat, a fixed scale indicator indicates hazards	2
Concept 2	Yes, the visual display indicates hazard types	3
Concept 3	Yes the windscreen display indicates hazard types	3
Concept 4	Yes, the assistant indicates hazard types	3

18. Is it likely that the user or car equipped with the system will not attend to and perceive a system message? ***Perceptibility***		
Concept 1	Quite likely	1
Concept 2	Quite likely	1
Concept 3	Not likely	3
Concept 4	Not likely	3

19. Is it likely that the user of a car equipped with the system will misinterpret a system message? ***Perceptibility, Traffic Safety***			
Concept 1	Yes, the indicator only indicates safety	1	1
Concept 2	No, system indicates messages trough text and speech	3	3
Concept 3	Yes, symbols on the HUD may me misinterpreted	2	2
Concept 4	Not likely, the system indicates messages trough speech	3	3

20. Could the system issue too much warnings that then will come to be ignored? ***Trust, Acceptance***			
Concept 1	Yes, the indicator may be ignored after indicating safety for a longer period of time	2	2
Concept 2	Possibly visual cues may be ignored	2	2
Concept 3	Not likely, as warnings appear in the line of sight	3	3
Concept 4	Not likely, as the assistant will change behaviour accordingly	3	3

8.2 European Statement of Principles for HMI design

A review of the EsoP 2005 is used to evaluate the interface concepts, and possibly find gaps. The principles have been divided over several sections.

1. Design Goals
2. Installation Principles
3. Information Presentation Principles
4. Interaction with Displays and Controls
5. System Behaviour Principles
6. Information about the System

Section 6 is considered irrelevant for this project, as it discusses guidelines for instructions and manuals. From the other sections, all principles will be discussed briefly.

1.1 The system supports the driver and does not give rise to potentially hazardous behaviour by the driver or other road users.
This guideline is used throughout the design of both the global system and the interface. The basic idea of each concept is to enhance safety, and by using the defined system framework each concept should be able to achieve this goal.

1.2 The allocation of driver attention to the system displays or controls remains compatible with the attentional demands of the driving situation.
This is achieved by offering different sates of support and assistance, with suiting amounts of system output.

1.3 The system does not distract or visually entertain the driver.
This guideline is a more classic one aimed at the design of in-car information and entertainment systems. Obviously, ADAS system interfaces need to distract the user to inform about hazardous situations.

1.4 The system does not present information to the driver which results in potentially hazardous behaviour by the driver or other road users.
Concept 1 may potentially cause negative behavioural changes, because it doesn't always indicate what's going wrong exactly. This is a major drawback of the concept, and should be considered for re-design. The other concepts use explicit warnings and assistance to inform the user.

1.5 Interfaces and interaction with systems intended to be used in combination by the driver while the vehicle is in motion are consistent and compatible.
This guideline is a more classic one aimed at the design of in-car information and entertainment systems. It should be noted though that the design of the interface must be consistent with the global interior design.. Also, ADAS interfaces should be consistent with possible car system interfaces. (For example, speedometer and safety indicator of concept 1)

2.1 The system should be located and securely fitted in accordance with relevant regulations, standards and manufacturers instructions for installing the system in vehicles
Irrelevant, since the concept is an integrated part of the car design

2.2 No part of the system should obstruct the drivers view of the road scene
This guideline is relevant for several concepts. First, concept 3 uses a windshield display. This solution is not yet allowed in certain countries, partly because of this guideline. Though HUDs are becoming more common, research should further investigate the benefits of these displays. Furthermore, concept 4 may have a problem, as it uses a physical appearance to assist the user. This 'robot' shouldn't obstruct the field of vision, but at the same time must be noticed in case of emergencies.

2.3 The system should not obstruct vehicle controls and displays required for the primary driving task
Irrelevant for these concepts

2.4 Visual displays should be positioned as close as practicable to the driver's normal line of sight
No problems are expected with concepts 1 and 2. For concept 3 and 4 the same problems as stated under 2.2 are addressed by this guideline.

2.5 Visual displays should be designed and installed to avoid glare and reflections
Only concept 3 may have major problems with glare and reflections. Further development of head-up displays and other transparent display technology may come with solutions.

3.1 Visually displayed information presented at any one time by the system should be designed such that the driver is able to assimilate the relevant information with a few glances which are brief enough not to adversely affect driving
All concepts have been designed with this guideline in mind. The effectiveness should be tested with field tests.

3.2 Internationally and/or nationally agreed standards relating to legibility, audibility, icons, symbols, words, acronyms and/or abbreviations should be used.
This guideline is met by using the standards mentioned in appendix 3.

3.3 Internationally and/or nationally agreed standards relating to legibility, audibility, icons, symbols, words, acronyms and/or abbreviations should be used.
This guideline is met by using the standards mentioned in appendix 3.

3.4 Information which has the highest safety relevance should be given priority
This guideline is covered by the priorities definition in the Interface Development chapter.

3.5 System generated sounds, with sound levels that can not be controlled by the driver, should not mask audible warnings from within the vehicle or the outside.
This guideline should be taken into account when further developing one of the concepts.

4.1 The driver should always be able to keep at least one hand on the steering wheel while interacting with the system.
None of the concepts have problems with this guideline

4.2 The system should not require long and uninterruptible sequences of manual-visual interactions. If the sequence is short, it may be unininterruptible.
This guideline should be taken into account when further developing one of the concepts.

4.3 System controls should be designed such that they can be operated without adverse impact on the primary driving controls.
Only concept 1 may have problems with this guideline, as it uses controls fitted on the steering wheel. Concepts 2 trough 4 mainly use voice control.

4.4 The driver should be able to control the pace of interaction with the system. In particular the system should not require the driver to make time-critical responses when providing inputs to the system.
This guideline should be taken into account when further developing one of the concepts.

4.5 The driver should be able to resume an interrupted sequence of interactions with the system at the point of interruption or at another logical point.
This guideline should be taken into account when further developing one of the concepts.

4.6 The driver should have control of the loudness of auditory information where there is likelihood of distraction.
This guideline should be taken into account when further developing one of the concepts.
4.7 The systems response following driver input should be timely and clearly perceptible.
This guideline should be taken into account when further developing one of the concepts.

4.8 Systems providing non-safety dynamic visual information should be capable of being switched into a mode where that information is not provided to the driver.
This task is relayed to the workload management system.

5.1 While the vehicle is in motion, visual information not related to driving that is likely to distract the driver significantly should be automatically disabled, or presented in such a way that the driver cannot see it.
In a way this contradicts with the general idea of the ADAS concept. By taking over the driving task, more time and space is available for secondary tasks. However, the driver should always be available to regain vehicle control.

5.2 The behaviour of the system should not adversely interfere with displays or controls required for the primary driving task and for road safety.
See 5.1

5.3 System functions not intended to be used by the driver while driving should be made impossible to interact with while the vehicle is in motion, or, as a less preferred option, clear warnings should be provided against the unintended use.
See 5.1

5.4 Information should be presented to the driver about current status, and any malfunction within the system that is likely to have an impact on safety.
The system “Failure” state covers this.

5.5 In the event of a partial or total failure of the system, the vehicle should remain controllable, or at least should be capable of being brought to a halt in a safe manner.
The system “Failure” state covers this.

Appendix 9 – Project Approach

9.1 Conceptual Design

An overview of the entire project. Who are the participants, what are their requirements. How are they involved? The exact assignment description and objectives of this research are phrased.

Actor analysis

The two key participants within the project are Stichting Natuur & Milieu[31] (Society of Nature & Environment, SNE) and the Nexus project[32].

SNE is an environmental organisation, working for a “wealthy nature and a healthy environment”. They confer with government and business relations, or protest against pollution, environment unfriendly law, etc. Originally SNE is a known opponent of cars and car drivers. However, they've accepted the presence of the car, and now aim for minimising the damage it's causing. . Instead of adapting society to the car, let the car adapt to society.

The Nexus project is a cooperation of students from Twente, Delft and Eindhoven, working on this project. A joint venture called 3TU is responsible for the inter-university cooperation. The aim of the Nexus group is to develop a sustainable mobility concept, and make sure it appeals to the potential user. A 'vision-driven' design method is used to reach this goal.

Assignment

The project was initiated by SNE. They’re interested in starting a discussion on future transport. A new “mobility concept” should cover aspects like propulsion and vehicle intelligence. Several other members of the Nexus group are already working on propulsion and suspension systems.

This research will focus on the implementation of Advanced Driver Assistance Systems (ADAS) for the car of the future. The exact assignment description is as follows:

“Design a display/interface to let the user of the car of the future understand how the ADAS operates. Besides looking at existing solutions, it's possible and allowed to think up new systems.”

Objective

With the development of concepts for the car of the future, the possible application of ADAS is considered. A design oriented research is needed to find out which ADAS exist, and how they can be implemented in the concept car. The research will be divided into three phases.

The first phase includes a market analysis to give an impression of the available ADAS. Furthermore, the requirements and preferences of participants and users must be acquired by doing stakeholder- and user analysis. The result of phase 1 will be an overview of available ADAS and a list of requirements and preferences of stakeholders and end-users.

During phase 2, combinations of systems will be designed and presented. When required, new ADAS solutions can be developed. Concepts will be presented to stakeholders using drawings and 3d models. Based on stakeholders input one concept will be selected to elaborate on.

In the end, a functional prototype of this concept will be constructed in phase 3. The success of the concept should be tested by setting up a usability test with the prototype.

31 See “Terminology”
32 See “Terminology”

The entire research, including concept development and prototyping is to be finished within three months. After consulting both the Nexus-group and the university tutor, it's been decided to focus this research on both the concept phase and prototyping phase. This means the literature research is to be kept to a minimum. A more detailed schedule is available[33].

Reaching the objective results in a final design report, containing research results, concept developments, and system specifications. Also, a functional prototype will be built. The prototype should give an impression of how the interface operates and interacts with a user. The use of software and electronics, virtual reality and simulations is considered.

Research questions

To achieve the goals stated above, the following main questions are to be answered:

1. Which ADAS are available?
2. Which ADAS are applicable in the "Car of the Future" project?
3. How should the ADAS be implemented?
4. Does the implementation satisfy?

Using the answers of questions 1 and 2, the first phase of the objective can be completed. Phase 2 is covered by the answer to question 3. The answer of question 4 will complete phase 3 of the objective.

To find the answers to these questions, sub-questions are phrased:

1. Which ADAS are available?
   - 1.1 Which ADAS exist today?
   - 1.2 Which ADAS will be available in the future?
   - 1.3 Who are the (future) users of the ADAS?
   - 1.4 Which factors affect accceptance of ADAS?
2. Which ADAS are applicable in the "Car of the Future" project?
   - 2.1 What are the requirements and preferences of (future) users?
   - 2.2 What are the requirements and preferences of SNE?
   - 2.3 What are the requirements and preferences of the Nexus-group?
3. How should the ADAS be implemented?
   - 3.1 Which combinations are useful?
   - 3.2 Which ergonomic constraints exist?
   - 3.3 Which practical constraints exist?
4. Does the implementation satisfy all participants?
   - 4.1 How well do users accept the ADAS?
   - 4.2 How well does the solution fit the needs of SNE?
   - 4.3 How well does the solution fit the needs of the Nexus-group?

33 See "Project Schedule"

9.2 Technical Design

With the research questions the objective can be reached. To find answers to the main research questions and sub-questions, a plan for research material and strategy is set up. A detailed project schedule is derived.

In the following table important parts of the research are put together. It shows the research questions as well as means to answer them (source, strategy).

Phase	*Research Question*	*Sub question*	*Source*	*Strategy*
1	Which ADAS are available?	Which ADAS exist today?	Internet, magazines, literature, newspapers	Reading
		Which ADAS will be available in 2020?	Internet, Literature	
		Who are the (future) users of the ADAS?	Nexus-group, SNE, magazines, internet, collage, mood board	
		Which factors affect acceptation of ADAS?	Literature [4]	
	Which ADAS are applicable in the “Car of the Future” project?	What are the requirements and preferences of (future) users?	Users, existing results & research	Study results
		What are the requirements and preferences of SNE?	SNE, website	Consultation and interview, reading website
		What are the requirements and preferences of the Nexus-group?	Nexus-group	Consultation
2	How should the ADAS be implemented?	Which combinations are useful?	Ergonomic guidelines, common sense, trial-and-error design	Reading and applying
		Which ergonomic constraints exist?	Ergonomic guidelines, existing research	Reading
		Which practical constraints exist?	Requirements from participants	Acquired from research sub-questions 2.1/2.3
3	Does the implementation satisfy all participants?	How well do users accept the ADAS?	(Future) users	Usability test, interview, questionnaires
		How well does the solution fit the needs from SNE?	Requirements and preferences from SNE	Compare results to requirements and preferences.
		How well does the solution fit the needs from the Nexus-group	Requirements and preferences from Nexus-group	Compare results, ask for feedback

Strategy

Most of the market analysis will be done using existing research results and literature. A lot of user needs research has already been done in the field of ADAS, and is available for this assignment. The use of existing literature saves valuable time, and takes out the risk of not finding enough interviewees to acquire relevant data.

In phase 2, ergonomic guidelines will make sure that concepts are conform rules and regulations regarding safety and usability. A prior research[34] will form a base for this.

During the usability-test interviews and questionnaires will be used to get feedback from the participants. As the test-group is not expected to contain more than 15 persons, interviewing is a suitable feedback method.

Literature

Literature mentioned in the table above can be found using source like internet, magazines, library and contacts within the AIDA group[35].

For the market review in phase 1, previous research on ADAS should be extended and updated where necessary. The research also discussed some ADAS/ITS projects like CyberCars[36] and ADASE[37]. If still up to date, these projects can be used again as source of information.

To asses the acceptance of ADAS, several sources of literature are available. The RESPONE I project final report covers the aspects of ADAS market introduction. Also, papers on acceptance of existing ADAS[38] like adaptive cruise control can be used. Because acceptance is a major aspect in designing a successful interface, sufficient time should be spent on this topic.

Results of surveys[39] can be used to get an idea of user needs towards ADAS. Previous research on ergonomic aspects of car interfaces should be specified to ADAS interfaces. An interesting source for this is the AIDE[40] project, where research and guidelines on ADAS interfaces is available.

Project Schedule

The phase-model mentioned in the objectives is also used to draw up a detailed project schedule.

Time spent on market research can be kept to a minimum. According to table 1, the literature research mostly consists of browsing the internet and reading literature. As said in the literature section, preliminary research has already been done in the field of ergonomic aspects of ADAS.

Drawing concepts, thinking up combinations of systems, and crafting functional prototypes takes a lot more time. As the focus of this assignment is on designing the interface, concessions to the literature research may be necessary.

The market review shouldn't take to much time. Earlier research can be used after updating it. However, discussing acceptability of ADAS, as well as defining a scenario, users and stakeholders takes time to do thoroughly. So it maybe necessary to make assumptions on certain areas or to ignore less important aspects of the research altogether in order to focus on the interface design.

34 See Cyberdash
35 See http://www.aida.utwente.nl
36 See http://www.cybercars.org
37 See http://www.adase2.net
38 See "Behavioural impacts of ADAS – An overview" – Brookhuis et al, 2001, Netherlands
39 See "Integrated driver assistance from the driver's perspective – Results from a user needs survey" Arem & v Driel 2005
40 See http://www.aide-eu.org

Risk Factors

Preparation and anticipation is necessary for several critical points.

- Usability test – The test depends on volunteers. Even though the test isn't a priority in this project, the schedule makes sure enough people are contacted in time to set up at least a small test.
- Nexus project group perspective – The Nexus group should be well informed about the possibilities and desired use of ADAS in the Car of the Future project. During the first meetings it became clear that their focus is currently on technical aspects like propulsion and suspension. There's no clear definition of users or user-scenario yet. The first major presentation should clarify these issues.
- Elaborating on the above, it's necessary to define a target user group and scenario in order to make design decisions. Scenarios can be based on literature, the target user group should be defined after consulting the Nexus group.
- Prototype construction – The prototype is likely to contain both electronics and software. Electronics can fail, and software is quite complicated to build and test/debug. Because prototyping has high priority, the majority of available time should be reserved and used for this subject.

Terminology

- Society of Nature & Environment, SNE, *(Stichting Natuur & Milieu)* – Dutch environmental organisation and initiator of the project. Has a lot of contacts in the 'green sector'. Mainly interested in environment-enhancing technologies. See http://www.natuurenmilieu.nl.
- Nexus-group – Cooperating group of students, from Delft, Eindhoven and Twente. Brought together by 3TU, a joint venture. The group consists of technical students, all of them working on this project. See http://www2.io.tudelft.nl/io1008595/index.php?id=7.
- Advanced Driver Assistance Systems, ADAS – Technology meant for car drivers, to improve safety, comfort and environment while driving a car, using high-tech solutions.
- Assignment – Reference to this Bachelor Assignment. Also referred to as "this research".
- Project – Reference to the general project: designing a concept for the car of the future. This assignment is just a small part of it.

References

- http://www2.io.tudelft.nl/io1008595/index.php?id=7 – *Website of the Nexus project*. Last visited: April 18, 2006
- http://www.adase2.net – ADASE II Webstie. Last visited: April 21, 2006
- http://www.aida.utwente.nl – AIDA website. Last visited: April 21, 2006
- http://www.aide-eu.org – AIDE Project website. Last visited: April 21, 2006-04-21
- http://www.cybercars.org – CyberCars project website. Last visited: April 21, 2006
- http://www.natuurenmilieu.nl – *Website of Society for Nature & Environment (Stichting Natuur & Milieu)*. Last visited: April 18, 2006.
- Arem and van Driel - "Integrated driver assistance from the driver's perspective – Results from a user needs survey", University of Twente, 2005
- Brookhuis et al - "Behavioural impacts of ADAS – An overview", 2001, Netherlands
- Thalen, J - "Cyberdash; Gebruikersanalyse & Conceptontwikkeling voor interfaces van autonome voertuigen in de toekomst" April-August 2004, Universiteit Twente

9.3 Evaluation of the Project Approach

A review of the research questions, and how they were used during the research.

1. Which ADAS are available?
   - 1.1 Which ADAS exist today?
   - 1.2 Which ADAS will be available in the future?
   - 1.3 Who are the (future) users of the ADAS?
   - 1.4 Which factors affect acceptance of ADAS?
2. Which ADAS are applicable in the “Car of the Future” project?
   - 2.1 What are the requirements and preferences of (future) users?
   - 2.2 What are the requirements and preferences of SNE?
   - 2.3 What are the requirements and preferences of the Nexus-group?
3. How should the ADAS be implemented?
   - 3.1 Which combinations are useful?
   - 3.2 Which ergonomic constraints exist?
   - 3.3 Which practical constraints exist?
4. Does the implementation satisfy all participants?
   - 4.1 How well do users accept the ADAS?
   - 4.2 How well does the solution fit the needs of SNE?
   - 4.3 How well does the solution fit the needs of the Nexus-group?

The first research question (1) has been dealt with as planned, using literature research. Sub-question 1.3 has been covered in the user analysis in Chapter 3. Research question (2), regarding requirements has also been answered in Chapter 2.

Concept development and the brainstorm have answered research question (3). However, as the research headed more towards a rough concept developing, detailed sub-questions like (3.2) and (3.3) were no longer relevant. Instead the objective of the research changed to finding multiple concepts.

Research question (4) regarding the satisfaction of participants is partly answered by the system and interface evaluations, as discussed in Chapter 5. However, the objected usability or user-test could not be kept, because of the change of objective. In order to do a usability test, one or two of the four concepts first have to be further developed, as recommended in Chapter 5.

Appendix 10 – Project Integration

10.1 AutoRAI Preparations

The first major step in the development of the Car of the Future will be the public presentation on the AutoRAI in 2007. A concept-car is to be presented, along with the separate research and design results of individual students. Therefore it's important to determine what to show during such a presentation.

Core Message

Taking in account the results of this research, the core message should at least include safety aspects, but also say something about comfort and product-attractiveness in order to attract the public. It is in the opinion of the author to use safety as a primary message, followed by comfort and attractiveness. Summarising, the core message of this research would be: “Improving Safety by adding Comfort”.

If the communication workgroup of the project argues that safety is not suitable for (commercial) communications, the core message could shift more to futuristic “Smart & Comfortable” or the like.

What to show

There's no use in showing average visitors the entire research report or technical analysis. To reach the visitor in a understandable way, yet still follow the lead of this research, the following layers of information are proposed.

1. Basic Information
   - Current and expected traffic safety figures
   - Current and expected ADAS systems[41]
   - Showing the four concept basics
2. Intermediate Information
   - Current and expected traffic safety figures
   - Current and expected ADAS systems[42], with system layouts of sensors and components
   - Showing the design approach and resulting system and interface concepts
3. In-depth Information
   - Current and expected traffic safety figures, supporting sources
   - Current and expected ADAS systems[43], with system layouts of sensors and components
   - Showing the design approach and resulting system and interface concepts, accompanied by technical specifications and research results

By showing this information, visitors will be answered the following questions.

– What are ADAS, and why would we want them?

– How is ADAS implemented in the Car of the Future?

The emphasis on the AutoRAI should be on the first question, as visitors are expected to be unfamiliar with ADAS in general. Though the concepts should be presented, it's not necessary to explain the ideas and reasoning behind their design.

41 See Chapter 3
42 See Chapter 3
43 See Chapter 3

Presentation Methods

The mentioned general unfamiliarity with ADAS can be resolved in several ways. The following list shows possible methods, in order of preference.

Simulator

An automotive simulator may be equipped with software and hardware to simulate ADAS. Visitors should be able to try the simulator and experience what ADAS does exactly. The simulator may be fitted into a physical model of the Car of the Future concept, but this is not necessary. A mock-up of the cockpit, including the windshield and a front-view simulation is sufficient.

Virtual Simulation

Another option is to use virtual simulations of ADAS, as presented in the previous paragraph. These simulations may either be interactive, so the visitor can actually operate the system, or non-interactive, just showing the workings of the four concepts.

Visual Presentation

As a final option, the workings of ADAS and the four interface concepts can be presented using posters and possibly flyers. Though not as attractive as an operational simulator or virtual prototype, posters and flyers offer a way to present a lot of information.

10.2 Virtual Prototype

As a first step towards a concept prototype, virtual models of the concepts have been made. These models can be used to demonstrate the workings of each concept, and may later be used in actual prototypes or presentations by providing interactivity.

The virtual prototype consists of a 3d concept model, an environment and a prescribed situation. Combined, these components result in a realistic presentation of a concept in a particular environment. The environments include the following types.

- Urban cruise
- Urban traffic
- Highway cruise
- Highway lane changing/overtaking

The model may be rendered as still image or as animations of a particular situation. Images below give an impression of the effects of a virtual prototype.

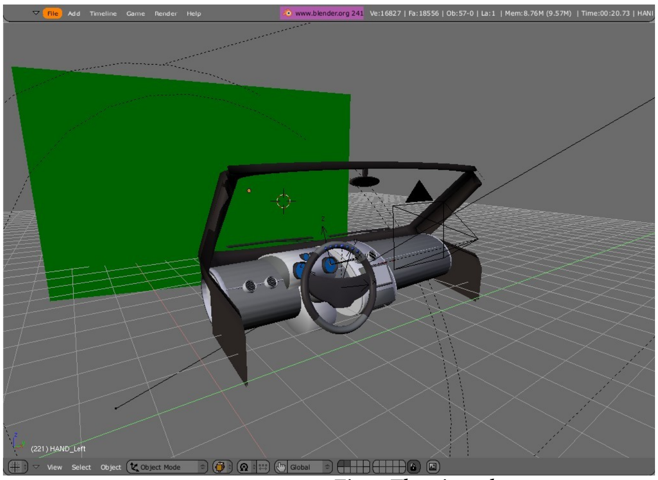


Fig 9: The virtual prototype set-up

Fig 10: Example of the virtual prototype

Appendix 11 - Literature Summaries

"Integrated driver assistance from the driver's perspective – Results from a user needs survey"

B. van Arem and van C.J.G. van Driel, CE&M Research Report, August 2005

Relevance: User needs, acceptance, system requirements

As part of a Congestion Assistant development research, this survey was held amongst internet users. The goal was to determine the driver assistance needs of drivers. General results is in favour of ADAS. A need for integration is found. Instead of independent systems, driver assistance should be integrated technically (i.e. Using the same sensors or electronics). The importance of a thorough HMI research is also noted. A HMI should be adjustable to achieve flexible use. Another important factor is intercommunication between systems and within the system itself. Cars should talk together, but so should for example the ACC and LDW systems.

The survey indicates speed regulating, lane change assistance, intersection assistance and reduced visibility systems are most popular. There's no indicated need for lane keeping. Furthermore, users like to be informed and assisted by ADAS, but control of the car should not be given away.

"When will ADAS be User-Adaptive? The Case of Adaptive Cruise Control"

R. Kovordányi, Cognitive Systems Engineering Lab., Linköpings Universitet, Sweden, 2003

Relevance: Negative behavioural adaptation and proposed solutions

The Negative Behavioural Adaptation effect is studied. ADAS turn out to cause negative behavioural changes amongst car drivers. With ACC users, this turns out in slower response times during critical situations. Two solutions for migrating the adverse effects of ACC are proposed. First, explicit warnings and cues can make the driver conscious of his mistakes. Secondly, the part of the system that's triggering behavioural changes can be changed or removed. ADAS should become more user adaptive, in order to prevent negative behavioural changes.

"User attitudes to automated highway systems"

I.J. Chalmers – The Highways Agency, United Kingdom, April 2001

Relevance: general overview, user needs, acceptance

A report of a research on user attitude and acceptance of Intelligent Vehicle Systems and Automated Highway Systems. This summary only covers the IVS/ADAS specific results of the research. A general positive attitude towards assistance systems was found, while automated systems are less popular. Automatic take-over is only accepted in emergency situations. The paper notes there's possible lack of understanding of systems operation and reliability. The research also shows that women are more positive towards the system overtaking control. Speed control was acceptable if it had a voluntary instead of compulsory intention.

Besides the positive reactions, several major concerns were discovered, being costs, risk of technical failure, surrendering control and driver dependency. Especially young people tend to have less trust in the system assistance.

The general conclusion of the paper says that users should be better informed about available technology, to increase acceptance, for the AHS particularly.

"In-Car Machine-Human Interaction - How the new vehicle technologies which respond to the vehicles needs could match with the user-centered approach and contribute to shape a user-centered design approach"

F. Tango and Roberto Montanan, University of Modena & Reggio Emilia, Italy, 2004 IEEE lnternational Conference on Systems, Man and Cybernetics

Relevance: Design method, human centred design, pros and cons of existing projects

The need for new mobility concepts is explained by presenting figures of traffic accidents. Application of ADAS can support these concepts. An aim for integrated design, considering both user and system needs is stated.

A design method is presented, starting with a user needs analysis. ADAS should be investigated on the following aspects: environmental status, users typology and HMI preferences. Sub aspects of environmental status include weather conditions, type of road, traffic density and traffic participants. Two example projects that followed this 'humancentred approach' are described. (COMMUNICAR and EUCLIDE).

Several problems with existing systems (Navigation and FCW) are presented. Supposedly, user needs and system needs don't form a functional system. Solutions to beter match these needs and requirements of users and system:

– More emphasis on internal and external scenarios
– Design a dynamic in-car machine-human interaction.
– Use co-operative systems (vehicle to vehicle and vehicle to infrastructure)

External scenarios are explained as 'what's going on outside'; visibility, road type, other traffic, etc. With the analysis of the outside world risks can be calculated and acted upon. The internal scenario refers to 'what the driver is doing'; workload, status, interaction, etc.

"Behavioural impacts of ADAS – An overview"

Brookhuis et al, 2001, Netherlands

Relevance: problems with workload, solutions

A general overview of traffic accidents causes, as well as needs for ADAS is given. After the introduction, problems with ADAS are presented. First presented is the increase of complexity of the car cockpit, causing the driver or the system to fail more easily. The second problem is described as the required additional driver attention, which is taken from the driving task.

The paper also points out the different degrees of assistance a system offers, as well as lack of willingness to leave control totally to a system. Providing the user with information is also found to be vital, but should be done with care. Negative changes in driving as a result of badly implemented ADAS are found in research, and called behavioural adaptation.

Problems with monitoring systems for malfunctions and vigilance tasks are described. A dynamical solution is proposed, sending information to the user when he/she is ready for it (Adaptive Task Alloction). Furthermore, discussion about human supervision. Automated control works fine during normal situations, but problems arise with other (emergency) situations, as the driver is less experienced.