

# Driver Assistant Systems

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## ABSTRACT

This report deals with the development of driver assistant systems (DAS) in automotive engineering. A historical look back at the driver assistant systems shows a rapid development of these systems. Decreasing prices of stores and the continually increasing computing capacity of the last decades favour the development of efficient assistant systems that make the driving task more comfortable for the driver and that increase the safety. This report focuses on the systems' classification into customer-relevant criteria of automotive engineering, like active and passive safety, environmental compatibility, economy and comfort. It gets evident here that the different driver assistant systems can be divided into three main categories: safety-DAS, comfort-DAS and economy-DAS. It is often not possible to categorize the systems in a definite way as the majority of them covers several areas at the same time. Furthermore, some of the current and of the future systems will be assigned to the three main categories and their functions as well as their system configuration will be presented.

## INTRODUCTION

After having invented the wheel ca. 7,000 years ago and after having developed the first wooden spoke wheel ca. 3,000 years ago, the first ground vehicles, being pulled by horses, were built. The Roman chariot (ca. 2,000 years ago) can be seen as a milestone of automotive development that experienced an "accelerated" advancement. Draught horses have been used for pulling the advanced coaches from then on until the year 1769, when the French engineer Nicolas Joseph Cugnot created the first self-driven vehicle. A steam engine was its driving motor.

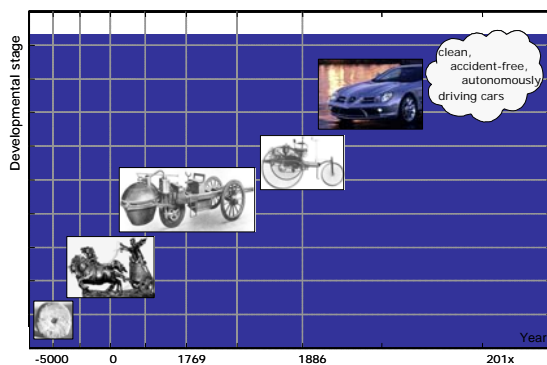


Figure 1: Milestones of automotive development

The year 1886 can be considered as being the birth of the automobile due to Carl Benz having developed the patent motor vehicle (figure 1). Compared to the period of time – covering nearly 7,000 years – from the invention of the wheel up to the development of a self-driven vehicle, it is interesting to see how rapidly the automobile development has been going on in the last 200 years. Where is this development leading to? The question is difficult to answer, but the vision of a zero-

emission, clean, safe and autonomously driving vehicle could easily be reality in the year of 201x.

The driver assistant systems (DAS) have made up a considerable part of the value-added chain of the automobile in the meantime. This development is, among others, basically due to two deciding effects.

The first effect refers to the decreasing prices of stores. At the beginning of the computer age in the 1970s, one megabyte memory capacity equalled the costs of a detached family house. This price, however, was reduced according to increasing numbers of computers to an equivalent of a VW Beetle up to the present where one MB memory capacity costs hardly more than a paper clip (Bosch 2001).

The second reason has its roots in the rapid development of the computing capacity that is of central importance for modern assistant systems. Already in 1965, Moore phrased his rule that the number of transistors on one chip, and thus its computing capacity, doubles every 18 months (Intel). This became true in the following years and was modified in 1995, saying that the average computing capacity doubles every two years. The rule is still valid and will keep on being true in the coming decades as well.

These two developments mentioned above are mainly responsible for the fact that memory- and computer time-intensive applications, like real-time capable vehicle models and image processing, make an entrance into the control units of a modern vehicle. This leads further to that fact that the majority of the innovations made in automotive development now comes from the area of electronics.

But this increase of electronic components in vehicles leads to new problems. In many cases, the quality and the reliability of these components do not achieve the desired level. This becomes especially

evident if the causes of a car breakdown are statistically processed and analysed. In 2003, most of the breakdowns, namely 35.9 %, were caused by electronic defects (ADAC 2003).

### CLASSIFICATION OF THE ASSISTANT SYSTEMS REGARDING CUSTOMER-RELEVANT DEVELOPMENTAL AIMS

In the following, the classification of the different assistant systems into customer-relevant criteria of vehicle development will be discussed. Besides the demand that a vehicle's interior- and exterior design has to satisfy the category-specific requirements of the customers, mainly six other criteria have to be fulfilled (figure 2).



Figure 2: Criteria of vehicle design

Active and passive safeties are the most important criteria for customers when buying a car. A modern vehicle actively supports the driver by different safety assistant systems (antilock system ALS, electronic stability programme ESP etc.) that are to prevent accidents. In case that an accident is not avoidable, the various programmes act to minimize the effects of the accident on the passengers.

Besides front-, side- and head airbags, systems for early detection (Pre-SAFE) are in existence by now. They initiate necessary and reversible means for preventing the passengers already before the accident happens (DaimlerChrysler).

Self-obligations of the automobile industry on the one hand and stricter vehicle emission limits on the other force manufacturers to develop environmental compatible vehicles that are more silent, that consume less fuel and that produce less emissions. This leads up

to Zero-Emission-Vehicles, vehicle concepts (hybrid, fuel cells) that produce very low or no emissions at all and that usually protect the limited resources of fossil fuels due to the use of regenerative energy sources.

The “economy“-criterion especially concerns – besides the cost of purchase – fuel consumption and cost of ownership. They can be positively influenced by driver assistant systems as well.

Furthermore, the comfort plays an important role when buying a car, especially for the upper vehicle classes. Comfort especially means, besides the general driving comfort, the ease of operation inside the vehicle. In this area, a variety of assistant systems is available at present that simplifies the fulfilment of the driving task for the driver.

Subsequently, the individual developmental aims of the vehicle will exemplarily be assigned to some assistant systems. It shows that the driver assistant systems can be divided into three complexes in this classification:

- Safety-DAS
- Comfort-DAS
- Economy-DAS

The problem that individual systems cannot always be definitely categorized becomes evident with the example of the active cruise control (Active Cruise Control ACC or ACC Stop&Go). For example, the system increases the comfort because the driver is spared braking and accelerating; at the same time, it contributes to keeping the safe distance and thus to increasing the driving safety. By ways of coordinating the traffic flow, economic aspects are concerned as well.

#### SAFETY-DAS

One emphasis within the development of safety-DAS for increasing the active safety of a vehicle is put on the area of lighting technology. The system Brake-Force-Display that is already available as standard indicates the following cars how much the own car decelerates. This is realised by the help of an adaptive brake light with illumination areas varying in size. The following cars can thus react faster on hard braking manoeuvres; therefore, the danger of collisions is reduced.

The Adaptive Light Control (also called Advanced Light Control) improves the illumination of the road in front of the vehicle by offering the driver an optimal light pattern in nearly every situation (Hella KG). Three possible applications are described and depicted in the following (figure 3).



Figure 3: Advanced Light Control (source: Hella KG)

The first application area, the cornering- and the turning light, is already covered in different cars as standard nowadays. Through the steering angle or by using the direction indicator, the cornering is picked up and swivelling head lights or additional lights illuminate the direction the vehicle is going to better. The second area concerns restricted areas and crossroads. There, the system illuminates the roadside more intensely with a light largely fanned out while, in the third application area, a broad illumination of country roads and autobahn, similar to the present driving light, is realised. This happens without blinding the oncoming traffic or vehicles going further in front. Recognizing the individual driving conditions will in the near future be realized by advanced navigation systems. They will have higher dissolved maps that will also show information about radii of curve and “intersection geometry”.

A further innovation concerning lighting technology is the pixel light (BMW Group). In the pixel light-head lights on DMD-basis (Digital Micromirror Device), 480,000 micro mirrors replace the reflector. The light of the radiator is reflected by the mini mirrors – each of these mirrors represents one pixel – and can individually be controlled and moved. The application possibilities of this innovation are various. By swivelling the mirrors, the pixel can be switched off for the short term and the light intensity can be varied. The light beam of the pixel light-head lights can be freely shaped by swivelling the mirrors. With suitable sensor technology, the oncoming traffic can be picked up and the area of the driver in the oncoming traffic can be darkened (figure 4). The projection of navigation information onto the road is conceivable with the pixel light. Obstacles that are not recognized by the driver could be made out by the

system and could then be exactly floodlighted and enhanced (BMW Group).



Figure 4: Pixel light

### Lane-Departure-Warning

A further current emphasis of the development of driver assistant systems for increasing the active safety is put on the driver attentiveness control. One component of these systems that also concerns the Institute of Automotive Engineering is the Lane-Departure-Warning. This is to warn the driver when – unintentionally – departing the lane (figure 5).

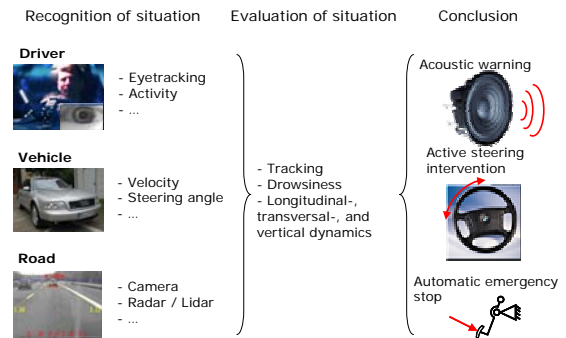


Figure 5: Lane-departure-warning

A camera installed behind the wind shield gives information about the traffic in front of the vehicle. The camera data is analysed by a picture processing that searches for lane markings in the pictures. As output, the picture processing supplies figures concerning the track width and the curvature of the lane as well as information about the position of the vehicle on the track. These values represent the input of the warning algorithm that primarily calculates the time until departing the lane, the so-called Time-To-Line-Crossing. Warning suppression mechanisms are meant to differentiate the intended from the unintended lane change. In the latter case, an acoustic warning for the driver is created by a synthetic rattling noise. With the help of eyetracking or of an activity observation,

for example, the driver gives meaningful information about his personal performance ability or tiredness. The relevant data about the vehicle is gained by the different data bus systems in the car. They do not only give information about the driving condition, but they also help to characterise the driver as far as his activities are concerned (braking, steering, blinking etc.). The third parameter road is covered by the help of the environmental sensor technology. Cameras inside the car as well as radar or Lidar sensors give information about the track course or also about potential obstacles in front of the vehicle.

The data gained constitutes the input of different models where, for instance, the tracking behaviour, the performance ability of the driver, but also the longitudinal and transversal dynamics are calculated.

Due to the results of the various models, the reactions of the systems suitable in the current situation are chosen; they range from a merely acoustic warning to an automatic emergency stop.

### Advanced ESP

Another possibility for increasing the active safety is the further development of the electronic stability programme ESP. In the following, four different scenarios of a vehicle cornering are looked at as examples (figure 6). In the first and in the second scenario, the vehicle faces the curve with 70 km/h. Without an assistant system, the speed is too high and the car loses stability. Through braking caused by the ESP, the vehicle can be stabilized at this speed and the curve can be passed. The third scenario shows that the limits of driving dynamics cannot be annulled. Here, the speed is increased up to 100 km/h: the brake intervention of the ESP is not sufficient for stabilizing the car.

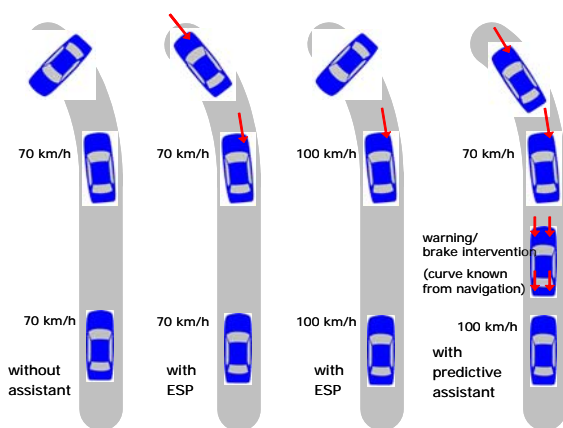


Figure 6: Advanced ESP

With a predictive assistant, the situation can be defused: if the radius of the curve in front of the

vehicle and its exact data is known from a navigation system, an according assistant system can reduce the speed in such a way that the vehicle keeps its stability.

### Automatic emergency brake system

In case an accident cannot be prevented, automatic emergency brake systems reduce the speed in so far that the accidental effects are minimized.

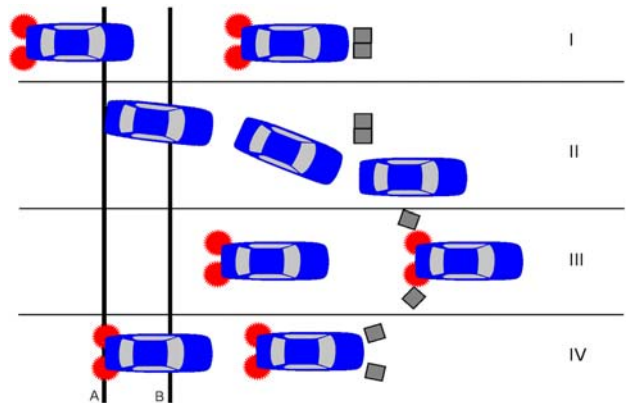


Figure 7: Automatic emergency brake system

In case the environmental sensor technology recognizes an obstacle in front of the vehicle, two virtual lines A and B depending on the driving condition are determined in the control unit (figure 7). Line A marks the distance towards the obstacle in front of which the vehicle can exactly be stopped by an immediate emergency stop carried out by the driver. With the help of an avoidance manoeuvre on line B, the driver can only just get out of the way of the obstacle.

If both manoeuvres are not carried out by the driver at the suitable points, an accident is, physically seen, unavoidable. At that moment, the emergency brake system initiates the emergency stop, so that the speed is, compared to a delayed reaction of the driver, considerably reduced.

### Pre-Safe

A precautionary protection against accidents has not been possible with the previous systems of passive safety. This is due to the fact that they act irreversibly, so that they can only be used once. Thus, airbags and belt pretensioners are pyrotechnically set off as soon as their sensors detect an impact. The protection systems have to be fully effective within a few milliseconds (DaimlerChrysler).

The disadvantage of pyrotechnical systems is the fact that they only mesh when the accident is

happening. The use of reversibly working systems offers the advantage that they can already be activated as soon as a situation of danger is discerned. Such danger situations can be recognized by activating the different active safety systems: brake assist system, ESP or even ALS. In addition to the activation of the belt pretensioners, the windows are closed, the back rests are brought into an upright position and the front seat cushions are lifted (figure 8).

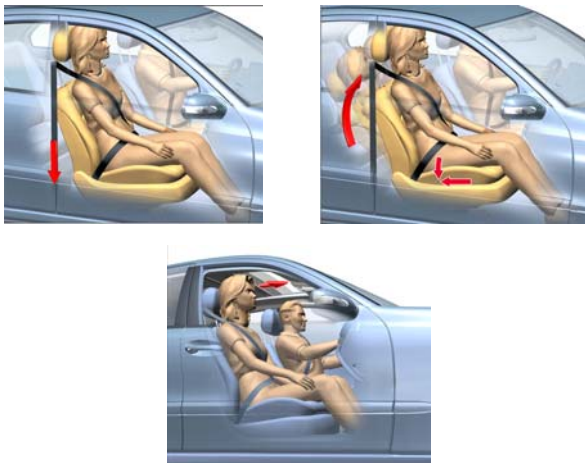


Figure 8: Pre-Safe-System (DaimlerChrysler)

In case of a crash, these means cause the effects that the passenger will not slip beneath the seat-belt and that an optimal position for the protecting function is achieved.

The passenger is, already at the beginning of the accident, perfectly protected. In case the collision can be avoided, the initiated means will be reversed.

### COMFORT-DAS

In the field of comfort, a variety of assistant systems that help the driver to fulfil the driving task is on the market. As it has already been pointed out in the historical look back, the comfort-DAS can be traced back right until the beginnings of the automobile mobility.

Some examples for this that can be given here are the ignition advance, the starter, the wipers and the direction indicator. In the last years, the dynamic navigation systems and the “active” cruise control ACC, for instance, have been added to this field.

#### Head-Up-Display

Head-Up displays are a further improvement of the driving comfort. Relevant information, like, for example, velocity, navigation instructions or warning

notes are mirrored onto the windscreen in the range of vision of the driver.

An impression is provoked in the driver that the information is floating above the engine hood; therefore, the difficulties are reduced by focussing on the Head-Up-Display because the driver does not have to avert his eyes from the traffic situation. Thus, not only the comfort but the safety as well is increased (BMW Group).

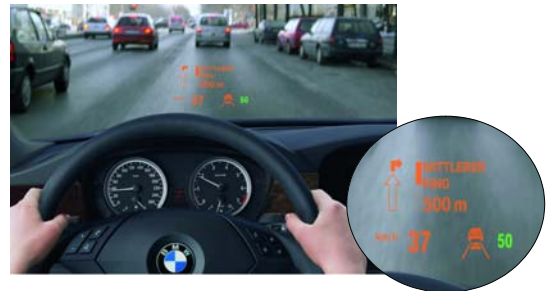


Figure 9: Head-Up-Display

About an emergency stop, it has to be differentiated between braking and stopping distance.

Since the braking distance describes the way that the vehicle covers after reaching the maximum deceleration until standstill, the stopping distance additionally expresses the distances covered during the reaction-, response- and build-up time. The response- and build-up times are influenced by the control- and transmitting devices of the brake system as well as by the condition of the brake while the response time depends on the driver. It expresses the period of time from the recognition of the obstacle, the decision of the driver up to relocating the foot from accelerator to brake pedal.

Table 1: Braking distances not used by reaction-, response- and build-up time in case of an emergency stop

|                          | figures       |                         |                          |
|--------------------------|---------------|-------------------------|--------------------------|
|                          | Most possible | 2% (only 2% are faster) | 98% (only 2% are slower) |
| Reaction                 |               |                         |                          |
| Without view turning     | 0.64          | 0.36                    | 0.78                     |
| With view turning 0.5-5° | 1.12          | 0.68                    | 1.33                     |
| With view turning > 5°   | 1.25          | 0.77                    | 1.48                     |
| Response time            | 0.05          | 0.03                    | 0.06                     |
| Build-up time            | 0.17          | 0.14                    | 0.18                     |

Table 1 shows the figures of these periods of time. It becomes clear that the reaction time of especially “lethargic” drivers can be reduced by up to 0.7 s due to being spared turning the eyes.

Table 2: Braking distances not used by reaction-, response- and build-up time

|             |       |       |       |      |       |       |
|-------------|-------|-------|-------|------|-------|-------|
| $t_r$       | 0,1   | 0,2   | 0,5   | 0,67 | 1     | 1,5   |
| $s_{ungen}$ | 2,778 | 5,556 | 13,89 | 18,6 | 27,78 | 41,67 |

In the period of time  $t_r$ , the vehicle goes on with a velocity nearly unreduced. Table 2 represents the unused distance  $s_{ungen}$  made during time  $t_r$  for an initial speed of 100 km/h.

A reduction of the reaction time by the 0.7 s mentioned above equals a shortening of the stopping distance of 100 km/h by ca. 19.5 m.

### Stop&Go Assistant

An essential improvement of the comfort has been achieved by the introduction of the active cruise control ACC during the last years. A radar or laser sensor at the front of the vehicle determines the distance and the relative velocity towards the object going ahead and it controls the own speed in a way that the vehicle in front is followed with a constant distance. This form of automated longitudinal guidance for velocities above 30 km/h is already standard of technology. At present, it is worked on a system for the low-speed section, the so-called ACC Stop&Go (figure 9).

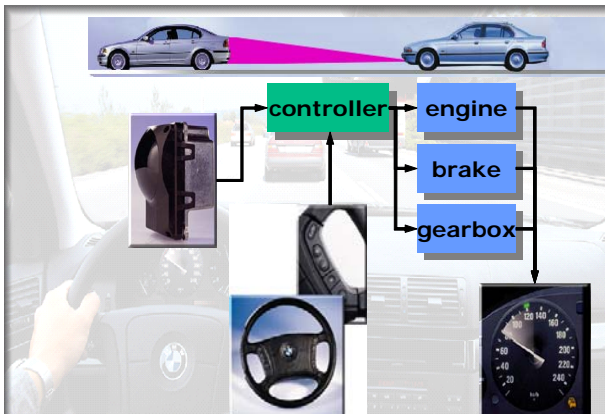


Figure 10: ACC-Stop&Go system network

For functioning faultlessly, the control unit integrated into the sensor has to communicate with different vehicle components through various bus-systems.

Besides the central control- and display elements inside the cockpit, mainly the engine electronics for

adjusting the speed are engaged. In case the brake power of the engine is not sufficient enough for reducing the speed, the brakes will be activated by the stability programme. The obtainable deceleration of this comfort system is limited to 3 m/s<sup>2</sup>. If this deceleration is not enough, the driver will be acoustically requested to act.

### Parking assistant

An advancement of the parking assistance based on ultrasound is the parking assistant. It enables manoeuvring into a parking space in a very comfortable way.

Since the parking assistant turns in independently at the optimal position and guides the vehicle into the space on an ideal course, the driver can take his hands off the steering wheel and can intensively concentrate on accelerating and braking. Thus he can focus all his attention on securing the surroundings and he can keep the vehicle under control all the time (figure 11).

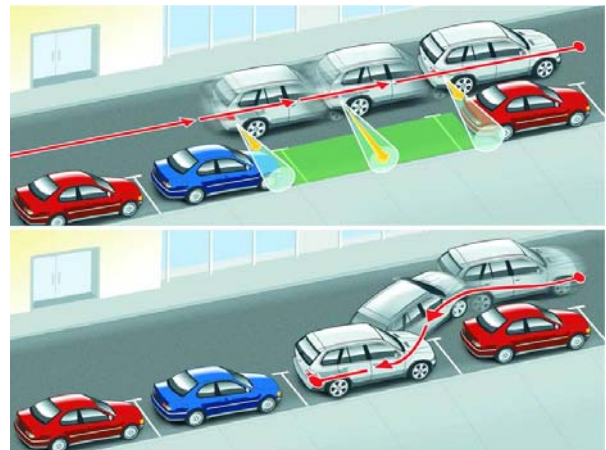


Figure 11: Parking assistant

A sensor is calculating beforehand whether the parking space is large enough. When passing the parking gap, the sensor measures the onset and the end of the gap as well as its width. If the space is sufficient, the driver only has to activate the parking assistant, to shift into reverse gear and to accelerate. As soon as the Park-Distance-Control signals that it is not possible to go back any further, the driver stops the car as usually. Now the parking assistant adjusts the steering wheel and the front wheels in such a way that he can, after having inserted reverse gear, park perfectly right in the middle of the parking gap (Volkswagen AG).

## ECONOMY-DAS

Environmental compatibility is often mentioned together with economy. Classic representatives of this kind of driver assistant systems are the automatic transmissions with adaptive control. They raise the comfort as the driver is spared shifting, but their adaptive shifting strategy also enables driving in the best possible gear in every operating situation, so that the fuel consumption stays on a low level.

By an active accelerator pedal, drive-by-wire systems as well may give the driver a feedback about using the optimal accelerator position.



Figure 12: Active accelerator pedal

### Navi-Matic

Concerning the control of automatic transmissions, Navi-Matic represents a distinctive innovation in the field of cross-linking assistant systems.

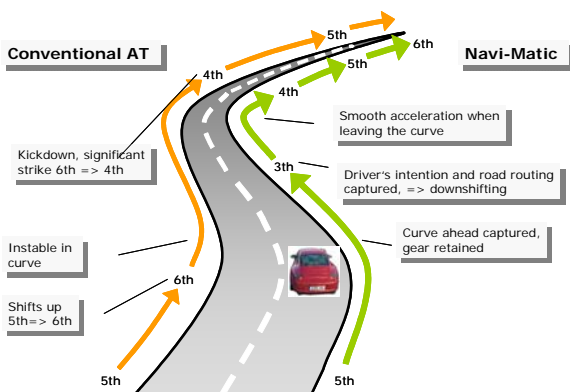


Figure 13: Navi-Matic

On the contrary to the conventional transmission control, data from the navigation system is taken to choose the suitable switching operation; thus, shifting

cannot only be adjusted to the driver's desire, but also to the routing of the road (Aisin-aw-co., Ltd.). The result of this is a more economic and comfortable driving style since the shifting frequency can distinctively be reduced, as it is shown in figure 11.

One of the most modern assistant systems concerning economy is Promote Chauffeur by DaimlerChrysler: two or more trucks are automated to drive in line with only a small distance between them. All of the drivers in line therefore benefit from the reduced aerodynamic drag which has positive effects on the operating costs and the emission behaviour (figure 14).

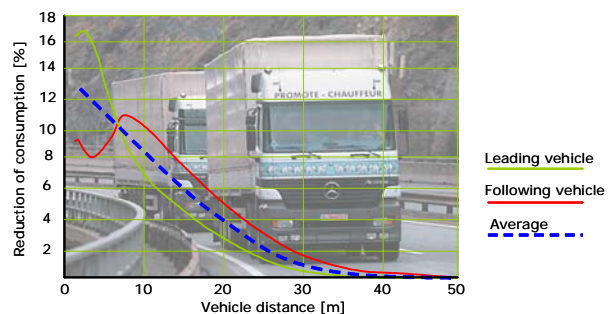


Figure 14: Consumption reduction by Promote Chauffeur

As the line has reduced space requirements compared to the individual truck and as passing manoeuvres with only a small speed difference do not take place, the total flow rate of vehicles in road traffic can additionally be increased. The diminished danger of congestion caused by this has positive effects on the environmental pollution (DaimlerChrysler).

## CONCLUSION

The future of car development is characterised by the vision of the clean, accident-free and autonomously driving car. With the automated longitudinal guidance of ACC Stop&Go as well as the automated transversal guidance of Heading Control, two systems building up this vision will be on the market in the near future.

A central subject in the field of safety-DAS is the system concerning the attentiveness control of the driver. The Lane-Departure-Warning system developed at the IFF is capable of warning the driver if he is departing the lane unintentionally. Furthermore, the present developments concerning lighting technology (Adaptive Light Control, adaptive stoplight) as well as the extended ESP and the automatic emergency brake have been discussed.

The comfort-DAS are determined by extensions in the field of navigation systems: with Head-Up-displays that insert information about the route and important vehicle data on the one hand, with economy-increasing systems like Navi-Matic on the other. The parking assistant enables the vehicles to park independently on their own. The adaptive accelerator pedal and the automated driving in line of several trucks within the project “Promote Chauffeur” enable an operation that is more economic.

In all three categories of driver assistant systems, further advancements and innovations are to be expected within the next years. The cross-linking of the assistant systems, especially with regards to their sensor technology, will play a crucial part in realizing many of these innovations.

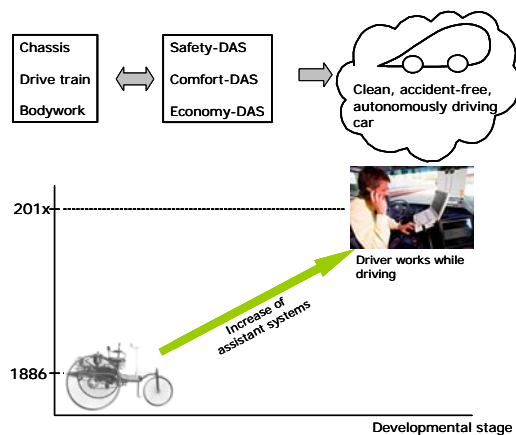


Figure 14: Outlook on the development of driver assistant systems

If the developments up to now or their increase respectively are extrapolated into the future, it can be assumed so far that the vision of the clean, accident-free and autonomously driving car will be true in the year 201x.

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