The Assisted Driver

Systems that support driving

Gerben Bootsma and Lex Dekker, Project Leaders of 'The Assisted Driver' pilot

1 The result is here!

Dear reader,

The Roads to the Future pilot entitled 'The Assisted Driver' is now completed, yielding excellent results. After roughly three years of reflection and action - a transition from conception to practice and a voyage of discovery - we now have the wealth of information we were looking for.

The Dutch Directorate-General for Public Works and Water Management (Rijkswaterstaat) wanted to know how new technologies in vehicles could contribute to its road management objectives. Would there be benefits for road safety, traffic flow throughput and the environment? Following a successful trial, the answer is a resounding "Yes". And what do road users think of these systems? They have alternating preferences, but are generally positive about Advanced Driving Assistance systems. The answers could have been different, but we are certainly satisfied with those we received.

Various drivers in approximately 40 vehicles equipped with ADA systems drove around the Netherlands. Behavioral aspects and traffic effects were analysed. A project team comprising staff from the Directorate-General ensured a successful partnership with road users, market parties and knowledge institutes. Many interested parties were involved and there was considerable interest in the media. This book describes the precise setup of the trial and the exact results it yielded. We have also produced a DVD that provides an overall view of this pilot.

The pilot team worked hard to present these results to you. This pilot would never have been possible without the help of Nathalie, Arie, Lex, Tom, Marco, Mattieu, Jonna, Johanna, Govert, Mireille, Peter, Hans, Wim and Pierre from Roads to the Future. Many thanks therefore! And of course we would like to thank all of those people outside the Directorate-General who contributed significantly to this pilot. This includes Pon's automobielhandel, Volkswagen, MobilEye, Verkeer.advies, Bishop Consulting, ADAS Management Consulting, DHV, PRC, TNS Nipo, TU Delft, TU Dresden, ARS, Toyota Motor Europe and EVE& Beleveniscommunicatie. Many thanks to all concerned!

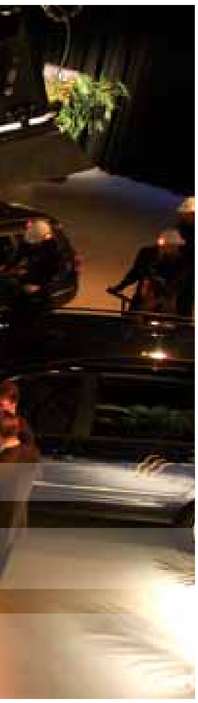
We hope you enjoy reading this book. We trust that you will also be convinced of the opportunities provided by ADA systems and will benefit from this technology.

Enjoy reading this document.

Gerben Bootsma and Lex Dekker
Project Leaders of 'The Assisted Driver' pilot

2 Summary

Roads to the Future is an innovation programme from the Dutch Directorate-General for Public Works and Water Management (Rijkswaterstaat). Together with companies and knowledge institutes, the programme gives rise to innovations relating to traffic and transport. These innovations can improve mobility within the Netherlands, ensuring that it is reliable, safe, quiet, clean and comfortable. 'The Assisted Driver' pilot was commissioned by the Roads to the Future programme. This pilot provided an insight into the future use of ADA systems in vehicles. It also examined how users appreciate and use these systems and their impact on road safety, throughput and the environment. This report will focus on the various components of the pilot and the results thereof. We will use these to make recommendations regarding the potential effects of the pilot.



ADA systems

Over the past few years, various ADA systems have been developed and introduced onto the market, the aim of which is to support and simplify (part of) the driving task of the driver. Headway Monitoring and Warning (HMW), Adaptive Cruise Control (ACC), Lane Departure Warning (LDW) and Lane Keeping Assist (LKA) were used during 'The Assisted Driver' pilot

Virtual Reality

On October 14th 2004, 'The Assisted Driver' project was unveiled to the outside world for the first time by means of virtual reality. The presentation comprised a short film about ADA systems and a simulator that allowed the three systems (ACC, LDW and LKA) to be tested. The main aim of the virtual reality presentation was to place ADA systems on the agenda and simplify communication about this topic.

Demonstration day

A demonstration day was organised on May 24th 2005 for interested parties to acquire practical experience with ADA systems and increase awareness. The day was held on and around the test track of the Test Centre of the Rijksdienst voor het Wegverkeer (Dutch Road Transport Directorate) in Lelystad. After a presentation given by Richard Bishop and a panel discussion, visitors could attend various workshops and presentations. They were also given the opportunity to test drive one of the thirty demonstration vehicles. These vehicles were equipped with different ADA systems such as LDW, LKA, Blind Spot Monitoring, ACC, ACC Full Range, Collision Mitigation, Terrain Response and vehicle-to-vehicle communication.

VANpool

The VANpool project, which is running in and around the city of Amsterdam, enables employees to carpool to work in vans. These vans travel in the bus lane alongside the traffic jam from Flevoland to various business areas in Amsterdam. The Directorate-General for Public Works and Water Management (Rijkswaterstaat) has joined this project by installing ADA systems in several vehicles involved in the project. A pilot held from September 2005 until January 2006 enabled drivers and passengers to experience these technologies. The majority of participants in the pilot are satisfied with AWS. They find the system easy to use and believe that driving with both LDW and HMW is conducive to road safety. There is a preference for LDW above HMW.

Full-traffic test: behavior and acceptance

During the five-month trial (February 2006 until June 2006), nineteen people drove around in a Volkswagen Passat equipped with ADA systems (LDW and ACC). The objectives of this full-traffic trial were twofold. Objective data was obtained with the help of data-loggers and information was compiled via surveys and focus groups. This subjective component of the full-traffic trial answered the question whether participants personally experience a change in their driving behavior by using these systems. The subjective study revealed that participants become accustomed to both systems relatively quickly. Participants see added value in ACC in particular. In their opinion, this system contributes more significantly to road safety and ensures that drivers feel less agitated while driving. According to them, this contribution to road safety is provided primarily by an increased following distance, which minimises the risk of rear-end collisions. With regard to LDW, it can be concluded that participants do indeed activate this system more often than ACC, but that they appreciate it relatively less. Its added value is less apparent to them and they do not feel that they can trust the system completely (yet) as they believe it produces unnecessary warnings in some situations.

Full-traffic test: objective study

Objective information was compiled with the help of data-loggers. An analysis of this data then revealed what effect ADA systems would have on individual driving behavior and the consequences thereof for traffic flow. Consider aspects such as safety, throughput and the environment.

OVERVIEW OF ADA SYSTEMS

The following ADA systems were used during the various tests and pilots of 'The Assisted Driver'.

Headway Monitoring and Warning (HMW)
HMW constantly indicates the distance to the vehicle ahead on a display. The distance is expressed in tenths of a second. A warning is provided the moment the distance is less than the specified limits. The system emits an audio warning and the colour of the display changes from green to orange. In that case, the following distance is between 0.7 and 1.2 seconds. If the following distance decreases even further (less than 0.7 seconds), the colour changes to red and a continuous audio warning is emitted. The system does not intervene on its own.

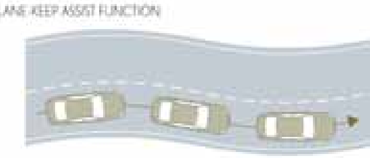
Adaptive Cruise Control (ACC)
ACC is the more advanced form of the cruise-control system currently installed in many cars. Like the standard cruise-control system, the user can specify the desired speed on this system. However, the minimum permissible distance to the vehicle ahead can also be specified. ACC then ensures that this distance is maintained automatically. If the car gets too close to the vehicle in front, the system will brake. If the road is clear, because the driver is moving into a lane on the left, the car will accelerate automatically until it reaches the specified speed. The driver can personally activate or deactivate the system.

Lane Departure Warning (LDW)
LDW is a system that warns the driver when the vehicle is about to leave the lane it is travelling in unintentionally. When the driver uses the indicator, the system assumes that the lane change is intentional. In such a case, no warning is provided. LDW is a vailable in a version that only provides an audio warning and in one that corrects the steering slightly and emits an audio warning. The driver can personally activate or deactivate the system.

Lane Keeping System (LKS) and Lane Keeping Assistance (LKA)
LKS and LKA are systems that actively help the driver to ensure the car continues on the right course. The systems automatically corrects the steering when the car leaves the middle of the lane.

LANE DEPARTURE WARNING FUNCTION

LANE KEEP ASSIST FUNCTION



Use
The LDW system was used throughout most of the trial. ACC is used primarily on motorways and to a lesser degree on provincial roads. The use of these systems is limited to free traffic and heavy traffic. Drivers need a while to find headway time settings that suit them. This period of familiarisation is rarely longer than a month. There is usually a relationship between the selected headway time setting and normal following behavior: The cruise control speed is generally selected in accordance with the applicable maximum speed.

Effect on driving behavior
Average headway times with ACC on are longer compared to when ACC is off or inactive. The variation in headway times is smaller with ACC active than with ACC off/inactive. The percentage of short headway times decreases substantially, which has a positive effect on road safety. By and large, motorists do not appear to observe the applicable maximum speed limit more effectively with ACC. The distribution in speed and acceleration with ACC active is smaller than with ACC off or inactive. This can have a positive effect on safety, comfort, fuel consumption and emissions. The number of unintentional line crossings decreases thanks to LDW. Drivers reduce the SDLP of their vehicles to avoid warnings, which has direct consequences for the driving task load of drivers (they have to concentrate better). Direction indicators are used more often and more effectively. We cannot conclude that there are fewer lane changes due to ACC/LDW. We do see, however, that drivers continue driving in the left lane and particularly in the middle lane for longer.

Effect on traffic flow throughput, safety and the environment
The anticipated effect of the use of ADA on throughput is neutral. The expected effect on safety is positive: the number of accidents on road sections can decrease by 8%. The expected effect on the environment is slightly positive: fuel consumption falls by 3% and emissions decrease when ACC is switched on.

Clinic

During the three-day Assisted Driver clinic, several participants from the full-traffic trial test drove a Lexus equipped with ACC and LKA. It was the first time that a combination of these systems could be tested. Overall, the participants responded positively to the tested systems. All of them indicated that the systems help increase safety and comfort levels. The participants also pointed out that they can see the added value offered by LKA in comparison with LDW (as they were accustomed from the full-traffic trial). In their opinion, this is mainly due to the fact that LKA provides active assistance while LDW only issues warnings.

Conclusions

Behavior and acceptance

The three different components, namely the VANpool pilot, the full-traffic trial and the clinic, revealed that participants appreciate active assistance (intervention) more than warnings. Two warning systems were used in the VANpool pilot, namely LDW and HMW. Participants indicated a preference for LDW. In the full-traffic trial, a warning (LDW) and intervention (ACC) system were used. Practically all participants preferred ACC and indicated that it is more pleasant and comfortable than LDW. During the clinic, a number of participants from the full-traffic trial, i.e. people who had experience with ACC and LDW, test drove a vehicle equipped with ACC and LKA: two active assistance systems. All participants agreed that LKA was an improvement in comparison with LDW. Here too, a preference was indicated for intervention instead of warning. Driving with two active assistance systems was not considered "excessive". The combination of ACC and LDW also appears to be complementary to a certain extent. Participants indicated that ACC facilitates driving and reduces the mental load. LDW does the opposite: the warnings issued by the system also make drivers more alert.

Traffic effects

A thorough analysis of the wealth of data compiled with the help of data-loggers during the full-traffic trial provided an insight into the effects of driving with ACC and LDW on traffic flow. The effects on road safety, throughput and the environment were examined. The pilot indicates that accidents on motorways and secondary roads would decrease by 8% if everyone in the Netherlands were to use ACC and LDW. This does not appear to go hand in hand with a reduced traffic flow. Fuel consumption during the trial dropped by 3% on average and corresponding emissions could decrease by a maximum of 10%.

Other effects

'The Assisted Driver' pilot has provided a deeper insight into the effects of driving with ADA systems. These results go a step further than information that was available up until now from literature and are therefore "harder" in that sense. To acquire even harder results, more extensive tests are required that must not only involve more participants, but must also run over a longer period. The results of such large-scale field tests can also be improved. The full potential of ADA systems will eventually come to light via large-scale application in practice and long-term evaluation (analysing accidents, measuring throughput, monitoring driving behavior, etc.).

Whether or not the results of 'The Assisted Driver' pilot will be sufficiently convincing for policymakers remains to be seen. At any rate, a step forwards has been taken in revealing the potential of ADA systems for road safety as well as throughput and the environment. In the Netherlands, the pilot has undoubtedly helped increase awareness for the possibilities and impossibilities of ADA systems substantially.


3 Introduction

Roads to the Future

One of the objectives of the Dutch Directorate for Public Works and Water Management (Rijkswaterstaat) is to improve traffic flow in terms of road safety, throughput and the environment by implementing innovative solutions. The innovation programme entitled Roads to the Future (WnT) was launched in 1996 within this framework. It aims to develop for innovative solutions by drawing upon the expertise of various parties – ranging from citizens to companies and from government to research institutes. Entrusted with the assignment "on the way towards clean, safe and comfortable mobility", the innovation programme has already initiated a large number of ideas and projects. The programme embraces the adage "long-term thinking, short-term action". Roads to the Future is carrying out pilot projects within this framework that are becoming more and more interesting, one of which is 'The Assisted Driver'.

Reason

Various studies and workshops served as the basis for this pilot. In 2003 and 2004, surveys of the future were made to acquire an insight into how the population of the Netherlands wishes to travel in the future and which social developments will be relevant. These social surveys revealed the future of the transport system, resulting in a three-part list of opportunities; ADA systems, cars that travel on a separate infrastructure (such as trains) and an individualised public transport system were tested to ascertain how effective they would be in ensuring the main road network is used more efficiently. The Almere-Amsterdam corridor was selected as a problem area. After further examination and consultation with "the environment" there, it was decided that a pilot involving ADA systems would be the most effective, desirable and feasible option. Afterwards, a study was carried out to determine which ADA systems would support the objectives of the Dutch Directorate for Public Works and Water Management (road safety, throughput and the environment) most effectively. Eventually, a combination of longitudinal and lateral assistance systems for motorists was chosen.

ADA systems

Over the past few years, various ADA systems have been developed and introduced onto the market. The aim of these is to support and simplify the driving task of the driver. We make a distinction between systems that support the lateral driving task and ones that support the longitudinal driving task. Lateral systems are geared towards preventing steering mistakes. Via counter-steering or an audio warning, the driver is notified when he threatens to leave the lane he is travelling in unintentionally. The number of accidents caused by steering mistakes may be reduced as a result. Longitudinal systems focus primarily on ensuring the driver maintains a constant speed and distance to the vehicle ahead. These types of systems can have a positive effect on throughput , but could also help reduce the number of accidents caused by excessive speeds or inadequate distance headway.

Effects of ADA systems

Both on an international and national level, hardly any large-scale research has been carried out into the effects of ADA systems in practice. Such knowledge, particularly of the situation in the Netherlands is vital in that it provides input for policymaking by the Dutch Ministry of Transport, Public Works and Water Management and for the Dutch Directorate for Public Works and Water Management as the road authority. Via 'The Assisted Driver' pilot, Roads to the Future wants to provide a view of the future use of ADA systems, ensure they become more widely known and acquire an insight into their effect on traffic flow.

Timeline

During the annual meeting of the Roads to the Future programme held on 14 October 2004, 'The Assisted Driver' project was unveiled to the outside world for the first time with the help of virtual reality. A simulator allowed participants to test the Advanced Cruise Control (ACC), Lane Departure Warning (LDW) and Lane Keeping Assist (LKA) systems while a film provided an overview of the pilot.

On 24th May 2005, Roads to the Future organised a demonstration day called "Maatschappelijke kansen voor in-car technologie" (Social opportunities for in-car technology). Over two hundred local and international visitors were given the opportunity to personally experience what it is like to drive with ADA systems. More than thirty vehicles were provided by different manufacturers to this end. From September 2005 until January 2006, a trial was held under the flag of VANpool. The Dutch Directorate for Public Works and Water Management equipped a number of vehicles with the Headway Monitoring and Warning (HMW) and LDW ADA systems for this purpose. Participants were asked about their experiences with and appreciation of the systems.

A practical trial unique to the world was held from February until June 2006, during which twenty vehicles drove around the Netherlands equipped with ACC and LDW and one data-logger. This full-traffic trial charted the driving behavior of drivers and the effect on road safety, traffic flow throughput and the environment. Participants were also asked about their experience with and appreciation of the systems. On May 30th and May 31th May and on June 1st 2006, Roads to the Future organised a clinic for participants in the full-traffic trial. During a trip lasting over an hour, they were given the opportunity to acquire experience with LKA. The participants were interviewed to determine whether LKA offers added value in relation to LDW. The study results of 'The Assisted Driver' pilot were presented on October 23rd 2006 at the Mediapark in Hilversum and are being used in various ways. By way of example, articles have been published, presentations and congresses have been held, and the Dutch Ministry of Transport, Public Works and Water Management is trying – both internally and externally – to increase awareness for these study results.

October 14th 2004	Presentation in virtual reality
May 24th 2005	Demonstration day
September 2005 – January 2006	VANpool trial
February 2006 – June 2006	Full-traffic test
May 30th, 31st, June 1st 2006	Clinic
October 23rd 2006	Presentation of study results

Organisation

'The Assisted Driver' pilot was carried out within a project team comprising staff from various specialist departments of the Dutch Directorate for Public Works and Water Management. The Netherlands Transport and Research Centre (AVV), the Construction Department (Bouwdienst) and the Corporate Department of the Directorate were well-represented in particular. The project team worked by order of the executive committee of the Roads to the Future programme. The team cooperated closely with the Roads to the Future programme office in Delft. Within the project team, a distinction was made between project management, research, technology, communication and regional account management.

Partners

The following companies and organisations were involved in 'The Assisted Driver' pilot. Pon's automobielhandel, Volkswagen, MobilEye, Verkeer.advies, Bishop Consulting, ADAS Management Consulting, DHV, PRC, TNS Nipo, TU Delft, TU Dresden, ARS, Toyota Motor Europe and EVE& Beleveniscommunicatie.

Guido van Woerkom: "Fascinating results."

Guido van Woerkom, Managing Director of the ANWB (the Dutch Automobile Association), has added a car equipped with Adaptive Cruise Control to his 'wish list'. "It yielded fascinating results", he says with regard to 'The Assisted Driver' pilot.

"The tested systems are interesting tools for enhancing road safety and improving air quality", believes Guido van Woerkom. "Of course they are still fairly costly and are only being installed in expensive cars at this stage. Once the government makes concessions to consumers – by granting exemption from tax on private motor vehicles and motorcycles, for example – you can start thinking about implementation on a wide-scale." When such a market break-through is a reality, the ANWB will certainly emphasise the positive effects of these systems. Guido van Woerkom knows that doing so can have a stimulating effect. "After all, the ANWB also played a role in the introduction of blind-spot mirrors on trucks."

Calm

"I have had personal experience using the systems and was particularly impressed by ACC. It provides a certain feeling of calm while driving and increases comfort levels. A car equipped with ACC is most certainly on my wish list. LDW did not impress me as much." He comments further: "The distances that are driven in our country are smaller and motorists have to respond far more quickly. You can perhaps imagine that these systems could make you less alert in traffic."

Driving Simulator

4 Virtual Reality

At the annual meeting of the Roads to the Future programme held on October 14th 2004, 'The Assisted Driver' project was publicly unveiled for the first time with the help of virtual reality. The meeting commemorated the very beginning of 'The Assisted Driver' pilot, which will be examined briefly in this chapter.

Film and simulator

The aim of the virtual reality presentation held for the first time on October 14th 2004 was to place the topic of driving assistance technology on the agenda. The demonstration was attended by a large number of interested parties (policymakers from the Dutch Directorate-General for Public Works and Water Management (Rijkswaterstaat) and the Dutch Ministry of Transport, Public Works and Water Management). The presentation provided a clear insight into the technical possibilities. The virtual reality presentation comprises a short film about ADA systems. This animated film shows how ACC (Adaptive Cruise Control), LDW (Lane Departure Warning) and LKS (Lane Keeping System) function. The film also takes a look into the future and examines even more far-reaching applications. In addition to the film, the virtual reality presentation features a simulator upon which the three systems can be tested. Using simple means, this simulator enables interested parties to experience how the systems work.

On October 14th, the opportunities provided by ADA systems were introduced to a large number of interested parties for the first time. Those present were overwhelmingly positive and enthusiastic about 'The Assisted Driver' pilot. The Dutch Minister of Transport, Public Works and Water Management at the time, Karla Peijs, received an explanation later on about the virtual reality presentation and also took a seat in the simulator. The presentation was used on several more occasions after October 14th 2004. It appears to be an excellent tool for explaining 'The Assisted Driver' pilot.

May 24th 2005

5 Demonstration day

On May 24th 2005, a demonstration day was held, enabling interested parties to acquire practical experience with ADA systems. This chapter gives some background into how and why this demonstration day was held.

Reason

On May 24th 2005, Roads to the Future organised a demonstration day called "Maatschappelijke kansen voor in-car technologie" (Social opportunities for in-car technology). The pilots Belonitor, Wijzer op Weg and 'The Assisted Driver' played a central role in this regard. More than two hundred interested parties from the Netherlands and abroad, policymakers, representatives from universities, TNO (Dutch knowledge organisation for companies, government bodies and public organizations), ANWB (Dutch automobile association), SWOV (Dutch national road safety research institute), leasing companies, the European Commission and the automotive industry were present. They were given the opportunity to personally experience what it is like to drive with ADA systems. The purpose of the demonstration day was to enable these parties to familiarise themselves with these systems, make them aware of the possibilities and impossibilities of in-car technologies, and to stimulate the discussion around this theme.

Run-down of the day

The demonstration day was held on and around the test track of the Test Centre of the Rijksdienst voor het Wegverkeer (Dutch Road Transport Directorate) in Lelystad. The session kicked off with a presentation given by Richard Bishop, an expert in intelligent transport systems and ADA systems. He outlined various technologies currently available, touched upon the possibilities offered by existing systems and described what the future could look like. According to him, the automotive industry has focussed primarily on improving the ability of vehicles to withstand collisions and the protection of occupants over the past two decades. Bishop predicts that great emphasis will be placed on accident prevention during the coming twenty years. He believes that the government must promote the development and use of ADA systems.
An interactive panel discussion was held after the presentation. This panel was made up of André Vits (European Commission), Guido van Woerkom (Managing Director of ANWB), Berno Kleinherenbrink (Marketing Director of Leaseplan), Menno Olman (Director General of the Dutch Ministry of Transport, Public Works and Water Management), Carsten Spichalsky (Director of Research and Development at Volkswagen AG) and Petra Delsing (Head of Infrastructure and Traffic Management Rijkswaterstaat).

After the panel discussion, a vote was held to gauge the opinions of the participants. It emerged that 62% were of the opinion that consumers should personally pay for safety systems in their, while 77% agreed that these types of systems should be made compulsory.

After the plenary session, visitors were able to attend various workshops and presentations. They were also allowed to test drive one of the demonstration vehicles. Thirty vehicles provided by various car manufacturers were parked on the test track, equipped with various ADA systems. All of these systems could be tested on the test track as well as motorway nearby. The opportunity to personally experience the various systems was seized with much enthusiasm.

Richard Bishop

Used systems

The cars used for the test drives were provided by Volkswagen, Audi, Pon's Automobielhandel, Continental, ADC (Automotive Distance Control), Omron, Citroën, Bosch, DaimlerChrysler, Nissan, DAF, WABCO, Ford (Jaguar and Land Rover), Opel, Toyota, Lexus, Delphi and MobilEye. Those who participated in the test drives were introduced to various ADA systems.

LDW (Lane Departure Warning)
LDW is a system that warns the driver when the vehicle threatens to leave the lane its travelling in unintentionally. LDW is available in various versions: one that only provides an audio warning, one that adjust the steering briefly and emits an acoustic warning, and one where the driver's seat starts vibrating.

AutoTelegraaf.nl
Meer auto dan ooit.
Autonieuws
Slimme auto maakt verkeer veiliger
AMSTERDAM - Uit een praktijkproef blijkt dat slimme auto's het verkeer veiliger maken. Dat meldt Rijkswaterstaat, dat onder de noemer Wegen naar de Toekomst een innovatieprogramma heeft uitgevoerd. Voertuigen werden uitgerust met apparatuur waarmee je veilig afstand houdt tot je voorganger en waarmee je beter de belijning blijft. De conclusie is dat wanneer auto's in het dagelijkse verkeer zouden zijn uitgerust met de systemen er acht procent minder ongevallen zou plaatshebben.
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Slimme auto maakt rijden veiliger en comfortabeler
PReVENT
The Dutch "Road to the Future" shows the way to go
Een tw eede paar ogen
Innovatieve in-carsystemen dragen bij aan verkeersveiligheid

LKS (Lane Keeping System)
LKS actively helps the driver to keep the car in its lane. The system automatically corrects the steering when the car drifts from the middle of the lane.

Blind spot monitoring
The purpose of blind spot monitoring is to provide the driver with a better view of blind spots. Special mirrors (that may or not be heated), cameras or a radar give drivers a good overview of what is happening alongside and/or behind the vehicle. The system is available in two versions. The first system produces an audio warning when the driver indicates that he intends to overtake but a vehicle is travelling in the blind spot. In the other version, a virtual warning is displayed in the driver's mirror the moment a vehicle enters the blind spot.

HMW (Headway Monitoring and Warning)
HMW indicates the distance in seconds until the vehicle ahead on a dashboard display. When the car gets too close to the vehicle in front of it, the system emits an audio warning. The system only provides information and does not actively intervene.
(www.MobilEye.nl)

ACC (Adaptive Cruise Control)
ACC is a more advanced version of the cruise control system currently installed in many cars. The ACC system automatically adjusts the speed of the car to that of the vehicle ahead of it. If the car gets too close to the vehicle in front, the system will brake. If the road is clear, because the driver is moving into a lane on the left, the car will accelerate automatically until it reaches the specified speed.

ACC-LSF (Adaptive Cruise Control – Low Speed Following)
This system also functions at low speeds and facilitates "traffic-jam driving". ACC-LSF stops a car automatically when the vehicle ahead stops. Once the vehicle in front starts driving again, the driver often has to intervene to get the car moving again. This can be done by pressing a button or touching the accelerator pedal, for example.

Brake Assist
The Brake Assist was developed in the knowledge that driver do not always brake properly in emergencies (often not hard enough). Depending on the situation, this system determines how much braking power is required to prevent a collision.

CMBS (Collision Mitigation Brake System)
CMBS uses a radar to detect the distance between a car and a vehicle ahead of it. The driver is warned when the distance becomes too small. The system will brakes automatically if an accident can no longer be avoided. The car's seatbelts are tightened simultaneously to prevent any injuries.

APIA (Active Passive Integration Approach)
APIA is a system that integrates active and passive safety systems. The system assists the driver as soon as a collision is imminent. The use of APIA significantly reduces a car's braking distance, thereby minimising the risk of a collision. (www.conti-online.com)

Terrain Response
Terrain Response allows a driver to specify the type of surface the vehicle is travelling on (asphalt, grass, snow or sand) with the push of a button. The system than adjusts the engine, transmission, suspension and traction controls to the relevant surface to ensure optimal performance.

Vehicle-to-vehicle communication demonstration
TNO has provided two Smarts that can communicate with one another and automatically follow one another at a short distance (platooning). This is part of the European Cartalk project. Vehicle-to-vehicle communication is an extension of ADA systems.
The main difference, however, is that ADA systems react to situations while vehicle-to-vehicle communication systems anticipate to situations.

Peter van Zadelhoff on ACC: "Wonderfully soothing."

Participating in 'The Assisted Driver' pilot provided Peter van Zadelhoff with an ideal opportunity to purchase a Volkswagen Passat. Initially the facade consultant and the garage had difficulty agreeing on a price, but his remuneration for participating in the project of the Dutch Directorate-General for Public Works and Water Management helped overcome this financial obstacle.

For Peter van Zadelhoff, the project was certainly no punishment. "The Passat did indeed catch my eye while participating in the project, but I have always had a profound interest in technology. I also spend a lot of time on the road because of my company, Adviesbureau Van Zadelhoff. I drive fifty thousand kilometres a year on average, which makes me an ideal candidate."

ACC more appealing
Peter van Zadelhoff is enthusiastic about ACC. "I noticed that it really does work incredibly well. In traffic jams in particular, the system is very soothing since you do not have to do anything. The car intervenes automatically." However, it nearly all went terribly wrong on one occasion. Peter van Zadelhoff was driving along the A50 motor-way when snow fell on the emblem, blocking the laser situated behind it. The system could not detect any vehicles ahead as a result. "As I joined the traffic jam in the snow, the car accelerated until 120 km/h. That was quite frightening. Now I deactivate the system in extreme weather." Peter van Zadelhoff has noticed that he is slowly starting to trust the system more and more. Ultimately, he preferred using ACC than LDW. "The audio signal often irritated me, but I left it on deliberately. I believe that if you are involved in such a project, you must also participate properly. I must admit though that I was disappointed when I noticed how often I drifted towards the lines. I use my indicator far more often now. That is a positive development."


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6 VANpool pilot

The VANpool pilot provides an insight into the acceptance of ADA systems and driver behavior. This chapter will explain how the pilot was set up and which aspects are examined. We will focus on the results of the study and summarise the conclusions of the pilot.

6.1 Introduction

The VANpool project is running in and around the city of Amsterdam. Employees are given the opportunity to carpool to work in a Volkswagen Sharan (a family car that seats a maximum of six people). These "vans" travel in the bus lane alongside the traffic jam from Flevoland to various business areas in Amsterdam. VANpool is an initiative of Bureau Verkeer.advies commissioned by Stichting Amsterdam Zuidoost Bereikbaar. The Dutch Directorate-General for Public Works and Water Management (Rijkswaterstaat) has joined this project by installing ADA systems in several vehicles involved in the project. A pilot held from September 2005 until January 2006 enabled drivers and passengers to experience these technologies.
The aim of the pilot was to acquire an insight into the behavior and acceptance of these systems among drivers as well as passengers.

Two systems
The participating vans (20 in total) are equipped with two types of ADA systems, both of which form part of MobilEye's Advanced Warning System (AWS)[1].
The Lane Departure Warning system (LDW) warns the driver when the vehicle threatens to leave the lane it is travelling in unintentionally. The Headway Monitoring & Warning system (HMW) indicates the distance in seconds until the vehicle in front on a dashboard display. When the car gets too close to the vehicle ahead, the system emits an audio warning.
Both systems only provide information and do not actively intervene.
More information about these systems is available on page 9.

[1] Additional information can be found on www.MobilEye.com.

6.2 Study setup

Training
All participants were trained before the pilot started in September 2005. Part of the training focussed on driving the car in the bus lane and on the hard shoulder. Participants were notified about applicable rules that they had to observe. Drivers were also told how LDW and HMW should be used in practice.

Surveys
Three measurements were carried out shortly before and during the pilot (September 2005 – January 2006), during which both the van drivers and passengers were surveyed. The baseline measurement was performed in September 2005. During this first month of the pilot, the systems were not yet activated. The baseline measurement is therefore also intended as a benchmark. This measurement involved 16 participants (9 drivers and 7 passengers).
The first measurement was conducted in November 2005, once the participants had acquired some experience. This survey was completed by 19 participants: 14 drivers and 5 passengers.
The second measurement was conducted in January 2006, by which time the participants had acquired a reasonable amount of experience. A total of 13 participants (9 drivers, 4 passengers) participated in the second measurement. The surveys were carried out using paper questionnaires.

Focus groups
In addition to the surveys , two meetings were held in November 2005 involving a selection of participants. The aim of these focus groups was to acquire a deeper insight into experiences with ADA systems. The participants in the VANpool project were invited to take part in a group discussion about their experiences with LDW and HMW. Nine people in total participated in these two group discussions, which comprised an afternoon session with five participants and an evening session with four participants.

6.3 Results

It is worth mentioning beforehand that the following results are based on the opinions and experiences of participants (drivers and passengers). In other words, these are not objective facts. Moreover, we are discussing the verdict of a relatively small group.

The baseline measurement revealed that participants have a positive to neutral attitude towards ADA systems. Many have experience with cruise control systems, which no one was negative about. Approximately half of those with such experience believe that cruise control systems contribute significantly to comfort levels, while the other half believe it contributes slightly.

6.3.1 Survey results

General
Participants in the VANpool pilot were positive about the Advanced Warning System due to its functional values in particular (increased alertness, practical and helpful). Drivers and passengers think the system enhances safety and that LDW as well as HMW reduce the likelihood of accidents. The majority are satisfied with AWS and indicate they would like to have the system in their own cars. Most drivers are positive or neutral about making AWS obligatory. In the second measurement, more drivers indicate that AWS simplifies the task of driving in comparison with the first measurement. In that measurement, they also recommend the system more empathically within their own environment. It appears that drivers and passengers who look for the causes of accidents amongst themselves in particular have a more positive attitude towards AWS than those who often search for external causes.

LDW en HMW
Participants find that the warning signals of both systems are clear. Drivers find the signals provided by HMW more superfluous than those of LDW. During the second measurement, drivers and passengers find the warning signals less irritating and less often superfluous than during the first measurement. At the same time they are less convinced about its usefulness on provincial roads and motorways. During the second measurement, participants consider LDW to be more useful when driving in narrow lanes compared to the first measurement. In the second measurement, the system's usefulness for maintaining a better direction is lower again. The usefulness of HMW for following vehicles ahead at an adequate distance and travelling less nearer to them in traffic congestion is greater in the second measurement than in the first measurement. in the second measurement, drivers indicate that they maintain a greater following distance when using HMW.

Use
Drivers do not find it difficult to drive and operate AWS at the same time, and indicate this is easy to learn. Most of them always have AWS switched on, irrespective of the type of road or prevailing weather conditions. The majority of drivers indicate that the system barely influences or does not influence their concentration, anticipation, alertness and overview of traffic. They do not use their hands more often for other activities and when AWS is activated, they grip the steering just as firmly as when it is not activated. The latter would imply that drivers do not find driving with AWS to be more difficult or easier.

6.3.2 Results of focus groups

Expectations about LDW and HMW beforehand
Drivers who could imagine the pilot beforehand had high expectations. A number of them, for example, thought that a voice would give instructions or that the system would automatically ensure that the vehicle maintained an appropriate distance from the vehicle ahead. Some of the drivers who were surveyed were not properly informed about the pilot and therefore did not have any expectations beforehand.

General use of LDW and HMW
Drivers' experiences with LDW and HMW vary from negative and resigned to positive. In general, we can state that users do not enjoy being corrected, but do view the system as an asset. In particular, the surveyed drivers recognise the value and necessity of the system on provincial roads with oncoming traffic, during long trips and on unfamiliar roads. According to them, LDW in particular provides added value during heavy downpours or snowfall. However, the system does not function properly in such conditions.

Settings and design of LDW and HMW
Drivers provided the following comments about LDW settings:

- "The warning that is emitted when the vehicle crosses the line is irritating."
- On some roads, the driver has no choice but to cross the lines now and again. This occurs on narrow, local roads flanked by bicycle paths on both sides. The system then emits an unnecessary warning.
- Warnings are emitted too quickly.

With regard to HMW, users think that the distance until the vehicle in front could be greater.

Improvements to the design of the systems are also desirable. Drivers criticised the following aspects:

AWS:

- The system does not function underneath viaducts on occasions.
- Sometimes the system does not work when it is raining.

LDW

- The system sometimes detects old lines on the road.
- The system sometimes does not always work when puddles of water are on the road.
- The warning for "left" appears to be emitted earlier than "right". In all likelihood this is due to the fact that drivers are naturally inclined to drive slightly to the left of the middle of a lane.

LDW and HMW in their own car?

The majority of participants in the pilot would – depending on the price – like to have LDW and HMW installed in their own cars. They refer to an average price of € 500 (with exceptions ranging from € 250 until € 5,000).

6.4 Conclusions

The majority of participants in the pilot are satisfied with AWS. They find the system easy to use and believe that driving with both LDW and HMW is conducive to road safety. This is due to the fact that drivers' adapt their driving behavior (in a positive sense) in order to minimise the number of warnings. Participants also maintain their distance better, use their indicators more often and maintain their direction on the road more effectively. Furthermore, they also find the task of driving to be less demanding overall. Bear in mind though that this is their opinion.

To summarise, the system is considered irritating but effective, with a preference for LDW instead of HMW. HMW not only warns the driver more often than LDW, but participants think the warnings provided by this system are often also more unnecessary than those emitted by LDW.

Wouter Verkerk looks to the future

For the Director of Verkeer.advies, Wouter Verkerk, the success of 'The Assisted Driver' project confirms his ideal view of a future where vehicles are controlled automatically. "Commuting between home and work without any problems is a thing of the past in the Netherlands. It is time we started considering other alternatives seriously."

Wouter Verkerk is focussing on the future. "The positive results of 'The Assisted Driver' project are a continuation of the VANpool, which tested the same technologies. If you extend the VANpool even further, you are talking about a third traffic flow where automatically controlled vehicles pass traffic jams one after the other at high speed." The technologies for such an alternative form of travel are developing at breakneck speed. Wouter Verkerk estimates that technical obstacles impeding the development of automatically controlled vehicles will disappear in five to ten years.

Room for driver assistance

"The wonderful thing about 'The Assisted Driver' project is that people are once again positive about such intelligent technologies", says Wouter Verkerk. "I have driven a car equipped with ACC and was most impressed. People really do attach considerable value to freedom, but the most important aspect of all is that you can travel around quickly, comfortably and easily. In our country, a pleasant drive to work is a thing of the past ."

According to him, public acceptance will ensure that the emergence of this form of transport does not encounter any problems. Given the speed at which the technology will overtake the problem of traffic congestion, Wouter Verkerk believes that government policy faces a real risk that once social acceptance is complete, there will no longer be a infrastructure for these means of transport. "I think that additional room has to be created for these automatic vehicles. It would be advisable to start working on a safe infrastructure now that allows tests with automatic transport to be conducted." He dismisses criticism from environmentalists regarding this expansion of the road network. "Collectively controlled traffic can provide a solution to traffic congestion. And moving cars are better for the environment than stationary ones."

Official opening full-traffic test on March 10th 2006

7 Full-traffic test, behavior and acceptance

This chapter examines the "full-traffic test". This test comprises two parts: a study of the behavior and acceptance of driver-assistance systems (subjective study) and an analysis of log data (objective study). We will first explain how the two studies were carried out, before looking at the results of the subjective study. Finally, we will offer a list of conclusions. The results of the objective study can be found in Chapter 8.

7.1 Introduction

During the five-month trial (February 2006 until June 2006), nineteen people – living in various places throughout the Netherlands – drove around in a Volkswagen Passat equipped with driving assistance technology. During the first month, no ADA systems were used in order to chart the standard driving behavior of the driver in question (reference situation).

The full-traffic trial has two objectives. First of all, data loggers are used to compile objective information. An analysis of this data then reveals what effect driving assistance systems have on individual driving behavior and the consequences thereof for traffic flow. Consider aspects such as safety, throughput and the environment. The subjective component of the full-traffic trial answers the question whether participants personally experience a change in their driving behavior by using these systems. The researchers also outline the acceptance of and appreciation for driving assistance technology.

Two systems
Two types of ADA systems were installed in the participating cars. The Lane Departure Warning system (LDW) warns the driver when the vehicle threatens to leave the lane it is travelling in unintentionally. The Adaptive Cruise Control system (ACC) automatically adjusts the speed of the car to that of the vehicle ahead of it.
All of the cars used in the trial were fitted with an automatic transmission. Many participants had to get used to switching from a manual to an automatic transmission.

Participants
The participants in the trial were selected by Pon's Autolease. Customers who wanted to drive a Passat were asked to participate in the project. In exchange, ACC and LDW were installed in the cars for free. The group that participated in the full-traffic trial (sixteen men and three women) are lease drivers. Every year, they drive between 25,000 and 75,000 km and are mostly very interested in technical devices for cars. We can therefore assume that they use ADA systems more intensively than average drivers, which means they become more quickly accustomed to this type of technology.

7.2 Setup of subjective study

The subjective study into the acceptance of ADA systems was carried out by TNS-Nipo (the Dutch Institute for Public Opinion and Market Research). Surveys were conducted amongst participants and within focus groups, and a number of participants spoke in-depth about their experiences with these systems. The study focuses on the following aspects: use, habituation, behavior, appreciation and safety.

Online surveys
Three online surveys were carried out at the beginning of and during the trial. The baseline measurement was carried out in March 2006. At that moment, the participants in the trial had no experience with ADA systems. They were already driving the test car, but the system was still deactivated. The first measurement was conducted in April 2006, once the participants had acquired some experience. The third and final measurement was conducted in June 2006, by which time the participants had acquired a reasonable amount of experience.

For the surveys, all participants in the trial received a letter containing a link to website where the questionnaires could be filled in. The survey for the baseline measurement was completed by 10 participants, while that for the first and second measurements was filled in by 16 participants. Amongst other things, the surveys asked the participants to share their opinions on mobility and in-car systems, whether they had any experience with such technology and what they thought of LDW and ACC.

Focus groups
In addition to the online surveys, two focus groups were organised in May and June 2006. A selection of participants in the trial took part. The aim of these sessions was to acquire a deeper insight into their experiences with ADA systems.

The participants in the trial were called and asked to participate in the first consultation round on May 9th 2006. In the end, five participants participated in this focus group.
The second session comprised four in-depth interviews conducted by phone on June 29th and 30th 2006.

David Kat: "We are now even further along than we were during the project."

MobilEye has developed a visual technology featuring a small computer equipped with one lens that can estimate distances and identify lane markings. According to Manager David Kat, this intelligent video system can improve road safety. "But we are continuing to develop ourselves; we are becoming increasingly better."

David Kat explains that MobilEye was approached about three years ago to participate in a project of the Dutch Ministry of Transport, Public Works and Water Management called "Dear Truck". "We decided not to get involved as we did feel we were ready yet. However, we did participate in the VANpool project, which is how we became involved in Roads to the Future.

David Kat believes participating in this project is important because it allows the company to demonstrate on a reasonably large scale that the technology is ready for the market. "By the way, that does not imply that we are completely finished with development work. No less than 95% of our personnel are involved in R&D activities. We are now already much further along than we were at the time of the project. The more information we compile, the better the technology becomes."

Improved driving style

The results of the project did not really surprise David Kat. However, he does find it encouraging to see that so many objective drivers realise that such systems can contribute to road safety. "The fact that not all of the participants are convinced about the benefits implies that the systems can be improved. We are working extremely hard on this." According to him, policymakers must use these project results to consider whether such devices must be made mandatory. Especially now, given that the benefits of the systems outweigh the costs so clearly. "It is not the case that the system decreases the driver's workload while driving a car, but it does ensure that the driver pays more attention. In some cases, it appears that the driving style of participants has undergone a remarkable improvement. That is an impressive result for drivers with many years of driving experience."

For MobilEye, it is very important that manufacturers start installing the systems from 2007 onwards. David Kat: "We have agreements with seven of the top ten car brands. This naturally means a great deal for our company."

The following topics of discussion arose during the consultation rounds:

- the circumstances under which the participants activate ACC and/or LDW;
- the nature of and reasons behind the difference in appreciation for ACC and LDW;
- the effect of ACC and LDW on driving behavior and changes over the course of time;
- the contribution of ACC and LDW to safety;
- the differing effects of ACC and LDW on alertness;
- satisfaction with the design of the system and points for improvement.

7.3 Results of subjective study

The results of the subjective study were based on the opinions and experiences of the participants. In other words, this does not specifically involve objective facts!

Use

The surveys and focus groups revealed that the participants have LDW activated far more often than ACC: three-quarters of those who were questioned always or usually have LDW activated. The road type, weather conditions and volume of traffic barely influence the decision whether or not to activate LDW. The participants use ACC primarily on quiet to moderately busy motorways or provincial roads. They prefer not to use the system during heavy rainfall or snowfall.

Familiarisation

The participants indicate that learning to drive with LDW is easier than driving with ACC. Approximately two-thirds were able to use LDW properly and thoroughly more or less immediately. Roughly half of the participants required a week to learn how to use ACC. We can conclude from this that drivers get used to the technology relatively quickly, but require more time for ACC than for LDW.

Behavior

The participants indicate that they maintain a greater following distance than usual thanks to ACC. Roughly half say that they tend to veer to the left sooner to prevent ACC from braking because they are too close to the vehicle ahead. A quarter of participants indicate that they continue driving in the left lane longer. They attribute this to the slow response of ACC. About half say that they use their indicators more than beforehand thanks to LDW.
During the first measurement, some participants reveal that they perform additional activities (smoking, eating, drinking, using a mobile phone) more frequently if LDW and/or ACC are activated. During the second measurement, this number increases even further.
When asked about concentration, a small group of participants indicate during the first measurement that they are less concentrated when using LDW and/or ACC. A clear majority remain just as concentrated as usual. During the second measurement, the number of participants that concentrate less well decreases significantly. One–third of those who were surveyed find that LDW and/or ACC provide them with a better overview. More than half do not see any difference, while a few reveal that using the systems reduces their overview.

Appreciation

The participants appear to be more satisfied with ACC than with LDW. During the second measurement, all participants actually choose ACC when asked to make a choice between both systems. They consider ACC to be fun and useful. However, the system scores lower as far as alertness is concerned. The participants do not like LDW, but do believe it increases alertness.
The warnings emitted by this system are considered “clear”, but also “irritating and disruptive”.

Safety
According to the participants, ACC minimises the likelihood of accidents more than LDW. Both systems help increase safety, but the participants believe that ACC does so more extensively.

7.4 Conclusions

Familiarisation relatively quickly
People who drive with LDW activated become accustomed to the system more quickly (ranging from a few days until a maximum of a number of weeks) than with ACC (from a few weeks until a month and a half). This primary reason for this is because ACC actively intervenes by itself whereas LDW does not. All in all, the participants become accustomed to both systems relatively quickly. However, this does necessarily hold true for the average driver. After all, the group participating in the full-traffic trial is a selective one that drives many kilometres and is very interested in the latest technical innovations. We may therefore assume that they use the systems more intensively than the average driver would, which means they can master them quicker.

Resolving teething problems
Overall, it emerges that participants believe ACC offers added value in particular. In their opinion, this system contributes more significantly to road safety and ensures that drivers feel less agitated while driving. According to them, this contribution to road safety is provided primarily by an increased following distance. They believe that this minimises the risk of front-end/rear-end collisions. The added value of ACC should be even greater once a number of teething problems in the system have been resolved. The participants believe that ACC accelerates too slowly when changing lanes to overtake, and brakes the car a bit too abruptly. As a result, they continue driving on the left needlessly and are overtaken on the right.
To prevent this from occurring, participants occasionally override ACC on busy roads or do not activate it all.

Encouraging people to purchase
Once these aspects have been improved, the participants declare they are willing to pay approximately five hundred euros for such a system when purchasing a new car. However, they do point out that it would be desirable and beneficial if the government made a contribution in this regard. The participants consider this reasonable given the positive contribution of ACC to road safety, in their opinion.

Less appreciation for LDW
Upon examining LDW, it can be concluded that participants do indeed activate this system more often than ACC, but that they appreciate it relatively less. Its added value is less apparent to them and they do not feel that they can trust the system completely (yet) as it produces unnecessary warnings in some situations. They are more in favour of an upgraded version of LDW, namely the Lane Keeping System (LKS). This system provides warnings with the help of steering corrections or actively keeps the car in the middle of the lane.

The ideal combination of ADA systems (in terms of comfort/driving pleasure as well as safety) would therefore be ACC and LKS. This would provide synergy effects or, as one of the participants puts it: “one plus one equals three”.

Available ADA systems

The list below indicates which car brands have introduced ADA systems onto the market or which ones will do so in 2007.

Source: ADAS Management Consulting

Full Speed Range ACC

BRAND	REGIONS
BMW 7-series	Europe, Asia and USA (2007)
Mercedes S-Class	Europe, Asia and USA (2005)
Renault Infiniti, FX, QX and M	Asia (2005), USA (2006)
Toyota Crown Majestic	Asia (2005)
Lexus IS, LS and GS	Asia (2006), USA (2007)
Volkswagen Phaeton	Europe, Asia and USA (2007)
Volkswagen Audi Q7	Europe, Asia and USA (2006)

ACC

BRAND	REGIONS
BMW 7-series	Europe (2001), Asia and USA (2002)
BMW 5-series	Europe, Asia, USA (2003)
BMW 3-series	Europe, Asia, USA (2005)
Mercedes S-Class, CL and SL	Europe (1989), Asia and USA (2001)
Mercedes E-Class and CLK	Europe (2001), Asia and USA (2002)
Chrysler 300c	USA (2006), Asia, Europe (2007)
Jeep Cherokee	USA (2007)
Fiat Stilo	Europe (2002)
Lancia Kappa	Europe (2002), USA (2003)
Ford Mondeo	Europe (2007)
Ford S-Max	Europe (2006)
Ford Galaxy	Europe (2006)
Volvo S80	Europe, Asia, USA (2006)
Jaguar S-type	Europe, Asia, USA (2003)

Jaguar XK 8	*Asia (2000), Europe, USA (2001)*
Jaguar XJ	*Europe, Asia, USA (2002)*
Land Rover Discovery	*Europe (2006), Asia, USA (2007)*
Honda Legend	*Europe, USA (2006)*
Honda Accord	*Asia (2004), Europe, USA (2006)*
Honda Avancier	*Asia (2000)*
Honda CRV	*Europe, Asia, USA (2006)*
Honda Inspire	*Asia (2003)*
Hyundai Sonata	*Asia (2006), Europe, USA (2007)*
Renault Velsatis	*Europe (2003)*
Renault Espace	*Europe (2008)*
Renault Megane	*Europe (2008)*
Nissan Primera	*Asia (2000), Europe (2001)*
Nissan Fuga	*Asia (2006)*
Nissan Diverse	*Asia (2003)*
Renault Infiniti FX	*Asia (2001), USA (2002), Europe (2006)*
Renault Infiniti QX	*Asia, USA (2001), Europe (2006)*
Renault Infiniti M	*Asia (2001), USA (2002), Europe (2006)*
Subaru Legacy	*Asia (2001)*
Toyota Sienna	*Asia (2002), USA (2003)*
Toyota Crown Majestic	*Asia (2000)*
Daihatsu Move	*Asia (2001)*
Lexus IS	*Europe, Asia (2005)*
Lexus LS and GS	*Asia (2003), Europe (2004)*

LDW and LKS

Citroën has included LDW in their C4 and C5 models. Mercedes and Man have installed LDW in their heavy vehicles. Nissan only produces LDW models for Japan. Infiniti (Nissan) has already brought LDW to the American market. In 2007, Europe is set to follow. Honda and Lexus only offer LDW and LKS in Japan and Great Britain. Both brands plan to introduce the systems to the European market in 2007, as will Audi.

Besides these 'prefab' models above, cars can also be fitted with LDW by installing the MobilEye system.

Tom Alkim, Research Coordinator

8 Full-traffic test, objective study

The objective study is an important part of the full-traffic trial. This chapter explains how the study was conducted. We will focus on the results (classified according to use and driving behavior) and the effects these have upon throughput, safety and environment. At the end of the chapter, we will provide a summary and list of conclusions.

8.1 Introduction

As indicated in chapter 7, the full-traffic trial has two objectives. The subjective component of the full-traffic trial answers the question whether participants personally experience a change in their driving behavior by using these systems and whether they appreciate and accept ADA systems. Objective information has also been compiled with the help of data-loggers. An analysis of this data then reveals what effect ADA systems have on individual driving behavior and the consequences thereof for traffic flow. Consider aspects such as safety, throughput and the environment.

Nineteen participants selected by Pon's Autolease took part in the trial. Two types of ADA systems were installed in the participating cars: Adaptive Cruise Control (ACC) and Lane Departure Warning (LDW).

8.2 Setup of objective study

The objective component of the study was carried out by TU Delft. ARS Traffic & Transport Technology and TU Dresden were also closely involved.

Approach
The first phase of the study entailed the compilation of vehicle data with the help of data-loggers. All vehicles were equipped with hardware and software so that data could be saved on a vehicle PC and sent to a central server. Special software was written in order to process this crude data.

The manner in which ADA systems are used and how they influence the driving behavior of the motorist were also examined. The impact study investigated what effect changes in driving behavior would have on road safety, throughput and the environment.
The first results of the trial were presented to several experts during an expert workshop. They voiced their opinion about the setup of the trial and the initial findings. During the last phase of the study, the field results and results from the expert workshop were combined.

8.2.1 Primary study questions and sub-questions

The aim of the study is formulated as follows:
"Carry out an objective analysis of the effect of driving with ACC and LDW on individual driving behavior and the consequences thereof for traffic flow as a whole, including the compilation of data on driving behavior required to this end."

The following related study questions were derived from this study aim:

1. How do drivers use available ADA systems?
2. What effect does the use of these systems have on individual driving behavior?
3. How do changes in driving behavior influence traffic flow throughput?
4. How does ADA influence road safety?
5. To what extent do fuel consumption and emissions change because of the ADA systems examined here?

The primary focus of the study is on the immediate, quantifiable effects in relation to the use of ADA, the effect on driving behavior, the effect on traffic flow throughput and the effect on road safety and the environment.

Sub-questions relating to the use of ADA
In order to predict the effects of LDW and ACC, it is essential that we obtain an insight into the extent and manner in which drivers use the various systems. After all, if the driver hardly uses the systems, we cannot expect any major effects either. To acquire this insight, the following sub-questions must be answered:

a. On what type of road are the systems used (motorway, provincial road, city road)?
b. Under which traffic conditions are the systems used?
c. When are the systems activated?
d. When and how are the systems deactivated?
e. Which settings are used (headway time, speed) and how are these related to the applicable speed limit, road type and traffic conditions?

Sub-questions regarding the effects on driving behavior
The use of ADA will lead to changes in driving behavior. This is a direct consequence of the fact that drivers are assisted in one or more of the sub-tasks they have to perform. From now on, we will classify these sub-tasks into the following four groups:

- Choice of free speed and acceleration characteristics
- Vehicle tracking behavior
- Maintaining position within the lane
- Lane changing behavior (overtaking)

We can formulate the following sub-questions on the basis of this classification:

a. To what extent does ADA influence the choice of free speed (in relation to the applicable maximum speed)?
b. How do acceleration characteristics change as a result of ADA?
c. How does the tracking behavior of the motorist/vehicle change as a result of ADA (in relation to the selected ADA settings)?

d. How do weaving and the Standard Deviation of Lateral Position (SDLP) change as a result of the available ADA systems?
e. How does lane changing behavior alter?

Sub-questions regarding the effects on traffic flow throughput
Changes in driving behavior due to the use of ADA naturally lead to changes in traffic flow throughput. In the underlying study, traffic flow throughput refers primarily to the capacity of bottlenecks and related characteristics (speed, journey times, etc.). It is essential to acknowledge that capacity is more or less determined by minimal headway times (per lane) and the (efficient) distribution of traffic across available lanes. Finally, there are also indirect effects that are caused primarily by changes in road safety. The following sub-questions have been formulated with regard to the effects on traffic flow throughput:

a. To what degree does capacity change per lane as a result of ADA?
b. To what extent does the distribution of traffic across lanes change?
c. What is the anticipated effect thereof on congestion and travelling times?
d. What are the anticipated indirect effects on traffic flow throughput as a result of the change in road safety?

Sub-questions regarding the effects on road safety
In addition to throughput, ADA will also influence road safety. A distinction can be made between direct and indirect effects:

a. To what extent is the risk of an accident involving one vehicle/party influenced?
b. To what extent does ADA influence the risk of a rear-end collision?
c. Will the likelihood of a sideways collision change due to ADA?

Sub-questions regarding fuel consumption and emissions
Finally, it is essential to examine whether there is a change in environmental impact. We will focus primarily on fuel consumption and emissions:

a. What effect does driving with ADA have on fuel consumption?
b. What effect does driving with ADA have on emissions?

8.2.2 Relationship between sub-questions and indicators

Table 8.1 Relationship between study questions, indicators and data sources for the use of ADA

Study question	Indicators	Data sources
On what type of road are the systems used (motorway, provincial road, city road)?	• Status of ACC as a function of time and road type	• Status ACC/LDW • Road type
Under which traffic conditions are the systems used?	• Status of ACC/LDW as a function of time and traffic conditions	• Status ACC/LDW • Prevailing traffic conditions
When are the systems activated?	• Activation time and relation-ship between preceding traffic conditions, road type	• Status ACC/LDW • Road type • Prevailing traffic conditions
When and how are the systems deactivated?	• Road type and conditions at the moment of activation • Time between activation and deactivation	• Status ACC/LDW • Road type • Prevailing traffic conditions
Which settings are used (headway time, speed) and how are these related to the applicable speed limit, road type and traffic conditions?	• Status of ACC/LDW as a function of prevailing traffic conditions, road type and applicable speed limit	• Status ACC/LDW • Road type • Speed limit • Speed

Table 8.2 Relationship between study questions, indicators and available data for the effect of ADA on driving behavior. All indicators apply per road type and various traffic conditions.

Study question	Indicators	Data sources
To what extent does ADA influence the choice of free speed (in relation to the appli-cable maximum speed)?	• Speed in free traffic as a function of the use of ADA	• Speed • Prevailing traffic conditions • Road type, applicable maximum speed • ACC status and settings, LDW statu
How do acceleration characteristics change as a result of ADA?	• Acceleratie en absolute acceleraties als functie gebruik ADA	• Speed (derivative) • Prevailing traffic conditions • Road type, applicable maximum speed • ACC status and settings, LDW status
How does the tracking behavior of the motorist/vehi-cle change as a result of ADA (in relation to the selected ADA settings)?	• Headway time as a function of the use of ADA	• Status ACC/LDW • Prevailing traffic conditions • Road type, applicable maximum speed • ACC status and settings, LDW status
How do SDLP and the average lateral position change as a result of the available ADA systems?	• Lateral position as a function of the use of ADA • Line crossings	• Lateral position • LDW warnings • Prevailing traffic conditions • Road type, applicable maximum speed • ACC status and settings, LDW status
How does lane changing behavior alter?	• Number of lane changes as a function of the use of ADA • Use of direction indicators as a function of the use of ADA • Used lane as a function of the use of ADA	• Number of lane changes • Indicator usage • Used lane • Prevailing traffic conditions • Road type, applicable maximum speed • ACC status and settings, LDW status us

Table 8.3 Relationship between study questions, indicators and data for the effect of ADA on traffic flow throughput

Study question	Indicators	Data sources
To what degree does capacity change per lane as a result of ADA?	• Minimum headway time as a function of the use of ADA	• Prevailing traffic conditions • Road type, applicable maximum speed • ACC status and settings, LDW status
To what extent does the distribution of traffic across lanes change?	• Lane use as a function of the use of ADA	• Used lane • Status ACC/LDW • Prevailing traffic conditions
What is the anticipated effect thereof on congestion and travelling times?	• Predicted traffic flow as a result of ADA	• Modelling and simulation
What are the anticipated indirect effects on traffic flow throughput as a result of the change in road safety?	• Predicted reduction in number of accidents due to the effect of ADA on road safety	• See "Road safety indicators"

Table 8.4 Relationship between study questions, indicators and data for the effect of ADA on road safety

Study question	Indicators	Data sources
To what extent is the risk of an accident involving one vehicle/party influenced?	• Speed in relation to applicable speed limit and use of ADA	• Speed • Applicable speed limit • Status ACC/LDW
To what extent does ADA influence the risk of a rear-end collision?	• Likelihood of short headway times (< 0.7 s) • Likelihood of short TTCs (< 1.5 s)	• Headway time • Relative speed • Status of ACC/LDW
Will the likelihood of a sideways collision change due to ADA?	• Lateral position of vehicle within lane • Number of lane changes • Use of direction indicators	• Lateral position • LDW warnings • Number of lane changes • Use of direction indicators • Prevailing traffic conditions • Road type, applicable maximum speed • ACC status and settings, LDW status

Table 8.5 Relationship between study questions, indicators and data for the effect of ADA on the environment

Study question	Indicators	Data sources
What effect does driving with ADA have on fuel consumption?	• Fuel consumption in relation to the use of ACC	• Fuel consumption • Prevailing traffic conditions • Road type, applicable maximum speed • ACC status and settings, LDW status
What effect does driving with ADA have on emissions?	• Emissions in relation to the use of ACC	• Fuel consumption • Predicted emissions from model • Speed, acceleration • Prevailing traffic conditions • Road type, applicable maximum speed • ACC status and settings, LDW status

8.2.3 Comparison of situations before and after

The study method that was followed comprised:

- The comparison of indicators for the pre-measurement and post-measurement (and in some cases the transitional period). Averages are calculated for the entire population to this end, provided sufficient data is available for pre-measurement and post-measurement.
- The comparison of the various statuses of ADA systems.

During the comparison between the situation beforehand and afterwards, it is essential to take into account the composition of the compiled data. In the situation beforehand, for example, more or fewer cases of congestion can occur compared to the situation afterwards. Alternately, drivers (on average) in the situation beforehand have spent more time on the main road network than in the situation afterwards.

This means that indicators encompassing an entire period must be handled extremely carefully. In most cases, it is better to consider the indicators for a specific case (e.g. a motorway, heavy traffic).

8.2.4 Hypotheses

Part of the method that was used involves determining the anticipated impact beforehand. In the underlying study, this was done partly on the basis of the results from the expert workshop and partly on the basis of the personal expertise of the project group.

This pre-assessment resulted in the formulation of several hypotheses, which are outlined below.
First of all, we will describe the reasons behind the hypotheses and then advance the hypotheses. We will then successively list hypotheses on the use of ADA systems, their impact on driving behavior, traffic flow throughput, road safety and the environment.

8.2.4.1 Hypotheses on the use of ADA

Use of ACC
The ACC system examined here functions at a speed of 30 km/h or higher. The system also deactivates in the event of excessive deceleration. As a result, it is expected that ACC will be used primarily outside urban areas and only in free traffic (speeds > 90 km/h) and in heavy traffic (speeds between 70 km/h and 90 km/h), and not in congested traffic (speeds < 70 km/h).

1. ACC is rarely used within urban areas.
2. Drivers deactivate ACC more frequently during rush hour (in heavy traffic and congested traffic).

As traffic becomes busier, drivers are expected to adopt a more active attitude. This will manifest itself in the temporary overruling of system, for example (ACC activated and acceleration).

3. During rush hour, the ratio “ACC activated and acceleration” increases. Drivers accelerate more often to overtake slower vehicles.

With regard to ACC settings, we expect that a familiarisation period will be required. During this period, drivers will test various headway time settings. They will eventually select a headway time that corresponds properly to the standard behavior (without ACC) of the driver. The chosen speeds will probably match the applicable maximum speed.

4. Initially, drivers select a longer headway time; during the trial, the specified headway times decreased.
5. During rush hour, drivers select a shorter headway time in relation to outside of rush hour.
6. The selected headway time depends on the standard driving behavior of the motorist.
7. ACC is set at the applicable maximum speed.

Use of LDW
LDW is a passive system that does not intervene directly while driving. Under certain conditions, however, the system can be considered disruptive. It is therefore expected that LDW will be deactivated on narrow roads. Another possibility is that the volume may be switched off or reduced.

8. LDW is deactivated on narrow roads (access roads).

8.2.4.2 Hypotheses on the impact of ADA on driving behavior

Speed selection and acceleration
ACC has a direct effect on the execution of longitudinal driving tasks. This applies to driving freely (speed selection) as well as tracking the vehicle ahead. The effects of LDW on these driving tasks will be limited, mostly indirect (since the driving task will become more intense – the driver will have to maintain the correct course more accurately). The average free speed is expected to change, even though drivers are more aware of speed (this is specified after all). In other words, driving at speeds well above the maximum speed limit implies that the driver has quite consciously chosen to drive at this speed. On the other hand, the driving task load decreases thanks to ACC, which is possibly compensated by a higher free speed. In addition, there is no (temporary) decrease in speed due to a drop in attention levels (the system maintains the speed after all).

1. The average speed with ACC activated is higher than with ACC deactivated.
2. Motorists observe the speed limit less.

With respect to the dynamics in speeds, we expect ACC to be so efficient in free and busy traffic that the average (absolute) acceleration will be smaller compared to when the system is deactivated.

3. The distribution in acceleration is smaller with ACC than without.

Vehicle tracking behavior
ACC is expected to have the most significant effect on vehicle tracking behavior. With respect to the anticipated effects, it is important to realise that this involves a partial range system, and that the driver retains responsibility. This implies that the driver must be able to resume the tracking task at any moment and must supervise the functioning of ACC. In view of the fact that the driver must have enough time to intervene, we expect that the specified headway times will be slightly greater than normal (minimum) headway times. We do expect, however, that ACC will respond accurately to changes in the headway time.

4. Average headway times with ACC activated are longer compared to ACC deactivated.
5. The variation in headway times with ACC is smaller than without ACC.
6. Relatively few shorter headway times occur if ACC is activated.

Lane changes and selection
Lateral behavior is influenced by both LDW and ACC. With regard to ACC, we expect that drivers will be more inclined to conform to prevailing traffic conditions ("go with the flow") and therefore change lanes – particularly in heavy traffic. Drivers are probably more inclined to remain in the left lane longer – especially in free traffic – so that they can continue driving at the specified speed.

7. Fewer lane changes due to ACC.
8. Drivers remain in the left lane longer.

With respect to overtaking itself, when ACC is activated, drivers will probably make less use of small gaps to overtake. The reason for this is the behavior of the vehicle when the headway time in relation to the (new) vehicle ahead is too short.

9. Drivers do not use small gaps to overtake.

The LDW system issues a warning every time the vehicle crosses a line (desired or undesired) that does not go hand in hand with the use of direction indicators. LDW therefore encourages the use of indicators.

10. Direction indicators are used more often and more effectively.

Position within the lane and crossing lines
In addition to more effective use of direction indicators, it is likely that drivers will maintain a greater distance from line markings due to the LDW system. This is reflected in both SDLP and the average position of the vehicle in relation to the middle of the lane.

11. SDLP decreases as a result of LDW.
12. The average distance until the middle of the lane decreases due to LDW.
13. LDW issues more warnings on provincial roads and access roads.

Attention levels, additional tasks and driving task load
The preceding section focused on the anticipated direct effects of ADA systems on driving behavior. Secondary or long-term effects of the systems (change in driving task load, attention levels, carrying out additional tasks, etc.). Although available measurement data do not allow a direct verdict to be given about such side effects, a number of hypotheses have been formulated that express an expectation about these effects.

14. A shift in focus has occurred from other traffic to navigational tasks.
15. Motorists spend more time on additional tasks while driving (calling, making themselves up, etc.).
16. Motorists continue driving non-stop for longer periods (more than two hours).
17. The attention level decreases due to ACC and actually increases thanks to LDW. ACC is sleep-inducing, while the opposite applies to LDW.
18. Motorists lose their driving skills, the driving task changes from steering to supervision.
19. Motorists will drive carelessly in city traffic in particular (where ACC is not used) because they no will longer immediately adapt to performing driving tasks themselves.

Hypotheses 14 to 19 will not be examined further in the rest of the study.

8.2.4.3 Hypotheses impact ADA on throughput

As stated earlier, changes in driving behavior will have a direct impact on throughput, road safety and the environment. We will briefly describe the anticipated effects on throughput and express these expectations in a number of hypotheses.

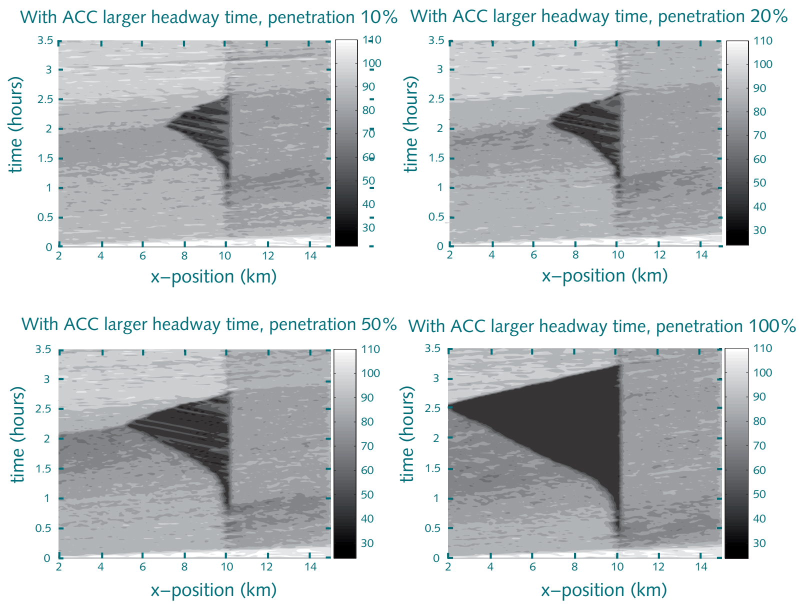

Figure 8.1 shows the various factors that can have an effect on capacity
The figure reveals that capacity is determined in particular by (minimum) headway times per lane (due to vehicle tracking behavior) and the distribution of traffic across lanes (because of lane changing behavior). ADA will have an effect on both aspects.

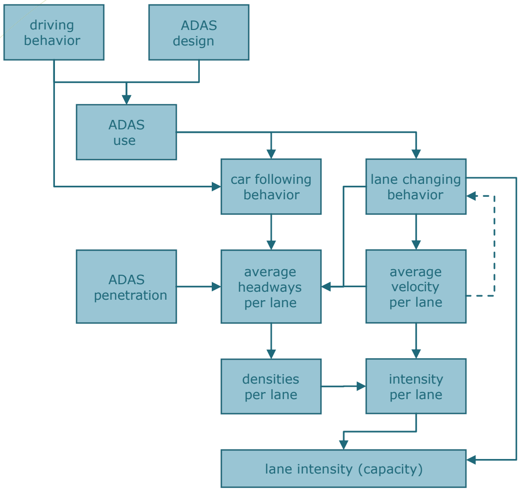

Figure 8.2 Influence factors for capacity

The analysis of the expected effects on driving behavior already indicated that a (minor) increase in average headway times is expected. In addition, a(n) (even) more distorted distribution of traffic across lanes could arise due to more intensive use of the left lane. On the other hand, the number of lane changes decreases and the distribution of speed, acceleration and headway times is smaller. Overall, a slight decrease in free capacity (the capacity before a traffic jam develops) is expected.

Since a limited number of drivers will use ACC in congested traffic, the queue discharge rate (capacity during congestion) is not expected to change significantly.

If a large percentage of traffic on the main carriageway is equipped with ACC, this may have an effect on the implementation process. The number of large gaps will decrease due to the smaller distribution of headway times. Furthermore, the vehicle controlled by ACC can over-react because of the merging vehicle.
The aforementioned mechanisms give rise to the following hypotheses on throughput and the effects of ACC/LDW:

1. Due to ACC, free capacity (before congestion occurs) is smaller; this means that congestion occurs earlier.
2. Due to ACC, the queue discharge rate increases, provided ACC is also used in congested traffic. The reason for this is that concentration levels usually diminish in congested traffic.
3. Increased use of the left lane will improve the performance of 80 km/h zones with section control.
4. The capacity of access ramps decreases. This is caused by the effect of ACC when merging vehicles use the gap in front of the ACC-controlled vehicle. This vehicle may react too strongly, which will have a cascade effect on vehicles behind.
5. Traffic flow becomes more reliable (capacity becomes slightly more spread).
6. A change in road safety leads to a change in throughput (increased safety improves throughput and vice-versa).

[1] In 80 km/h zones (section control), this can nevertheless have a positive effect. This usually involves insufficient use of the left lane.

8.2.4.4 Hypotheses on the impact of ADA on road safety

Direct effects of ADA on road safety

The expected changes in the behavior of motorists will also have an effect on road safety, just like on throughput. On the one hand, we expect a positive effect thanks to the decrease in the percentage of short headway times and the number of unintentional line crossings, and an increase in the use of direction indicators. The number of lane changes is also expected to diminish and the distribution of speed will lessen.

In order to obtain a better impression of the potential effects of ACC and LDW, we will examine the results of the studies conducted by Louwerse (2003) and Louwerse and Hoogendoorn (2005) that analysed accidents in the province of Zuid-Holland.

Figure 8.3 displays an overview of percentages of lethal and injured accidents on various road types (classification according to Duurzaam Veilig (Sustainable Safety)). On the basis of the figure, we can conclude that a large percentage of accidents occur on distributor roads within and outside urban areas. Only a small percentage of overall accidents occur on motorways.

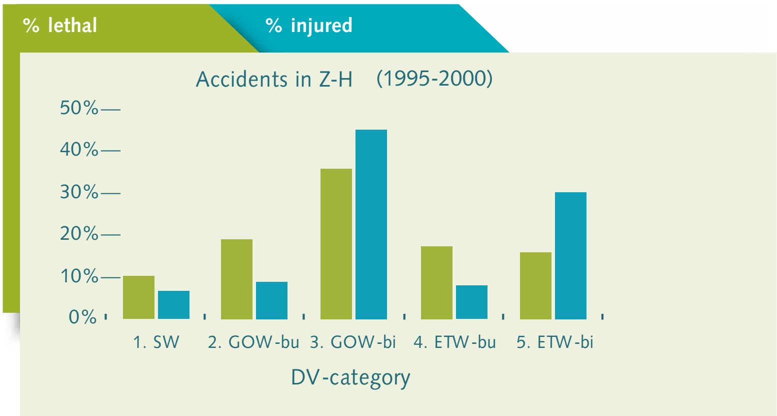

Figure 8.3 Percentage of accidents according to road type (Louwerse & Hoogendoorn, 2005)

Figure 8.4 displays the same information, but in this case only for accidents on road sections (with the exception of accidents at intersections). This is relevant because the ADA systems examined in this study will probably not have that much effect on the number of accidents at intersections.

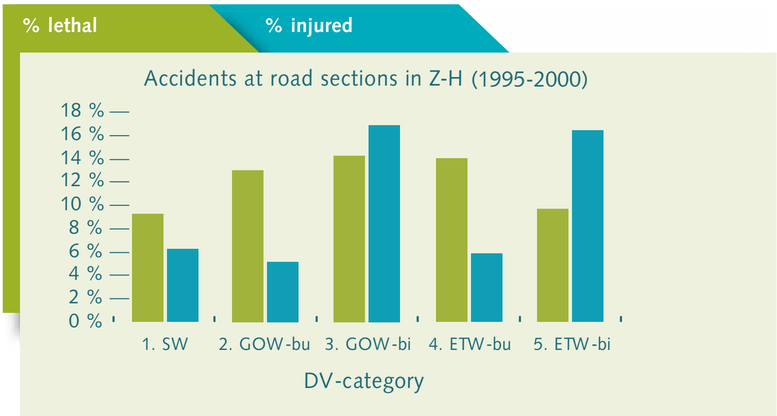

Figure 8.4 Percentage of accidents on road sections according to road type (Louwerse, 2003)

Table 8.6 indicates the primary circumstance for various accidents on each road type (classification according to Sustainable Safety) for road sections and intersections. The table is a selection of the table from appendix 3 from Louwerse (2003), which only looked at road sections but disregarded access roads (after all, it will emerge later on that neither ACC nor LDW are used there). The percentage of the total number of registered accidents is greater than 1%. A selection of relevant circumstances was also made, i.e. those circumstances that can reasonably be expected to be influenced by ACC or LDW.

We can conclude from the table that 6.3% of all accidents in the province of Zuid-Holland occurred on through-roads; 5.2% and 16.9% of accidents occurred on distributor roads outside and inside urban areas.

For the remainder of the analysis, it was assumed that the figures for Zuid-Holland are representative for the whole of the Netherlands.

From the table we can conclude the following relevant aspects for the underlying study:

Table 8.6 Percentage of overall number of accidents per circumstance (for road sections)

	Sustainable Safety road section type		
Road section	**Through-roads**	**Distributor roads outside urban areas**	**Distributor roads inside urban areas**
Overall number of accidents in cat.	**2611**	**2158**	**6958**
Percentage of overall accidents on road sections	**12.5%**	**10.3%**	**33.2%**
Percentage of overall accidents	**6.3%**	**5.2%**	**16.9%**
Circumstance			
Direction indicating			
05 Not indicating	0.1%	0.6%	1.0%
06 Indicating incorrectly	0.0%	0.0%	0.1%
Merging and exiting			
08 Merging incorrectly	1.3%	0.5%	1.5%
09 Exiting incorrectly	0.9%	0.0%	0.6%
Maintaining distance			
11 Maintaining an inadequate distance	46.7%	24.2%	18.1%
12 Unexpected/sudden braking	2.1%	0.7%	0.6%
13 Traffic jam that suddenly appears	0.0%	0.0%	0.0%
Overtaking			
17 Overtaking on the right	0.0%	0.2%	0.6%
18 Overtaking on the left	0.0%	6.2%	5.3%
19 Cutting in	0.0%	1.1%	1.0%
20 Accelerating while being overtaken	0.0%	0.0%	0.0%
Position on the road			
25 Not driving on the right enough	2.2%	7.0%	5.1%
26 Driving on the right too much	2.4%	5.7%	5.4%
27 Wrong lane/side of the road	0.1%	1.4%	2.3%
28 On section intended for other traffic	0.1%	0.3%	1.8%
Speed			
35 Driving too fast	2.0%	1.3%	1.5%
36 Driving too slowly			

1. On motorways, 47% of accidents are caused because drivers do not maintain an adequate distance. On provincial roads and urban roads, these percentages are lower (24% and 18% respectively).
2. On motorways, 4% of accidents are caused by the lateral position of the vehicle in relation to the road (too far to the left or to the right). On provincial and urban roads, this is significantly higher, namely 13% and 10%.

The *safety potential* of the examined ADA systems can be determined using the data in table 8.6. This potential describes the greatest attainable effect on road safety, on the basis of the most favourable effect of ADA and on the assumption that all vehicles are equipped with ACC and LDW and actually use these systems 100% of the time.

For ACC, this means that:
- no more accidents occur due to maintaining an inadequate distance (circumstance 11), unexpected braking (12) and a traffic jam that suddenly appears (13).

For LDW, this means that:
- drivers always indicate properly (circumstances 05 and 06);
- no more accidents occur due to the vehicle's position within the lane (not driving on the right enough(25), driving on the right too much (26)).

It is also assumed that because of ACC/LDW:
- drivers do not drive on the right more often than before (17) or on the left (18), nor do they cut in more frequently (19) or increase their speed during overtaking (20);
- there is no effect on speeds that are driven, i.e. motorists drive neither too quickly (35), nor too slowly (36);
- driving behavior does not change during merging (08) or exiting (09).

Table 8.7 displays the result of this analysis. We can conclude from the table, for example, that ACC can prevent a maximum of 48.8% of accidents on through-roads (on road sections). For LDW, this is 4.6%. Together, ACC and LDW reduce the number of accidents on through-roads by a maximum of 53.4%. This is 6.7% of the total number of accidents on road sections and 3.4% of the total number of accidents (road sections and intersections combined).

We can conclude from the table that the safety potential of the systems combined is 20.7% of all accidents on road sections, which amounts to 10.5% of all accidents on road sections and intersections combined.

Table 8.7 Safety potential of ACC/LDW (for road sections)

Road section:	Through-roads	Distributor roads outside urban areas	GOW-bi roads inside urban areas	Total /aver.
Overall number of accidents in cat.	2611	2158	6958	11727
Percentage of overall accidents on road sections	12.5%	10.3%	33.2%	56.1%
Percentage of overall accidents	6.3%	5.2%	16.9%	28.4%
ACC	48.80%	24.90%	18.70%	30.80%
LDW	4.70%	13.30%	11.60%	9.87%
Total	53.50%	38.20%	30.30%	40.67%
Reduction in overall no. of accidents on road sections	6.7%	3.9%	10.1%	20.7%
Reduction in overall no. of accidents	3.4%	2.0%	5.1%	10.5%

This study has revealed (as will be demonstrated in the following chapter) that ACC is not used continuously (LDW is activated nearly all of the time). The system will also not be 100% effective because it is not a full-range ACC system after all. This study therefore determines both the use and effectiveness.

Table 8.8 contains an example of the correlation used on the basis of effectiveness: the reduction in accidents relating to those circumstances upon which the two ADA systems are expected to have an effect. Effectiveness is used to indicate which reduction in the accident risk relating to that type of circumstance (during the continuous use of ACC/LDW).

Table 8.8 Example of a correlation table of circumstances for considered ADA systems

	Effectiveness	
Circumstance	**ACC**	**LDW**
Direction indicating		
05 Not indicating		100%
06 Indicating incorrectly		100%
Maintaining distance		
11 Maintaining an inadequate distance	100%	
12 Unexpected/sudden braking	100%	
13 Traffic jam that suddenly appears	100%	
Overtaking		
18 Overtaking on the left	-10%	
Position on the road		
25 Not driving on the right enough		100%
26 Driving on the right too much		100%
Speed		
35 Driving too fast	-1%	

To sum up, we can lay down the expected effects of ACC/LDW in relation to road safety in the following statements:

The number of *rear-end collisions* will decrease because:

1. there is a drop in the number of sudden braking movements;
2. the number of minimum headway times will decrease;
3. there is a smaller distribution of speed.

The number of *side-impact collisions* will decrease because:

4. there is an increase in the use of direction indicators, which ensures that lane changes are indicated more effectively;
5. there is less SDLP;
6. there are fewer lane changes.

The number of *collisions involving one vehicle/party* will change because:

7. there is an increase in speed;
8. there is a decrease in the number of unintentional line crossings.

Long-term effects of ACC on road safety.
Like traffic flow throughput effects, changes can eventually occur in driving behavior due to the performance of additional activities, changes in attention levels and driving skill. These are the potential (negative) safety effects in the long term:

9. Changes in road safety due to an increase/decrease in congested traffic (secondary effect).
10. Less attention is paid to other traffic due to ACC, but attention levels do increase thanks to LDW.
11. Drivers start trusting ACC too much.
12. ACC makes motorways more appealing. This increases the use thereof, which is conducive to road safety.

These hypotheses (9 to 12) fall outside the scope of this study and are therefore excluded from the rest of this report.

8.2.4.5 Hypotheses on the impact of ADA on the environment

The changes in driving behavior and traffic flow throughput have an effect on fuel consumption and emissions. Given the relationships between speed, acceleration and consumption – due to the decrease in the distribution of acceleration – a minor decrease in fuel consumption is expected. This means we expect that the positive effect arising from the decrease in acceleration will be more influential than the increase in free speed.

The same applies to emissions.

1. Fuel consumption will decrease thanks to ACC.
2. Emissions will decrease thanks to ACC.

8.3 Use of ADA systems

This section will focus on how ADA systems are used. We will examine the following study questions:

a. On what type of road are the systems used (motorway, provincial road, city road)?
b. Under which traffic conditions are the systems used?
c. When are the systems activated?
d. When and how are the systems deactivated?
e. Which settings are used (headway time, speed) and how are these related to the applicable speed limit, road type and traffic conditions?

These sub-questions are dealt with below individually for ACC and for LDW. The relationship between the hypotheses advanced in section 8.2.4.1 and the findings described here is defined explicitly.

8.3.1 Use of ACC

The use of ACC is not considered pleasant and useful under all conditions. It is conceivable, for example, that drivers use ACC primarily in free and heavy traffic, and considerably less in congested traffic. One of the reasons is that ACC does not function at speeds below 30 km/h and during excessive deceleration. The system also deactivates the moment the driver brakes. The road type will therefore also influence the use of ACC. In urban areas, for example, drivers have to brake regularly for traffic lights and traffic approaching from the right. In such cases, the speed is also lower than 30 km/h, which is why ACC is less useful within urban areas than outside.

It is interesting to know which ACC settings are used by various drivers, what the differences are between drivers and whether the settings change over the course of time. The relationship between ACC settings and the applicable maximum speed are also examined.

Relationship between the use of ACC and road type

Table 8.9 provides an overview of the use of ACC during the pre-period. The table distinguishes between ACC off, ACC inactive, ACC active and ACC active and acceleration. The difference between ACC off and ACC inactive is that in the first case, ACC has actually been switched off (via the switch provided for this purpose) while in the second case, the system may have become inactive by braking.

As can be concluded from the table, the use of ACC during the pre-period was restricted to a single driver who used ACC on the motorway. Various drivers indicated that they also always used cruise control on the motorway in the past and that they would continue doing so now.

Table 8.9 Use of ACC (pre-period) for various road types (in percentages)

	City	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off (%)	36.6	23.7	55.0	91.0	44.0
ACC inactive (%)	62.7	74.6	38.2	9.0	52.6
ACC active (%)	0.7	1.7	6.4	0.0	3.2
ACC active + accel. (%)	0.0	0.0	0.4	0.0	0.2
Total (%)	100.0	100.0	100.0	100.0	100.0
Total (hours)	65.2	11.0	59.0	1.1	136.3

Table 8.10 depicts the use ACC during the *transitional period* for all drivers. The table clearly shows that ACC is used primarily on the motorway (ACC is active 40.9% of the time) and to a lesser degree on provincial roads (active 21.5% of the time). In the city, ACC is only active 4.9% of the time.

Table 8.10 also reveals that the total amount of time that drivers (collectively) spent on 80 km/h motorways is minimal (only 4.1 hours in total). As a result, the results for this road type must be interpreted with some caution.

Table 8.10 Use of ACC (transitional period) for various road types (in percentages)

	City	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off (%)	20.7	7.7	16.7	28.5	17.3
ACC inactive (%)	74.4	70.4	40.4	49.3	55.6
ACC active (%)	4.8	21.5	40.9	21.5	26.0
ACC active+ accel. (%)	0.1	0.5	2.0	0.7	1.2
Total (%)	100.0	100.0	100.0	100.0	100.0
Total (hours)	154.2	44.7	234.4	4.1	437.4

Table 8.11 displays the same data, but for the *post-period* (April to June 2006). We see a similarity here with the transitional period, although the use of ACC for the road type 80 km/h motorway appears to have increased emphatically and is even slightly higher than for normal motorways. Statistically, the percentages that express the use of ACC on motorways or on 80 km/h motorways are identical.

Table 8.11 Use of ACC (post-period) for various road types (in percentages)

	City	Prov.	Motorway	Motorway (80 km/h)	Total
ACC uit (%)	9.1	4.2	7.8	7.4	8.0
ACC inactief (%)	86.8	73.2	49.1	49.2	66.8
ACC actief (%)	3.9	21.7	39.5	40.9	23.3
ACC actief + accel. (%)	0.2	0.8	3.6	2.5	1.9
Totaal (%)	100.0	100.0	100.0	100.0	100.0
Totaal (uren)	**503.5**	**115.9**	**590.5**	**21.8**	**1231.6**

Table 8.11 reveals that ACC is practically never used in urban areas (roughly 4% of the time) and is used to a limited extent on provincial roads (approximately 22% of the time). ACC is used most extensively on motorways: it is active more than 40% of the time. The difference between provincial roads and motorways may lie in the fact that vehicles usually have to stop less often on motorways (for traffic lights, roundabouts, main roads, etc.) than on provincial roads.

The aforementioned proves that the expectation that ACC is hardly used within urban areas is indeed correct. The rest of this report will therefore leave this situation largely out of consideration.

Use of ACC and relationship between traffic conditions
Tables 8.12 and 8.13 indicate the use of ACC per regime (free traffic, heavy traffic and congested traffic) for motorways, for the transitional period and post-period respectively.

The tables clearly indicate that ACC is used primarily in free traffic (at speeds greater than 90 km/h) and in heavy traffic (at speeds between 70 and 90 km/h): for the post-period, ACC was active 44% and 36% of the time that drivers were driving in free or heavy traffic respectively. In congested traffic (speeds below 70 km/h), ACC is used much less (around 7% of the time).

When we compare the transitional period with the post-period, we see a small decrease in the amount of time that ACC was active and indeed for all regimes. This indicates that after a certain period of familiarisation, during which drivers tested the system in various situations, they learned where and when ACC provides the best assistance.

However, we do see a distinct increase in the percentage ACC active + acceleration. During the experiment, drivers there overrule ACC more frequently in order to overtake a slower vehicle for example. This indicates that after a certain period of familiarisation, drivers adopt a more active attitude towards ACC and the use thereof. In other words: drivers experience the deficiencies of the system (during overtaking for example) and compensate by overruling the system more often. The increase occurs under all regimes, but is relatively strongest in free traffic.

Table 8.12 Use of ACC (transitional period) for various regimes (in percentages)

	Free	Busy	Congested	Total
ACC off/inactive (%)	43.1	61.4	92.2	57.1
ACC active (%)	54.2	37.1	7.5	40.9
ACC active + accel. (%)	2.7	1.6	0.3	2.0
ACC active (incl. accel) (%)	56.9	38.6	7.8	42.9
Total (hours)	**152.7**	**23.6**	**58.2**	**234.4**

Table 8.13 Use of ACC (post-period) for various regimes (in percentages)

	Free	Busy	Congested	Total
ACC off/inactive (%)	46.0	63.8	93.1	56.9
ACC active (%)	49.4	33.8	6.4	39.5
ACC active + accel. (%)	4.6	2.3	0.5	3.6
ACC active (incl. accel) (%)	54.0	36.2	6.9	43.1
Total (hours)	**418.4**	**57.0**	**115.1**	**590.5**

If we briefly look at the expectation regarding the use of ACC in section 8.2.4.1 (hypotheses 2), we can see that it is partly correct. Drivers do not or barely use ACC in congested traffic, but do use it in heavy traffic. ACC provides added value in this regime.

Hypothesis 3 also appears to be correct: the percentage of ACC active + acceleration increases as drivers become more familiar with the system.

Selected settings for ACC
Various drivers have a different driving behavior and various preferences. This means that not all drivers will use the same headway time settings. It is also conceivable that drivers initially search for a headway time they feel comfortable with or use various settings for different conditions.

The figure below displays the specified headway times for one of the drivers. The figure clearly reveals that the motorist initially tries various headway times (1.0 s, 1.4 s and 1.8 s) before selecting a more or less fixed headway time (1.4 s in the months of May and June).
This convergence is apparent among a large number of drivers: after a while, one headway time is usually selected that is always used. This setting differs from driver to driver. It also lasts longer for one driver than another.

In general, the selected headway times during the first months are slightly greater than during the following months. This corresponds to hypothesis 4.

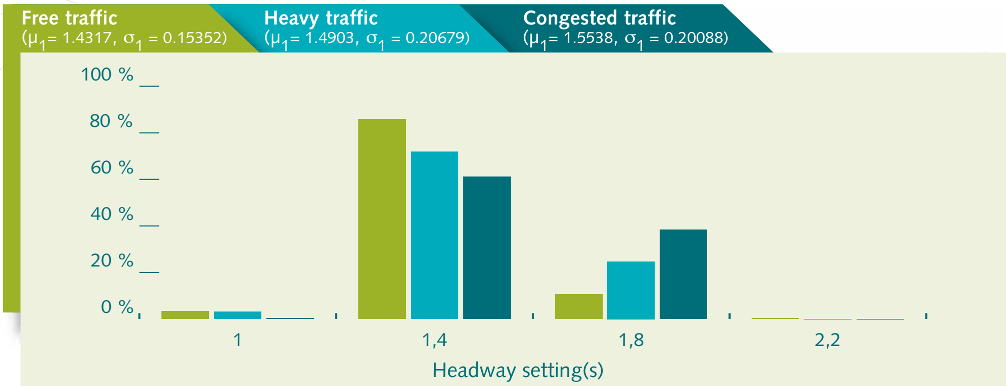

Figure 8.5 Selected headway times for driver 21 (transitional period). The headings of the figure indicate the traffic regime and the average and standard deviation of distribution.

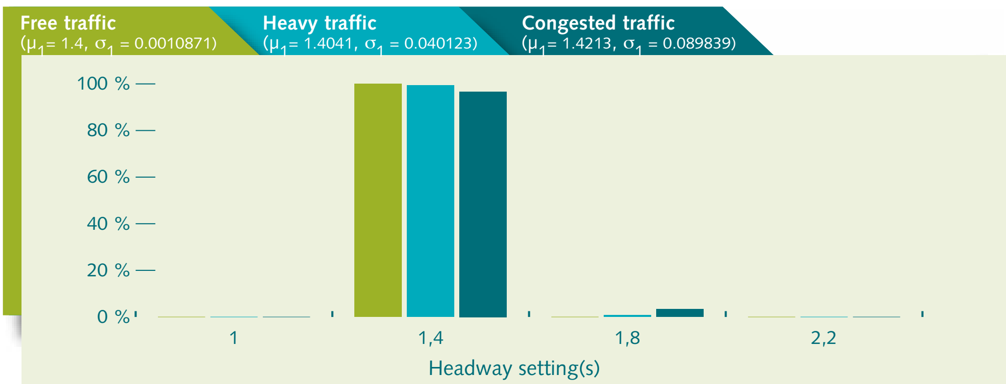

Figure 8.6 Selected headway times for driver 21 (post-period).

Figures 8.7 and 8.8 indicate the headway time setting of another driver (driver 12). For this driver as well, we can clearly see that the settings selected during the transitional period are more spread than the settings selected during the post-period.

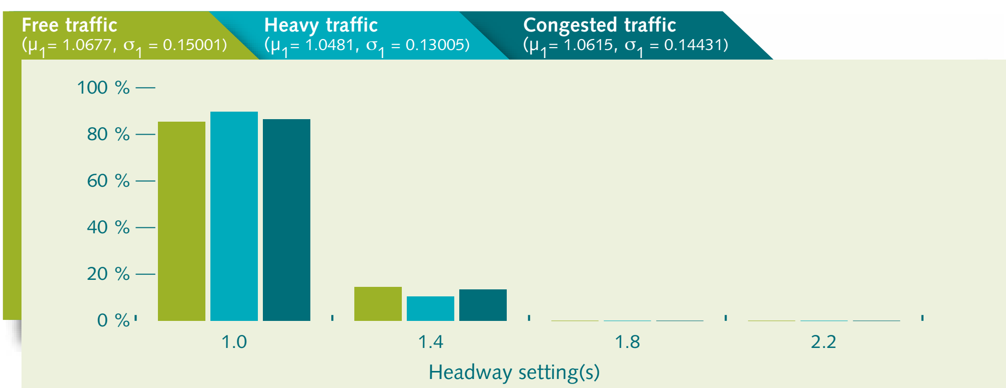

Figure 8.7 Selected headway times for driver 12 (transitional period)

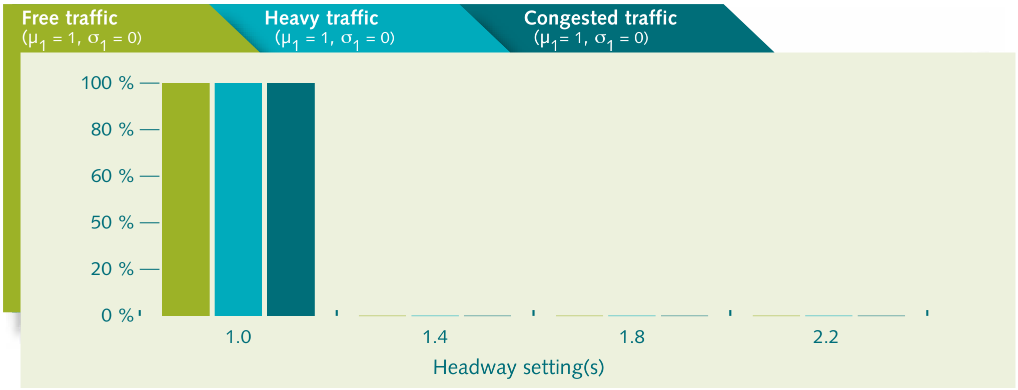

Figure 8.8 Selected headway times for driver 12 (post- period)

Figures 8.9 and 8.10 indicate the selected settings for driver 7 for the transitional period and post-measurement respectively. This also involves a degree of convergence, although driver 12 not always uses the same headway time: during the post-period, we see that the driver specifies a headway time of 1.4 s or 1.8 s with some regularity.

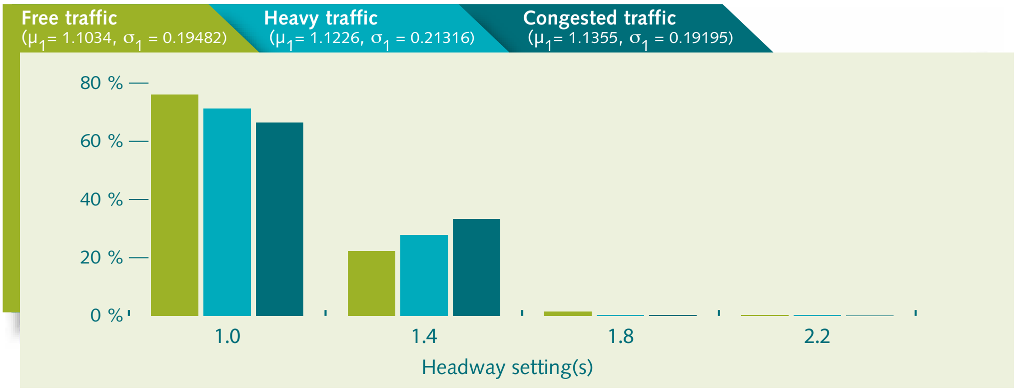

Figure 8.9 Selected headway times for driver 7 (transitional period)

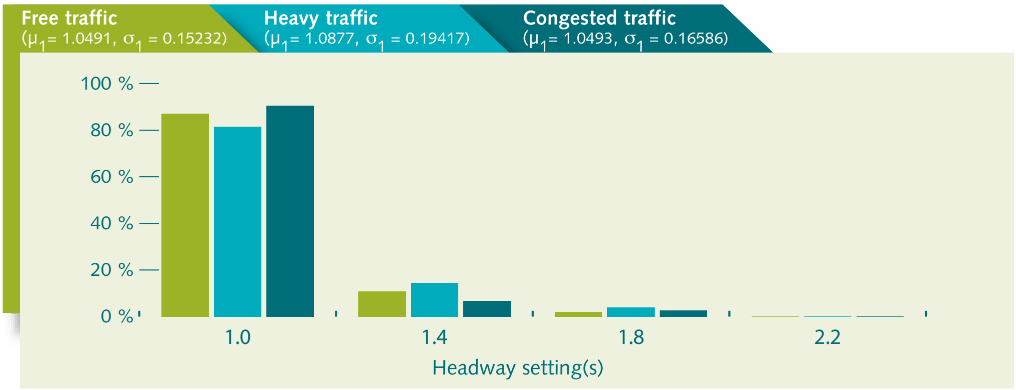

Figure 8.10 Selected headway times for driver 7 (post-period)

On the basis of the figures above, it cannot be concluded that this driver selects other headway times for various traffic regimes. Upon further analysis of other drivers, such a phenomenon could not be established conclusively. This is contradictory to hypothesis 5 in section 8.2.4.1.

Finally, figure 8.11 reveals the distribution of selected headway times over the entire driver population. The figure clearly indicates that most motorists select the smallest possible setting (1.0 s), but that there is a certain spread.

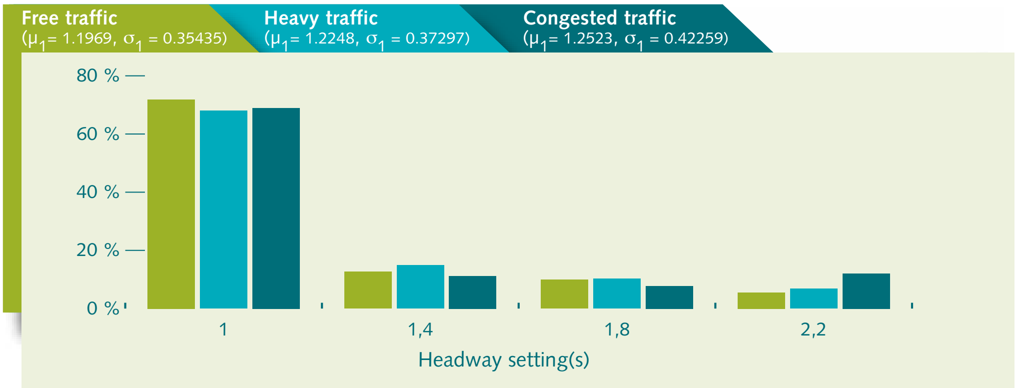

Figure 8.11 Distribution of probability for selected ACC headway time for various traffic conditions, for entire driver population (post-period)

Relationship between specified headway time and normal, attained headway times
Figure 8.12 displays the relationship between (average) specified headway times (per driver) and the headway times achieved by the driver (heavy traffic, ACC off). A weak correlation exists between the two indicators:

$$h_{\text{no ACC}} \approx 0.28 h_{\text{acc}} + 0.7$$

None of the parameters of the model differ statistically from zero. Moreover, the stated variance is relatively small (R2 = 0,11). We can therefore only carefully conclude that there is a relationship between the specified headway time and driving behavior without ACC. The weak statistical correlation is due to the fact that many drivers specify a minimum headway time of 1.0 s.

Hypothesis 6 from section 8.2.4.1 therefore appears to be more or less correct. The specified headway times are indeed related to the (normal) driving behavior of motorists: people who usually use a minimum headway time also select a minimum headway time setting for ACC.

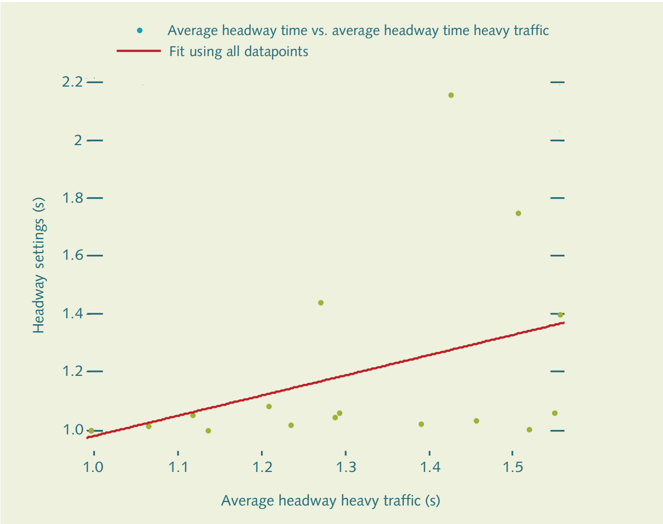

Figure 8.12 Average specified headway time in relation to average attained minimum headway time in the pre-period (post-period)

Speed settings

Figures 8.13 and 8.14 indicate the specified speeds the period of familiarisation and post-period for the entire driver population and all road types. We can clearly see that drivers often choose a speed around applicable maximum speeds, but in some cases also a speed that is well above this limit (130 km/h or 140 km/h). Whether or not this speed is actually attained depends on whether ACC has actually been activated. We will discuss this later on.

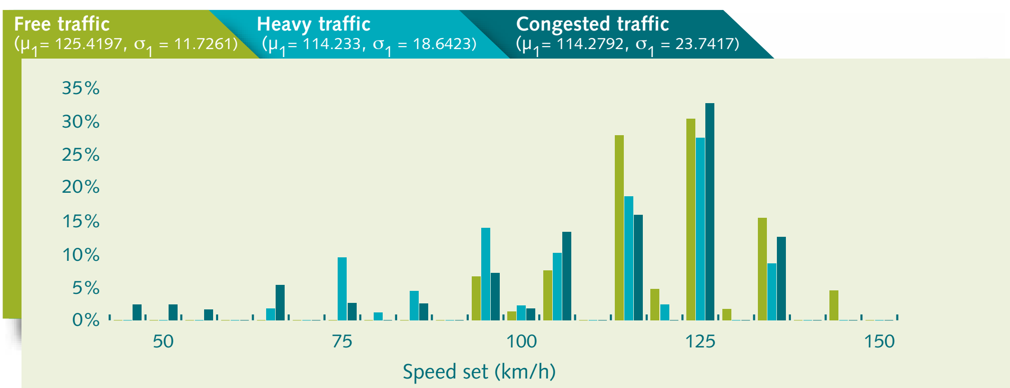

Figure 8.13 Specified ACC speeds for entire driver population (transitional period)

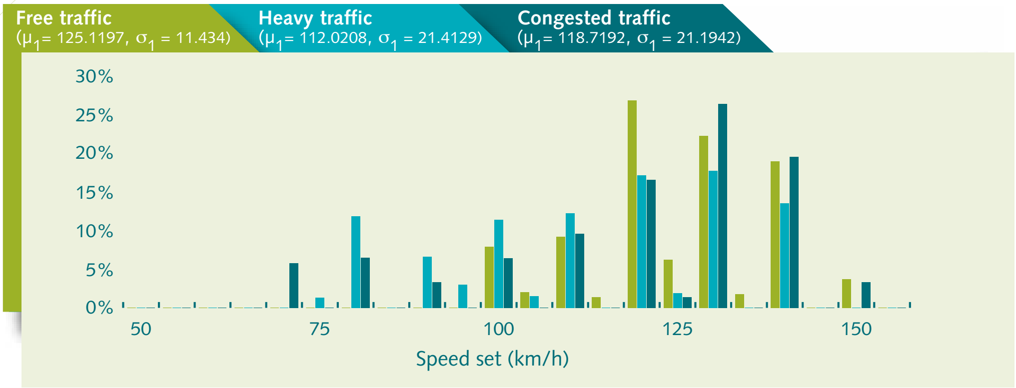

Figure 8.14 Specified ACC speeds for entire driver population (post-period)

Relationship between specified headway time and speed
It is interesting to examine whether a relationship exists between the specified headway time and the specified speed. In order to study this, the average specified headway time and the average specified speed are calculated for each driver (per period).

Figure 8.15 indicates the relationship between the average specified headway times and the average specified cruise control speeds (per driver). When we examine all drivers, we observe a weak linear correlation between the two variables. If we regard data point 16 (driver 31) as an "outlier", we find a much stronger correlation:

$$v_{acc} = 141 - 15h_{acc}$$

It appears that drivers who select minimum headway times choose a higher speed by and large. Only the constant is significant (at a significance level of 95%); the explained variance R^2 is 0.08.

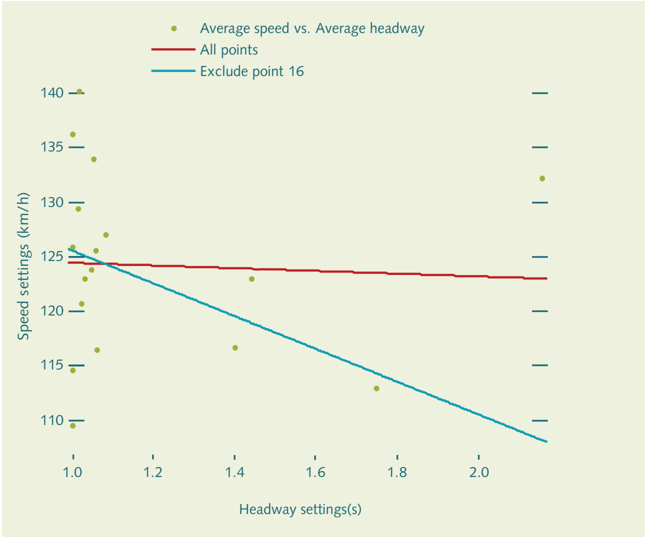

Figure 8.15 The relationship between average specified headway times and average specified cruise control speeds (post-period). A linear correlation clearly exists between both variables: $v_{acc} = 155 - 36{,}3\ h_{acc}$.

Specified ACC speed and applicable maximum speed
Drivers appear to select the speed in accordance with the applicable maximum speed. Table 8.14 portrays the difference between the driven speed (in free traffic) and the applicable speed limit. For motorways (incl. 80 km/h motorways), we notice that the difference between the driven speed and the applicable maximum speed is less than 5 km/h. For provincial roads, this difference appears to be considerably greater (15.3 km/h), although this difference with ACC activated is smaller than with ACC off/inactive (16.6 km/h).

Table 8.14 Difference between driven speed (km/h) and speed limit for free traffic (post-period)

	City	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	11.2	16.6	2.7	-1.8	6.8
ACC active	26.0	15.3	4.6	0.1	6.1
ACC active (incl. accel.)	26.0	15.4	4.7	-0.4	6.2
Total	**12.4**	**16.9**	**4.4**	**-1.0**	**6.6**

On the basis of this result, the expectation expressed in hypothesis 7 appears to be correct.

Switching on ACC
The study also examined when the motorist switches on ACC. One of the most remarkable findings is that drivers switch on ACC increasingly faster over the course of the trial. By way of example: the average reactivation time (time between deactivation and activation) of driver 15 is 214 s, 146 s and 118 s for March, April and May respectively. An explanation for this is the fact that drivers become accustomed to using ACC during the trial.

The distribution of reactivation times, incidentally, appears to be log-normal (relatively many short reactivation times).

If we examine under which circumstances drivers switch on the system, it emerges that drivers usually wait until they have been travelling on the motorway for some time before activating ACC. The system is often also activated quickly after the driver moves from heavy traffic and congested traffic (within 30 s) into free or heavy traffic.

Switching off ACC
The study also examined under which circumstances ACC is switched off and how this is done. For a number of drivers, switching off ACC often goes hand in hand with a transition from free traffic to heavy traffic or from heavy traffic to congested traffic. Other drivers only switch off ACC when they are already in a specific regime (usually congested traffic).
Among practically all drivers, the deactivation of ACC is coupled with gentle braking (roughly 50% of cases) or with hard braking (between 5% and 10% of cases). With regard to the latter, this may involve an emergency stop in a number of cases. We must also note that ACC warns the driver during an emergency stop before it hands the tracking task back to the driver.

8.3.2 Use of LDW

Insofar as could be concluded from the signals from the LDW system, virtually every driver had switched on and was using the LDW system during the post-measurement. During the months of April and May, this even related to 100% of the observations. During the month of March, drivers appeared not to have switched on the LDW system 20% of the time on average. This can be explained from the first week in March, which actually still counted as a pre-measurement. Since some drivers did start driving with ADA on 1 March, it was decided on the basis of ACC use (thus not on the basis of LDW usage!) to determine whether the driver started driving with LDW activated on March 1st or March 8th.

The hypothesis that LDW is switched off on narrow roads (hypothesis 8) is therefore incorrect.

8.3.3 Conclusions relating to the use of ADA

This section briefly describes the most important findings regarding the use of ACC and LDW. We do so with the help of sub-questions as formulated in section 8.2.1.

On what type of road are the systems used?

- ACC is used primarily on the motorway. More than 40% of the time that drivers drove on the main road network, ACC was active.
- ACC is rarely used in the city: less than 4% of the time that drivers drove in the city, ACC was active.
- With regard to provincial roads, drivers drove a substantial percentage of the time (roughly 22%) with ACC active.
- LDW is switched off rarely, irrespective of the type of road upon which drivers are travelling.

Under which traffic conditions are the systems used?

- ACC is used primarily in quiet and heavy traffic. In quiet traffic, drivers activate ACC more than 50% of the time. In heavy traffic, this is over 35%.
- In congested traffic, only very limited use is made of ACC, namely less than 8% of the time. This is due to the functionality of the system tested here (partial range ACC).
- LDW is also rarely switched off for various traffic regimes.

When are the systems activated? When and how are the systems deactivated?

- Drivers usually only activate ACC when they have been on the motorway for some time.
- As the trial progressed, drivers started using ACC more actively. This is expressed in the perceived increase in speed with which the system is activated.
- The system is usually switched off by touching the brake pedal, or by braking hard in a number of cases (emergency stop).

[2] One of the drivers indicated that his/her LDW system did not function during the trial. However, it proved impossible to conclude whether this was indeed the case from the logged data. In other words, the compiled data was correct. Obviously, no statements can be made for this driver regarding the use of LDW and its effect on driving behavior.

Which settings are used (headway time, speed) and how are these related to the applicable speed limit, road type and traffic conditions?

- At the beginning of the trial, drivers experimented with various ACC settings. In many cases, convergence occurs according to one headway time setting used for all regimes. This occurs quicker for one driver than for the other.
- Most drivers selected the shortest headway time of 1.0 s.
- There is a (weak) correlation between the selected headway time setting and normal tracking behavior: drivers who usually maintain a short tracking distance often select a shorter headway time setting (1.0 s).
- The cruise control speed is selected in accordance with the applicable maximum speed. The average difference between the speed driven in free traffic and the maximum speed is 5 km/h.
- A relationship does exist between the specified headway times and the specified cruise control speed: drivers who select a shorter headway time generally choose a higher cruise control speed.

8.4 Effects of ADA on driving behavior

ADA has an effect on the driving behavior of drivers. This applies to the selected free speed, vehicle tracking behavior, the position of the vehicle in relation to lane markings and lane changing behavior.

The following study questions are answered in this section.
a. To what extent does ADA influence the choice of free speed (in relation to the applicable maximum speed)?
b. How do acceleration characteristics change as a result of ADA?
c. How does the tracking behavior of the motorist/vehicle change as a result of ADA (in relation to the selected ADA settings)?
d. How do SDLP and the lateral position of the vehicle change as a result of the available ADA systems?
e. How does lane changing behavior alter?

Before we answer these questions, we will focus briefly on the expected effects of ACC and LDW, as indicated in section 8.2.4.2, on various aspects of driving behavior (selected free speed, acceleration characteristics, vehicle tracking behavior, SDLP and lane changing behavior). We will also look at the functional description of ACC and LDW.

8.4.1 Speed selection

The first key question is to what extent does ADA influence the choice of free speed (in relation to the applicable maximum speed)? In section 8.3, we already revealed that speeds on motorways in free traffic differ by less than 5 km/h on average from applicable maximum speeds.

With respect to average speeds, speeds attained in free traffic are particularly interesting. In heavy traffic or congested traffic, speed is determined by primarily by other traffic after all.

Tables 8.15 and 8.16 show average speeds in free traffic for ACC off/inactive, active and active + acceleration, during the pre-measurement and post-measurement respectively.

Table 8.15 Average speed (km/h) for free traffic (pre-measurement). Results for the city were disregarded given the small percentage of ACC usage.

	Prov.	Motorway	Motorway (80 km/h)
ACC off/inactive	89.3	113.3	81.4
ACC active	101.5	118.2	-
ACC active (incl. accel)	101.5	118.1	-
Total	**90.3**	**114.7**	**81.4**

[3] A number of drivers indicated during the pre-measurement that they also use ACC because they usually drive with cruise control. This primarily concerns drivers 22, 27 and drivers 4 and 31 to a lesser extent.

Volkswagen keen to kill two birds with one stone

Abe van den Brink, Manager for Fleet Sales Large Accounts at Volkswagen, hopes Adaptive Cruise Control will kill two birds with one stone. "The indicated improvement in road safety would lead to less damage, making the system commercially viable as well."

"ACC is now a factory option on the Volkswagen Passat", reveals Abe van den Brink. "The question is whether investments are being made with long-term benefits in the back of the mind. After all, less damage means a decrease in the total cost of ownership. This could be a financial incentive. It is therefore important for us that scientific research has demonstrated ACC's positive effect on road safety."

Abolishment of tax on private motor vehicles and motorcycles
Volkswagen has now reached a stage where ACC can be factory-installed in the Passat. This will also apply to new models in the future such as the Touran, Jetta and Golf. For "The Assisted Driver" pilot, the LDW system was supplied by MobilEye. "Since appreciation for this system was slightly less, we may have been somewhat more reluctant regarding direct production in our own facilities." Abe Van den Brink believes abolishing the tax on private motor vehicles and motorcycles could help achieve a real break-through. "When this tax was reintroduced for the cruise control system, we experienced a drastic decrease in the sales thereof. Now that the positive effects have been demonstrated, perhaps the Dutch Directorate-General for Public Works and Water Management should urge the Ministry of Finance to abolish this tax again. Our branch of industry, represented by the RAI and BOVAG, cannot exert that much influence in this regard."

Table 8.16 Average speed (km/h) for free traffic (post-measurement). Results for the city were disregarded given the small percentage of ACC usage.

	Prov.	Motorway	Motorway (80 km/h)
ACC off/inactive	92.9	111.5	78.1
ACC active	99.1	117.1	80.4
ACC active (incl. accel.)	98.8	117.2	79.9
Total	**95.9**	**116.2**	**78.8**

A number of aspects attract attention when comparing the two tables.

On provincial roads:
- the average speed with ACC off/inactive is lower in the pre-measurement than in the post-measurement, while the opposite is applicable when ACC is active;
- the average speed with ACC off/inactive is lower in both the pre-measurement and post-measurement compared to when ACC is active;
- the average speed in the pre-period is lower than in the post-period (difference of almost 6 km/h).

On motorways:
- the average speed with ACC off/inactive is higher in the pre-measurement than in the post-measurement (difference of 2 km/h). This also applies to free speeds measured with ACC active (difference of 1 km/h).
- in all cases (pre- and post-measurement), the average speed in free traffic is higher with ACC active than with ACC off/inactive (difference of roughly 5 km/h).
- the average free speed in the post-measurement is 1.5 km/h higher than in the pre-measurement. This is due to a greater percentage of time that drivers drove with ACC switched on.

On the basis of average free speeds, it therefore appears that driving with ACC leads to higher speeds, in accordance with the expectation stipulated in section 8.2.4.2. However, we must also note that ACC is actually often used if it is possible to drive at high speeds. In other words: being able to drive at high speeds is the reason for activating ACC and not the other way round.

To acquire a deeper insight into speeds that are driven, we will look at the speed distribution in the pre- and post-measurement. Figures 8.16 and 8.17 indicate the speed distribution for the pre-measurement and post-measurement respectively. In both cases, we see that the distribution with ACC active (pre-measurement: $\sigma = 13$ km/h, post-measurement: $\sigma = 14$ km/h) is smaller compared to when ACC is off/inactive (pre-measurement: $\sigma = 15$ km/u, post-measurement: $\sigma = 16$ km/h).

Speeds with ACC switched on are concentrated around a number of values (roughly 100, 110, 120, 130 and 140); with ACC off/inactive, the speeds are more spread.

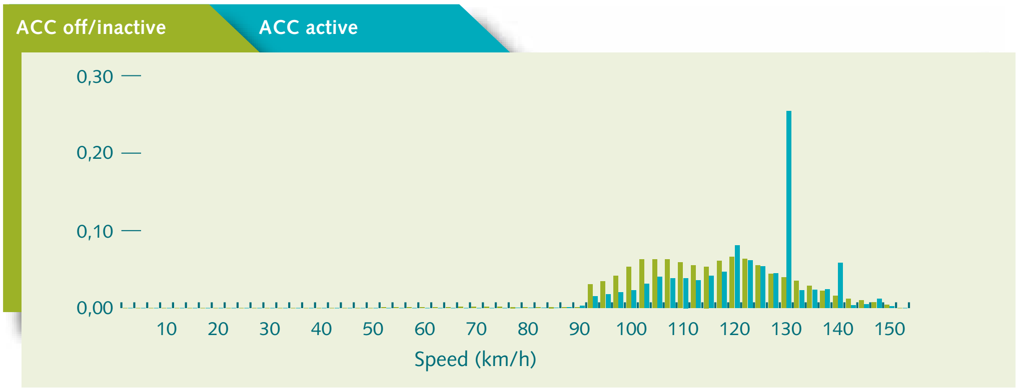

Figure 8.16 Speed distribution with ACC off/inactive and ACC active during free traffic (pre-measurement) (in percentage).

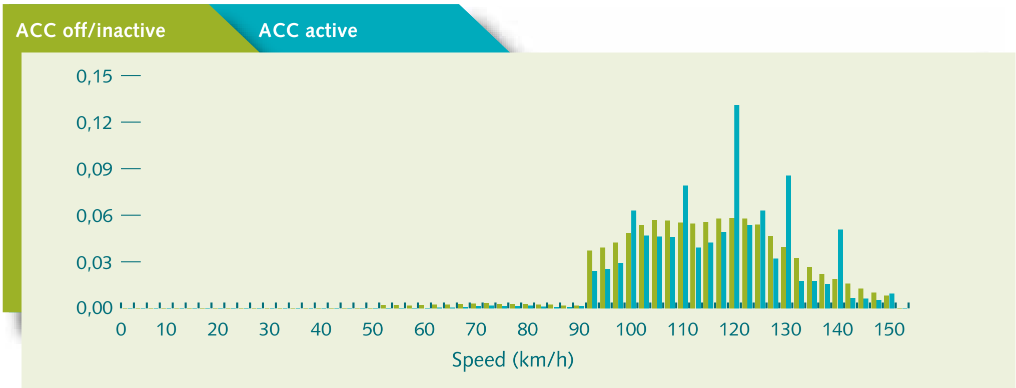

Figure 8.17 Speed distribution with ACC off/inactive and ACC active during free traffic (post-measurement) (in percentage).

Finally, instead of focussing on the baseline measurement, table 8.17 concentrates on all days that ACC was not activated the entire day (a sufficient number of days such as these could be determined for every driver).

Once again, the average speed for the entire population was considered for these days. In this case, it appears that the average free speed on motorways is 116 km/h. For motorways, this is identical to the average speed during the post-period (irrespective of the status of ACC). To a certain degree, this substantiates the notion that ACC does not result in higher speeds as such, but is actually switched on if it is possible to drive at high speeds. After all, on days that the motorist has not switched on ACC (for whatever reason), the average free speed is the same as on days that he or she did switch on ACC.

Table 8.17 Average speed (km/h) in free traffic on all days that ACC was not active (pre- and post-period)

	Prov.	Motorway	Motorway (80 km/h)
ACC off/inactivef (km) ACC activ e(km)	92.4 -	115.8 -	81.0 -
Total	**92.4**	**115.8**	**81.0**

We can therefore conclude that a statistical correlation does indeed exist between the level of free speed and the status of ACC, but for the time being there does not appear to be a causal connection (particularly not for motorways). The difference between the pre- and post-measurement cannot be unequivocally attributed to ACC; LDW or familiarisation with the new vehicle can also be explanatory factors for the differences.

To sum up, there is no conclusive evidence that the use of ACC leads to higher speeds (hypothesis 1), nor that motorists will observe the applicable speed limit less (hypothesis 2). It can be concluded, however, that the distribution in (free) speed is smaller with ACC active than with ACC off/inactive. This implies a smaller percentage of outliers (upwards and downwards). This small distribution is also expressed in the acceleration characteristics examined in the following section.

8.4.2 Acceleration characteristics

The fluctuations in speed and acceleration will probably be less when ACC is active compared to when the driver personally operates the accelerator. Fluctuations in acceleration can be described by looking at the average absolute acceleration. This indicator is determined by the following expression:

$$a\_acceleration = \frac{1}{T} \sum_{t=1}^{T} \left| a(t) \right|$$

Table 8.18 and 8.19 show the absolute acceleration per road type (provincial, motorway and 80 km/h motorway) for the pre-measurement and post-measurement. The table clearly shows that when ACC is active, the value of the indicator is significantly lower than when ACC off/inactive. This applies to all road types.

If we look at the difference between the situation beforehand and afterwards, it also emerges that the average value of the indicator has also decreased. With regard to 80 km/h motorways, however, it must be noted that not enough observations are available in the pre-measurement for a statistically significant judgement.

Table 8.18 Average absolute acceleration (m/s²) per road type for pre-measurement (free traffic)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	0.29	0.21	0.15	0.21
ACC active	0.07	0.10	-	0.09
ACC active (incl. accel.)	0.07	0.10	-	0.10
Total	**0.27**	**0.18**	**0.15**	**0.18**

Table 8.19 Average absolute acceleration (m/s²) per road type for post-measurement (free traffic)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	0.25	0.23	0.26	0.24
ACC active	0.08	0.10	0.08	0.09
ACC active (incl. accel.)	0.09	0.10	0.09	0.10
Total	**0.16**	**0.14**	**0.13**	**0.16**

Tables 8.20 and 8.21 display the same information, but now for heavy traffic instead of free traffic. Here too, there is a clear difference between ACC off/inactive and ACC active: in the first case, the average absolute acceleration is significantly greater. It is also apparent that in the situation beforehand, the value of the indicator is greater on average than in the situation afterwards (for all road types, except 80 km/h motorways).

Table 8.20 Average absolute acceleration (m/s²) per road type for pre-measurement (heavy traffic)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	0.22	0.33	0.09	0.36
ACC active	0.07	0.11	-	0.13
ACC active (incl. accel.)	0.07	0.13	-	0.14
Total	**0.21**	**0.29**	**0.09**	**0.34**

Table 8.21 Average absolute acceleration (m/s²) per road type for post-measurement (heavy traffic)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	0.23	0.34	0.20	0.38
ACC active	0.07	0.16	0.08	0.10
ACC active (incl. accel.)	0.08	0.17	0.10	0.11
Total	**0.15**	**0.26**	**0.15**	**0.29**

To sum up, this means that ACC leads to a smoother driving style with relatively fewer (sudden) braking movements. This will have an effect on fuel consumption and emissions in particular, since these partially depend on (fluctuations) in speed and acceleration.

8.4.3 Vehicle tracking behavior

In this section, we will look at changes in vehicle tracking behavior, i.e. focus on the question how tracking behavior changes due to ADA (in relation to selected ADA settings).

Tracking behavior can be studied in various ways, such as by estimating the parameters of a vehicle tracking model on the basis of available data. However, we will start with an overview of various variables and their distributions, which describe tracking behavior.

Average minimum headway times

We will focus here primarily on the minimum headway times that drivers maintain while following other vehicles. In order to determine these, the following selection criteria have been used so that set minimum headway times can be defined:

- Drivers are on the motorway.
- Speeds vary between 70 km/h and 90 km/h (in other words there is heavy traffic).
- The relative speed in relation to the vehicle in front (in an absolute sense) is less than 2 m/s.

De minimale volgtijden worden bepaald door het gemiddelde te nemen van de volgtijden waarbij aan bovenstaande criteria is voldaan. Deze minimale gemiddelde volgtijden zijn bepaald voor ACC uit/inactief en ACC actief.

Table 8.22 provides an overview of average headway times (for all drivers combined) that have been determined in accordance with the aforementioned criteria. A distinction has been made between ACC off/inactive, ACC active and average (total).

Table 8.22 Attained (net) headway times (in seconds) for the pre-measurement and post-measurement with ACC off/inactive, ACC on and total

	Pre-measurement	Post-measurement
ACC off/inactive	1.10	1.02
ACC active	-	1.22
Total	**1.12**	**1.13**

The table reveals that the average headway time with ACC active is approximately 0.2 s greater than with ACC off: drivers do indeed select a headway time that corresponds to their own tracking behavior; the selections are apparently conservative. An explanation for this is the fact that a partial range ACC is involved, where the driver has a supervisory task.
If required, the driver must be able to intervene on time.

It must also be noted that most drivers selected the minimum headway time of 1 s. With this setting too, it appears that the average headway time with ACC active is greater 1 s (1.22 seconds to be precise). In many cases (among 8 drivers), it appears that the normal headway time is less than the shortest headway time that ACC can achieve. If an even shorter headway time could have been specified, a number of drivers would probably have done so.

In any case, hypothesis 4 in section 8.2.4.2 has been formulated correctly.

However, if we examine the differences between the pre-and post-measurement, these appear to be exceptionally small. The data reveals that when ACC is not active, the attained headway times are shorter on average than the average headway time in the pre-measurement. However, we cannot determine whether drivers use a shorter headway time when the system is switched off, or whether they switch off ACC if a shorter headway time is required (if the driver had maintained a shorter headway time anyhow). In any case, the net effect of ACC on average headway times is extremely limited.

Headway time distribution and distribution in headway times: inter- and intra-driver differences in headway times

If we look at the headway time distribution, we can see that there is indeed a decrease in the distribution of headway times if ACC is active (incl. accel.). Figures 8.18 and 8.19 indicate these distributions for the pre-measurement and post-measurement. The figures (especially figure 8.19) also clearly reveal the difference in the distribution of ACC off/inactive and ACC active. Moreover, the percentage of shorter headway times with ACC active is significantly smaller than with ACC off/inactive.

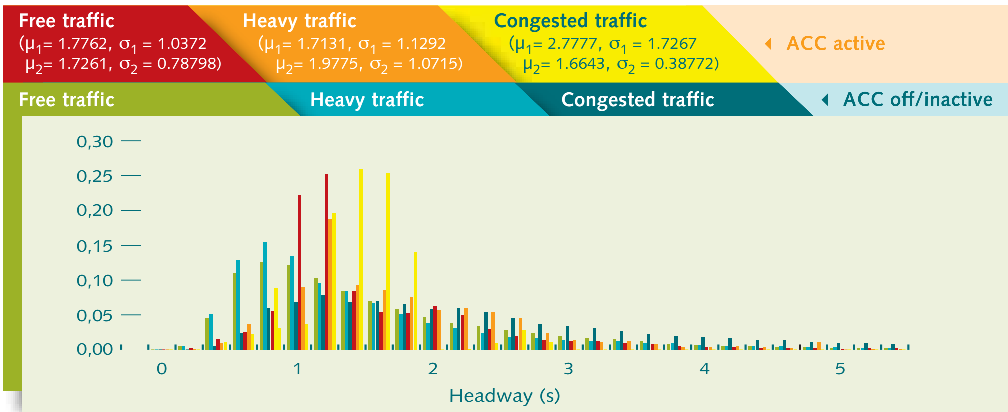

Figure 8.18 Distribution of headway times (for all drivers) in the pre-measurement for ACC off/inactive and ACC active. N.B.: the headway distribution for ACC active covers the driving behavior of four drivers only and comprises merely a number of observations.

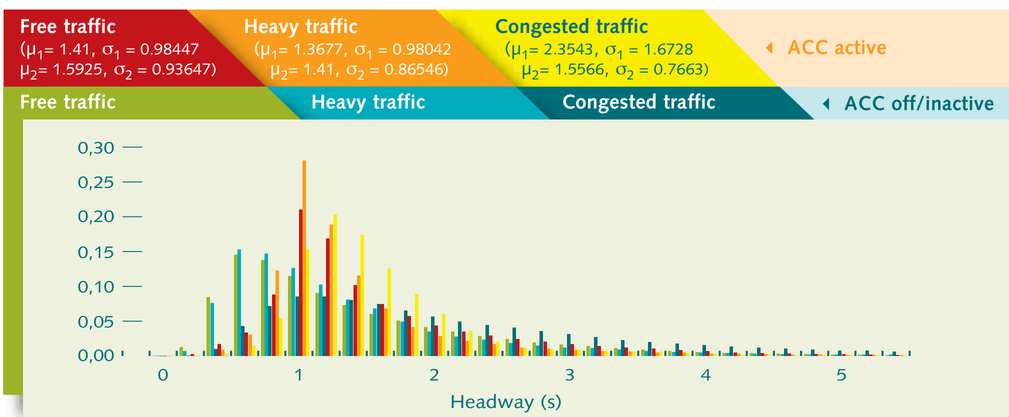

Figure 8.19 Distribution of headway times (for all drivers) in the post-measurement for ACC off/inactive and ACC active

[4] This distribution comprises headway time distributions for individual drivers fi(h). The following applies to the combined distribution:

$$f(h) = \frac{1}{n} \sum_{i=1}^{n} f_i(h)$$

Table 8.23 indicates the distribution in headway times for various periods, in the event that ACC is off/inactive, or ACC is active. N.B.: this involves the distribution over the entire driver population, in other words: including the distribution due to various average headway times and the distribution in headway time settings. In short: the table represents average inter- and intra-driver differences in attained net headway times. The table clearly reveals that the distribution in headway times is decreasing.

Table 8.23 Distribution in headway time per period (standard deviation in seconds)

		Pre-measurement	Post-measurement
ACC off/inactive	Free traffic	1.04	0.98
	Heavy traffic	1.13	0.98
	Congested traffic	1.73	1.67
ACC active	Free traffic	0.79	0.94
	Heavy traffic	1.07	0.87
	Congested traffic	0.39	0.77

Table 8.24 displays the averages of the distribution in headway times per driver. Effective corrections have been made here for differences in average headway times and headway time settings, which is why the table only indicates intra-driver differences.

Table 8.24 Average distribution per driver per period (standard deviation in seconds)

		Pre-measurement	Post-measurement
ACC off/inactive	Free traffic	0.85	0.93
	Heavy traffic	0.88	0.89
	Congested traffic	1.49	1.64
ACC active	Free traffic	0.67	0.87
	Heavy traffic	0.85	0.84
	Congested traffic	0.34	0.58

The table reveals that intra-driver differences in attained headway times decrease (with ACC active), provided there is heavy traffic or congested traffic. In free traffic, there does not appear to be a decrease in distribution. However, this cannot be expected either since headway times in free traffic are not determined by vehicle tracking behavior but by the random arrival process.

In any case, hypotheses 4 and 5 as formulated in section 8.2.4.2 are correct. We will touch upon the percentage of short headway times during the discussion on the effect of ACC/LDW on road safety.

8.4.4 Lane changes and selection

This section examines to what extent lane changing behavior alters as a result of ADA systems. To this end, we will look at the number of lane changes per hour and the percentage of time that motorists were driving in the left or middle lane.

Lane changes

In section 8.2.4.2, the expectation is expressed that ACC will lead to fewer lane changes. Drivers should remain in their lane in accordance with the "go with the flow" principle and allow the system to perform the driving task as much as possible.

Tables 8.25 and 8.26 display the number of lane changes per hour recorded by the MobilEye system for the situation beforehand and afterwards respectively. On the basis of the comparison of the tables, we can state that the number of lane changes in the situation afterwards has increased. This applies to all road types. The increase is greatest for provincial roads/80 km/h motorways (20%), although the figure for 80 km/h motorways is not reliable due to the lack of available data. For motorways, the increase is 13%.

It is impossible to identify the cause of this increase. In all likelihood, familiarisation with the new vehicle is partly responsible for this growth. After all, if we look at the number of lane changes per hour with ACC off/inactive in the post-period, an increase in relation to the pre-period is evident.

If we look at the differences between ACC off/ inactive and ACC active (particularly during the post-period), we can see a distinct decrease in the number of lane changes (19%) for provincial roads. For motorways – if we disregard ACC active incl. acceleration – there is a decrease of 1%; for the situation ACC including acceleration, we can see an increase of 6% in the number of lane changes. For 80 km/h motorways, there is – in relation to ACC off/inactive – an increase in the number of lane changes totalling 8%.

Table 8.25 Number of lane changes per hour (pre-period)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	30.4	51.2	38.9	49.5
ACC active	27.7	47.4	-	44.5
ACC active (incl. accel.)	27.7	48.0	-	45.2
Total	**30.7**	**52.5**	**38.9**	**49.1**

[5] The MobilEye system logs every lane change immediately.

Table 8.26 Number of lane changes per hour (post-period)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	36.6	56.8	63.9	54.2
ACC active	28.3	56.1	67.2	54.8
ACC active (incl. accel.)	29.5	60.1	69.4	58.3
Total	36.6	59.3	46.7	56.5
% in relation to pre-measurement	19%	13%	20%	15%
% active t.o.v. off/inactive	-23%	-1%	5%	1%
% active (incl. accel) in relation to ACC off/inactive	-19%	6%	8%	8%

To sum up, on motorways there is a slight increase in the number of lane changes with ACC on (6%). It is notable that a large percentage of these lane changes are performed via active intervention by the motorist (ACC active + acceleration): drivers "overrule" the system by accelerating and then changing lanes. If we disregard this active intervention, there is a minor decrease. For provincial roads, we see a significant decrease in the number of lane changes per hour (reduction of approximately 20%).

Once again, it is not easy to establish a clear causal connection because the situations in which ACC is active actually involve those situations in which drivers deem the use thereof to be opportune.
Nevertheless, the expectation that ACC leads to fewer lane changes (hypothesis 7) appears to be incorrect, even though the measured increase is limited.

Lane usage
We expect that drivers who have ACC switched on will remain relatively often/longer in the middle and left lane, due in part to high driving speed in these lanes. We also saw above that many drivers overrule ACC during overtaking. We therefore also expect – partly as a result thereof – that the use of the middle and left lane will increase.

Tables 8.27 and 8.28 depict the percentage of the time that drivers were in the right lane, for the pre- and post-period for free traffic. We can conclude from the table that there is a small difference in the situation before and after:

- There is a small decrease in the use of the right lane for motorways (from 54% to 52% of the time).
- There is a small increase in the use of the right lane for provincial roads (from 83% to 84%).

[6] The lane is determined on the basis of the logged lane changes to the left and right. This was selected because at higher speeds, the MobilEye system appeared unable to distinguish between various types of line markings (solid line, broken line, etc.).

If we consider, in the situation afterwards, the differences between ACC off/inactive and ACC active (situation afterwards), we see that the use of the right lane with ACC active is lower (50% of the time) than with ACC off/inactive (54%) for motorways during free traffic. With regard to 80 km/h motorways, we notice the same difference (decrease of roughly 4%).

Table 8.27 Percentage of time that driver was in the right lane (pre-period, free traffic)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	83.0%	55.4%	-	58.2%
ACC active	-	40.6%	-	41.4%
ACC active (incl. accel.)	-	38.9%	-	39.9%
Total	**82.7%**	**53.9%**	**-**	**56.8%**

Table 8.28 Percentage of time that driver was in the right lane (post-period, free traffic)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	82.9%	54.4%	74.3%	59.6%
ACC active	87.1%	51.8%	69.8%	54.6%
ACC active (incl. accel.)	86.2%	50.4%	69.6%	53.2%
Total	**84.1%**	**52.2%**	**71.5%**	**56.6%**

Tables 8.29 and 8.30 depict the percentage of time that drivers were in the right lane, for the pre- and post-period for heavy traffic respectively. Once again we see a minor difference between the situation before and after:

- There is a limited decrease in the use of the right lane for all road types (a decrease of about 3% in total).

When we compare ACC active with ACC off/inactive, we also see a decrease of approximately 2% in the use of the right lane.

Strangely enough, we notice a rise in the use of 80 km/h motorways in heavy traffic. The use of the right lane in such situations anyway is high (over 80% of the time). However, these latter results are based on a small random check and must therefore be considered unreliable from a statistical point of view.

Table 8.29 Percentage of time that driver was in the right lane (pre-period, heavy traffic)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	90.5%	69.7%	-	67.3%
ACC active	-	59.7%	-	73.1%
ACC active (incl. accel.)	-	57.2%	-	71.5%
Total	**89.8%**	**69.2%**	**-**	**67.3%**

Table 8.30 Percentage of time that driver was in the right lane (post-period, heavy traffic)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	87.8%	69.2%	81.8%	68.6%
ACC active	85.6%	68.4%	84.9%	77.1%
ACC active (incl. accel.)	85.5%	67.2%	84.4%	76.3%
Total	**86.9%**	**68.4%**	**83.4%**	**70.3%**

For motorways, it is interesting to also look at the use of the left and right lane. Tables 8.31 and 8.32 display the distribution of traffic across lanes (for motorways) for the situation before and after. Again, we see a decrease in the use of the right lane upon comparison of the situation before and after (of nearly 2%). This drop can be attributed entirely to an increase in the use of the left lane.

If we consider the differences (in the situation after) between ACC off/inactive and ACC active, we see in general that the use of the right lane with ACC off/inactive is lower than with ACC active; the exact opposite is applicable to the middle lane.

There is no increase in the use of the left lane. On the contrary, there is actually a limited decrease of about 2%. Bear in mind though that this decrease only appears to occur in quiet traffic; in heavy traffic there is actually a small increase (of 2%). However, due to the small percentage of “heavy traffic”, this increase is not that relevant for the total.

Table 8.31 Percentage of time that driver was in the right lane (pre-period)

	Right	Middle/left	Left
ACC	57.1%	31.1%	11.8%
ACC active	42.9%	29.7%	27.4%
ACC active (incl. accel.)	41.1%	29.6%	29.3%
Total	**55.7%**	**31.0%**	**13.3%**

Table 8.32 Percentage of time that driver was in the right lane (post-period)

	Right	Middle/left	Left
ACC off/inactive	56.2%	28.5%	15.3%
ACC active	53.8%	32.8%	13.4%
ACC active (incl. accel.)	52.4%	33.2%	14.4%
Total	**54.1%**	**31.1%**	**14.8%**

We can conclude therefore that ACC leads to a change in the use of lanes. There is a decrease in the use of the right lane of approximately 4% (for motorways). Consequently, hypothesis 8 also appears to be correct.

However, this change is not as large as may have been initially expected. This is probably because various factors are involved that cancel out each other to a certain degree. Some drivers may maintain a “go with the flow” attitude while others will overtake earlier and drive in the right lane.

Use of direction indicators
The LDW system may have an effect on the use of direction indicators. After all, every time a line marking is crossed and this is detected by the LDW system, the system will issue a warning. We implicitly assume that drivers do not always use direction indicators during the pre-period when this is strictly speaking necessary.

Tables 8.33 and 8.34 indicate the percentage of all lane changes logged by MobilEye for which direction indicators were used. This is determined by checking at the moment a lane change occurs whether the direction indicator is indeed switched on. It may be the case that at the moment the lane change occurs, the indicator has already been switched off. (In the Volkswagen Passat, the direction indicator can be operated by moving it briefly. The lights flash three times before the indicator switches off again. In practice, this is used primarily during lane changes.)

From the tables it can be concluded that there is a slight increase in percentages in all situations. The increase appears to be most substantial on provincial roads.

Table 8.33 Percentage of all lane changes for which a direction indicator is used (pre-period). The table indicates the average percentage among all drivers.

	City	Prov.	Motorway
To the left	13.0%	21.6%	43.9%
To the right	14.9%	16.9%	49.6%

Table 8.34 Percentage of all lane changes for which a direction indicator is used (post-period). The table indicates the average percentage among all drivers.

	City	Prov.	Motorway
To the left	15.0%	26.5%	44.9%
To the right	17.1%	33.2%	52.0%

This analysis therefore reveals that the expectation with regard to the use of the direction indicator (hypothesis 10) is correct.

8.4.5 Lateral position within the lane and LDW warnings

We verwachten dat de waarschuwingen die LDW geeft een effect zullen hebben op het aantal We expect that the warnings issued by LDW will have an effect on the number of unintentional line crossings. This can be examined by looking at the number of (virtual) warnings that the LDW system provides.

Tables 8.35 and 8.36 below specify the number of warnings per hour that LDW was supposed to have given (pre-period) or did give (post-period), on average across the entire driver population.

We see a distinct reduction in the number of warnings issued by the system. In addition, we notice that the relative number of warnings is greatest on the motorway. The differences are most significant during the pre-measurement.

Table 8.35 Number of warnings per hour for pre-period. N.B.: the warnings in the pre-measurement were not actually issued (LDW was switched off, after all).

	City	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	7.3	30.1	39.7	-	22.8
ACC active	9.3	0.0	29.6	-	26.3
ACC active incl. accel.	9.1	0.0	30.1	-	26.8
Total	**7.3**	**29.6**	**39.0**	**-**	**22.9**

Table 8.36 Number of warnings per hour for transitional period

	City	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	8.2	21.4	23.3	15.9	16.4
ACC active	21.2	16.8	23.9	22.0	23.1
ACC active incl. accel.	21.5	18.4	24.0	23.6	23.3
Total	**8.9**	**20.8**	**23.6**	**17.6**	**18.3**
Change in % in relation to pre-period	21.9%	-29.7%	-39.5%	-	-20 1%

RADAR MAAKT AUTO'S SLIM

Rijkswaterstaat houdt een proef met 'slimme' auto's. Twintig leaseauto's zijn voor dit vijf maanden durende experiment uitgerust met apparatuur waarmee het voertuig niet alleen binnen de belijning blijft, maar ook voldoende afstand houdt tot de voorganger.

'We gaan onderzoeken welke effecten deze systemen hebben op de verkeersveiligheid, de doorstroming in het verkeer en het milieu', zegt Jonna Brandsma van het innovatieprogramma Wegen naar de Toekomst. Een kastje in de auto registreert onder meer inhaalgedrag en snelheid. Ook houdt het de uitstoot van schadelijke stoffen en brandstofgebruik in de gaten. Bij Advanced Cruise Control (ACC) stelt de bestuurder zelf de gewenste snelheid en het aantal seconden afstan tot de voorganger in. Het systeem werkt met een radar die de afstand tot de voorganger meet. De auto remt gelijkmatig af als de bestuurder de wagen voor hem te dicht nadert.

De Lane Departure Warning Assistent (LDWA) waarschuwt de automobilist als hij de rijstrook verlaat zonder richting aan te geven.

'In duurdere auto's worden deze technieken soms ingebouwd', zegt Brandsma. 'Maar ze zijn nog er prijzig. De auto-industrie volgt met veel belangst ling onze proef. Als deze technologieën gunstige effecten hebben op de verkeersveiligheid, dan hebben zij daar ook baat bij.' Na de zomer zijn de resultaten bekend.

IVsource

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General Conclusions

LDW Nuggets

ACC Nuggets

Minister rijdt in 'slimme auto'

Verkeersminister Karla Peijs heeft zelf kunnen ervaren hoe het is om veilig en comfortabel te rijden in een auto die is uitgerust met rijtaakondersteunende systemen. Aanleiding vormde de praktijkproef met de Rij-assistent van Wegen naar de Toekomst die medio dit jaar van start ging met twintig lease auto's.

Om vast te stellen welke effecten 'slimme' systemen hebben op de verkeersveiligheid, de verkeersdoorstroming en het milieu zijn twintig lease auto's voor een periode van vijf maanden uitgerust met apparatuur waarmee het voertuig niet alleen binnen de belijning blijft, maar ook voldoende afstand houdt tot de voorganger. Een kastje in de auto registreert onder meer inhaalgedrag en snelheid. Daarnaast wordt de uitstoot van schadelijke stoffen en het brandstofverbruik in de gaten gehouden.

Bij Advanced Cruise Control (ACC) stelt de bestuurder de tijd in die de auto automatisch ten opzichte van de voorganger moet aanhouden en de gewenste snelheid. De auto doet de rest. Het systeem werkt met een radar die voortdurend de afstand tot de voorganger meet. Komt de auto binnen de door de bestuurder ingestelde aantal seconden, dan remt de wagen gelijkmatig af. De Lane Departure Assistent (LDWA) waarschuwt de automobilist als hij de rijstrook verlaat zonder richting aan te geven.

Rijkswaterstaat verwacht dat rijtaakondersteunende systemen kunnen leiden tot minder verkeersongelukken en files en een afname van schadelijke emissies en brandstofverbruik. Wegen naar de Toekomst verwacht dit najaar de eindresultaten van de proef te kunnen presenteren. Hiermee krijgen beleidsmakers en wegbeheerders advies over de mogelijke effecten van slimme voertuigondersteunende systemen en de rol die deze in toekomst kunnen spelen bij ontwikkelingen in de auto-industrie.

De 'Rij-assistent' waakt over het rijgedrag van minister Peijs.

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rai vereniging

Volvo maakte deze week bekend dat er binnen twee jaar een systeem op de markt komt dat juist bij lage snelheden in de stad en files botsingen moet voorkomen.

Nuttige hulpjes

8 Procent minder ongevallen, 3 procent lager brandstofverbruik, 5 tot 10 procent minder uitstoot van uitlaatgassen. Dat zijn de berekende voordelen van hulpsystemen die de juiste onderlinge afstand tussen auto's regelen en de auto binnen de wegbelijning laat rijden. Wat onderzoeker Gerben Bootsma (35) van Rijkswaterstaat betreft stimuleert Europa het gebruik ervan flink.

„As't witte wolst wat de ûntwikkelingen binne by de autofabrikanten moatst nei harren djoerste auto's sjen'', vertelt Gerben Bootsma, de in Wommels geboren onderzoeker van de Adviesdienst Verkeer en Vervoer van Rijkswaterstaat in Rotterdam. De topmodellen worden tegenwoordig uitgerust met geavanceerde veiligheidssystemen, of ze zijn als optie verkrijgbaar. Met Engelse aanduidingen als *lane-departure warning system* of *advanced cruise control* worden ze aangeprezen.

Het eerste moet voorkomen dat de automobilist onnodig zijn rijbaan verlaat of van de weg afraakt, het tweede zorgt voor een veilige afstand tussen de auto en zijn voorligger en voor comfortabeler rijden.

Het zijn nieuwe systemen die de automobilist meer bij de les moeten houden om ongevallen te voorkomen. Onderzoek heeft Rijkswaterstaat geleerd dat de meeste ongevallen op snelwegen toe te schrijven zijn aan drie oorzaken: te snel rijden, onbedoeld de rijstrook verlaten en onvoldoende afstand houden. De combinatie van het lane-departure warning system en de advanced cruise control kan al die factoren positief beïnvloeden.

Onderzoeker Tom Alkim (links) en projectleider Gerben Bootsma bij een van de testauto's. Foto Rijkswaterstaat

Dat zeggen de fabrikanten en dat wilde Rijkswaterstaat wel eens beproefd zien. Bootsma: „Fabrikanten basearje har risseltaten faaks op teoryen en op ûnderfinings mei in beperkt tal auto's. Dy ride dan ek noch faaks op in sletten circuit mei testriders fan 'e fabryk. Wy woenen witte of de systemen ek wurkje yn it gewoane ferkear, mei gewoane minsken efter it stjoer. Wy woenen ek witte of de automobilisten de ekstra elektroanika wol hawwe wolle.''

Onder de noemer Rij-Assistent startten Bootsma en zijn collega's in maart de proef met beide systemen. In verschillende combinaties. Tien luxe busjes voor personenvervoer werden uitgerust met het lane-departure warning system. Ze mochten over de vluchtstrook van Almere naar Amsterdam rijden.

Om vergelijkingmateriaal te krijgen eerst een maand zonder het systeem, daarna vier maanden met. Een datarecorder registreerde allerlei gegevens, zoals snelheden, handelingen als remmen, schakelen en optrekken enzovoort.

Dat gebeurde ook in de twintig personenauto's die met het lane-departure warning system en de advanced cruise control werden uitgerust. Deze cruise control meet de afstand tot de voorligger, remt de wagen zonodig af en trekt op zodra dat weer mogelijk is.

Tot slot zijn er, officieel buiten het onderzoek om, testritten gemaakt met een Toyota die is

Wielen

uitgerust met een systeem voor lane-keeping en met advanced cruise control. Lane keeping piept niet alleen zelf, maar voert stuurcorrecties uit wanneer de chauffeur om onduidelijke reden plotseling zijn rijbaan verlaat.

Volgens Bootsma zijn de uitkomsten van Rij-Assistent boven verwachting goed. Het vertalen van alle meetgegevens leverde op dat de combinatie van beide veiligheidssystemen op snelwegen het aantal kopstaartbotsingen met in ieder geval 7 procent doet verlagen en het aantal zijwaartse botsingen met 1 à 2 procent.

Niet minder belangrijk is de verbetering van het rijgedrag. Automobilisten gebruiken hun richtingaanwijzers correcter en houden zich beter aan de maximumsnelheid. Door de elektronica aan boord reden ze rustiger en daarmee zuiniger. De apparatuur remt geleidelijker en de auto trekt ook met een lager brandstofverbruik op.

„De besparring op brânstofkosten binne rûze op 3 prosint, de fermindering fan de útstoart fan skeadlike gassen tusken de 5 en 10 prosint op sneldiken. Op provinsjale diken sille de persintages noch heger wêze omdat op dy diken automobilisten mear skeakelje, remje en oplûke moatte.''

Opmerkelijk was volgens Bootsma ook de acceptatiegraad. „Wat ús opfoel wie dat de minsken de elektroanika net as ferlelend ûnderfûn hawwe. It makket it riden komfortabeler. Der wie ek in negatyf aspekt: de automobilisten joegen oan de oanstriid te hawwen mear te beljen ûnder it riden en sa. Soks wolle wy yn 'e takomst fjierder ûndersikje.''

De proef is inmiddels afgerond, het cijfermateriaal verwerkt tot rapporten en presentaties. Deze liggen inmiddels bij het ministerie van verkeer en waterstaat en bij de Europese Commissie. Maar de uitkomsten zijn volgens de onderzoekers ook voor autofabrikanten en verzekeraars interessant. Bootsma en zijn collega's vinden de resultaten zo hoopgevend dat een brede toepassing van beide systemen overwogen moet worden.

„By de Jeropeeske Kommisje lobbye wy foar in grutskalige proef.'' Dat is volgens Bootsma nodig om de systemen breder in beeld te krijgen bij de consumenten, fabrikanten en verzekeraars. Europa zou de veiligheidsmaatregelen uiteindelijk breed kunnen promoten of verplicht kunnen stellen.

Ondertussen wordt op het ministerie van verkeer en waterstaat bekeken of de aanschaf van het lane-departure warning system en de advanced cruise control kan worden gestimuleerd. De systemen zijn met respectievelijk ongeveer €800 en €1100 niet echt goedkoop. Daarin komt pas verandering als de apparatuur op grote schaal kan worden geproduceerd. Het ministerie beraadt zich er nu over wat ze met deze onderzoeksresultaten gaat doen, aldus Bootsma.

Mocht het ministerie onder de indruk zijn van de resultaten van Rij-Assistent, dan zou het kunnen besluiten de aanschaf van de apparatuur te bevorderen, bij voorbeeld via belastingkorting. Eerder is zo al de verkoop van de katalysator, de hybridemotor (Toyota Prius), het roetfilter en milieuvriendelijke (vracht)auto's gestimuleerd.

DICK OFFRINGA

Table 8.37 Number of warnings per hour for post-period

	City	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	8.5	19.9	27.1	16.6	16.5
ACC active	19.8	16.3	26.4	22.6	24.8
ACC active incl. accel.	20.3	16.5	27.0	23.9	25.5
Total	**9.0**	**19.1**	**27.1**	**19.9**	**18.8**
Change in % in relation to pre-period	23.3%	-35.5%	-30.5%	-	-17.9%

Remarkably, the number of warnings per hour on motorways is the largest on average. This is contradictory to the expectation outlined in hypothesis 13.

If we look again at motorways only, the figure below indicates changes in the number of warnings per hour for various periods. What particularly catches the eye in figure 8.20 is that after an initial significant decrease in March in relation to February, there is a limited increase in the number of warnings in April.

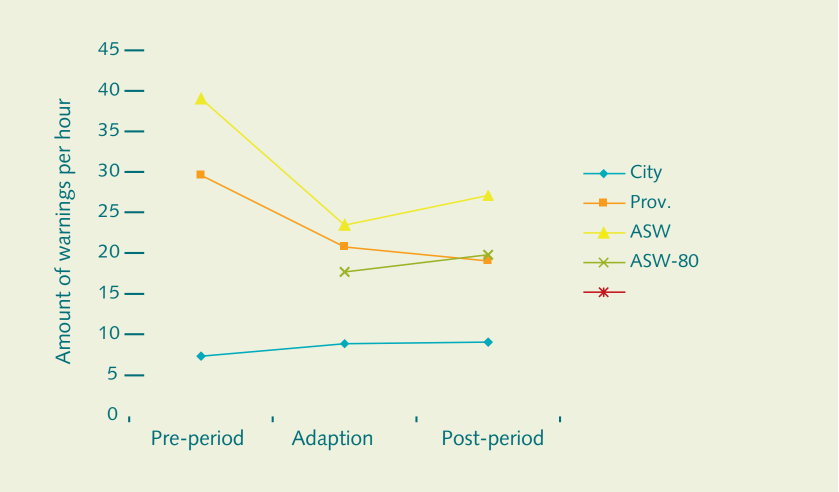


Figure 8.20 Number of warnings per hour for various periods, for urban areas, provincial roads and motorways

The above explicitly shows that there are significantly fewer unintentional line crossings with LDW than without . This is in accordance with the anticipated effect of LDW (see hypotheses 11 and 12): there is less SDLP as a result of LDW. This has a positive effect on road safety. We will discuss this last point again later.

This hypothesis is also endorsed by compiled data relating to the lateral position of the vehicles: we see a small shift to the middle of the lane (depending on the regime). This is shown in figures 8.21 and 8.22.

[7] This can be explained in part by an increase in the use of direction indicators.

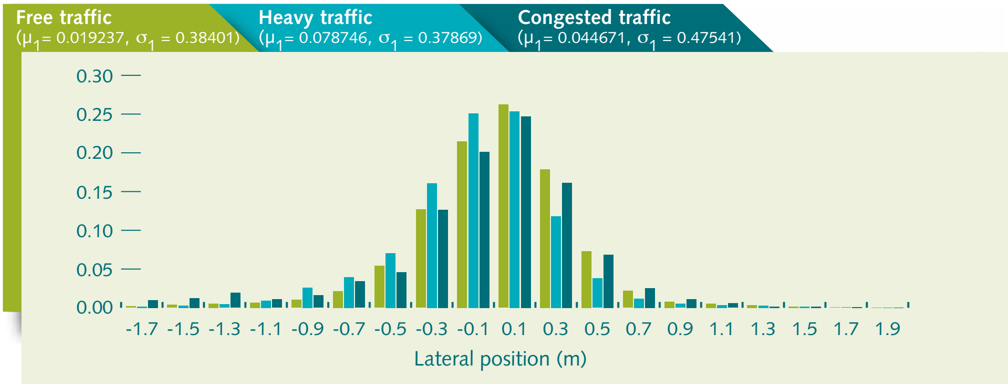


Figure 8.21 Distribution of lateral positions for all vehicles for the pre-period (February 2006)

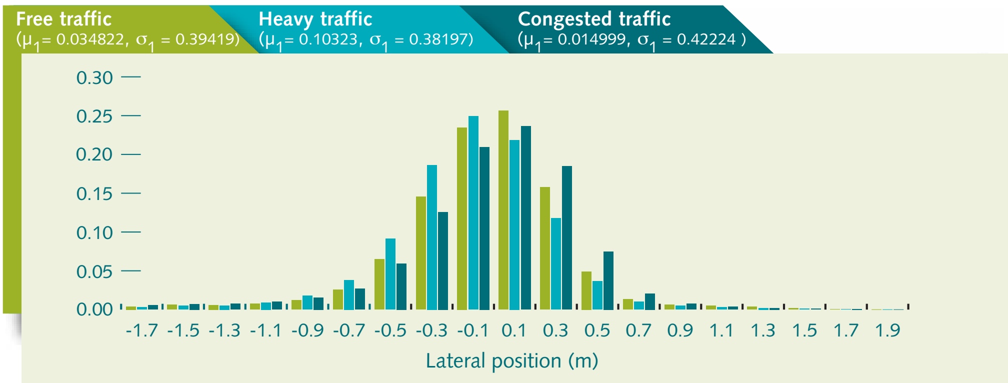


Figure 8.22 Distribution of lateral positions for all vehicles for the post-period

Table 8.38 indicates the average lateral position of the vehicles in the pre- and post-period for the various traffic regimes. On the basis of the indicated results, it cannot be concluded that LDW has a strong impact on the average position of the vehicle in relation to the axis of the lane.

Table 8.38 Average distance from middle of vehicle until middle of lane for various periods and various regimes, for all vehicles combined

	Pre-period	Post-period
Free traffic	0.02 cm	-0.03 cm
Heavy traffic	-0.08 cm	-0.10 cm
Congested traffic	-0.05 cm	-0.01 cm

In table 8.39, the distribution in lateral position is indicated for the various periods and assistance. Here too, we see little difference between the pre-and post-measurement, except in the case of congested traffic.

Table 8.39 Standard deviation distance from middle of vehicle until middle of lane for various periods and various regimes, for all vehicles combined

	Pre-period	Post-period
Free traffic Heavy traffic Congested traffic	0.38 cm 0.38 cm 0.48 cm	0.39 cm 0.38 cm 0.42 cm

On the other hand, if we look at the averages of the distribution per driver, we really do notice a decrease in distribution in the situation afterwards in relation to the situation beforehand. Table 8.40 indicates that this decrease is between 1 cm and 5 cm, depending on the traffic regime in question.

Table 8.40 Standard deviation distance from middle of vehicle until middle of lane for various periods and various regimes, for all vehicles combined

	Pre-period	Post-period
Free traffic Heavy traffic Congested traffic	0.40 cm 0.43 cm 0.49 cm	0.39 cm 0.39 cm 0.44 cm

Finally, figure 8.23 indicates the differences in the distribution of the lateral position for ACC off/inactive and ACC active. We can conclude from the figure that there are differences in both the average and the distribution. The latter is usually smaller with ACC active than with ACC off/inactive. This may indicate that the alleviation of the driving task due to ACC helps decrease SDLP even further.

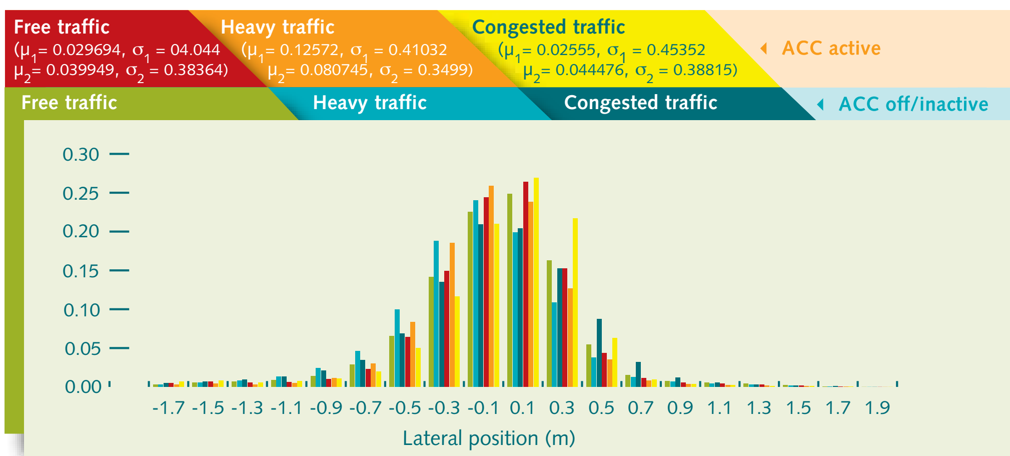


Figure 8.23 Distribution of lateral position of all vehicles for the post-period, with a distinction between ACC off/inactive and ACC active

8.4.6 Key findings regarding effects of ADA on driving behavior

With reference to driving behavior, the following aspects sum up the most important findings regarding the effect of ADA on driving behavior. We will use the following sub-questions once again in this summary:

To what extent does ADA influence the choice of free speed (in relation to the applicable maximum speed)?

- There is no reason to assume that motorists will observe the speed limit sooner with ACC than without it.
- The differences between the average free speed (with ACC) and the applicable maximum speed is limited (5 km/h on average).

How do acceleration characteristics change as a result of ADA?

- The distribution in acceleration with ACC active is smaller than with ACC off/inactive. This will have a positive effect on comfort, fuel consumption and emissions.

How does the tracking behavior of the motorist/vehicle change as a result of ADA (in relation to the selected ADA settings)?

- Average headway times with ACC active are somewhat longer than with ACC off/inactive (increase of roughly 0.2 s).
- The variation in headway times with ACC is smaller than without ACC. This applies to both inter-driver differences and (to a lesser degree) intra-driver differences. The percentage of minimal headway times decreases substantially.

How do SDLP and the lateral position of the vehicle change as a result of available ADA systems?

- The number of unintentional line crossings decreases thanks to LDW (for provincial roads by 35% and for motorways by 30%).
- LDW issues more warnings on motorways than in urban areas and on provincial roads.
- Drivers reduce the SDLP of their vehicles to avoid warnings. This has direct consequences for the driving task load of drivers (they have to concentrate better).
- A (statistical) correlation appears to exist between SDLP (particularly the distribution in lateral position) and whether or not ACC is active. This can signify a reduction in the driving task load in the event ACC is active.

How does lane changing behavior alter?

- Direction indicators are used more often and more effectively.
- We cannot conclude that there are fewer lane changes due to ACC/LDW.
- Drivers continue driving in the left lane and particularly in the middle lane for longer.

8.5 Analysis of throughput effects

This section will focus on the anticipated effects of ADA systems on traffic flow throughput. Some of the conclusions here are based on behavioral effects as described in the preceding section while others are based on the results of the model study.

The questions we answer here relate primarily to the capacity of the road and changes therein as a result of ADA systems. The following sub-questions will be answered more specifically:

a. To what degree does capacity change per lane as a result of ADA (with a distinction between free capacity and the queue discharge rate)?
b. To what extent does the distribution of traffic across lanes change?
c. What is the anticipated effect thereof on congestion and travelling times?
d. What are the anticipated indirect effects on traffic flow throughput as a result of the change in road safety?

8.5.1 Effects of ACC on free capacity

Free capacity involves the maximum intensity before congestion has occurred. This capacity is influenced by a number of aspects:

- Capacity per lane, which is determined directly by vehicle tracking behavior per lane.
- Distribution of traffic across lanes.
- Number of lane changes.
- Distribution in headway times and speeds.

In section 8.4.3, the average effect of ACC in particular on headway time distribution is examined. The most important conclusion was that with ACC active, drivers maintain a longer headway time on average compared to ACC off/inactive. However, the average realised minimum headway times in the post-period appear to be barely influenced.

But we do see an increase in the use of the middle lane and (to a lesser extent) of the left lane. As a result, there could be a disproportionate use of lanes (with a high ADA degree of penetration).

The number of lane changes does not decrease. Instead, there is a (very limited) increase in the number of lane changes.

The distribution in speed does indeed decrease. This can be concluded on the basis of the decrease in (absolute) acceleration, but also from the time variation in speeds. Since this provides a similar picture with absolute acceleration, quantitative data is not taken into consideration.

On the basis of the findings mentioned above, it is not easy to provide an unequivocal, quantitative verdict on the effect of the used ADA systems on capacity. On the grounds of the fact that there are both negative effects (limited longer headway times, a small increase in the number of lane changes) and positive effects (small distribution in headway times, small distribution in speeds), no definitive verdict can be made on the basis of empirical data alone.

It is expected that there will be an extremely small drop in free capacity. The model study, however, reveals that this reduction is so small that there is barely a deterioration in traffic flow throughput.

8.5.2 Effects of ACC on the queue discharge rate

The queue discharge rate is the intensity that is measured just downstream of the traffic jam, i.e. the capacity with which the traffic jam dissipates.

The ACC examined here will have a negligible effect on the queue discharge rate. It has already emerged from the use of ACC that drivers make relatively little use of ACC in congested traffic (only 8% of the time). On the one hand, this can be explained by the fact that drivers prefer performing the vehicle tracking task themselves in congested traffic.
On the other hand, the functioning of ACC (and of the LDW system too) is limited to a certain minimum speed (30 km/h for ACC), or to an acceleration of -2.5 m/s^2 or more. In stop-and-go traffic, the system will therefore not function or not do so properly. The 8% of the time that drivers do use ACC appears to occur during light congestion in particular (speeds greater than 30 km/h, no start-stop waves).

It is expected that the queue discharge rate will change significantly as a result of ACC, particularly because the system often does not function in congested traffic.

The model study revealed that switching off the system at speeds of 30 km/h or lower cancels out a large number of negative or positive throughput effects of ACC.

8.5.3 Capacity of access ramps

During the workshop, the hypothesis was formulated that the capacity of access ramps will decrease. The reason for this would be the response of the ACC-controlled vehicle if a merging vehicle used the gap in front of the ACC-equipped vehicle.

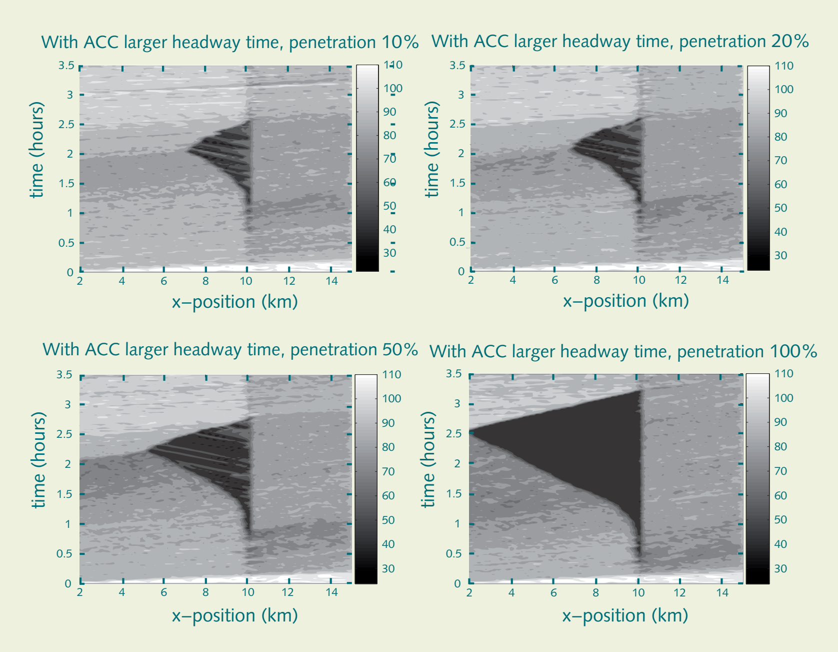


Figure 8.24 Simulation results for the access ramps scenario. These simulations examine the effect of various degrees of penetration on traffic flow throughput. It is assumed that motorists select a longer headway time when driving with ACC compared to when they drive entirely on their own.

Figure 8.24 shows the simulation results for the access ramp (for various degrees of penetration), whereby it is assumed that the average headway time is roughly 20% greater with ACC than without (which corresponds reasonably with empirical data).

On the basis of the model study, it cannot be concluded that the functioning of ACC itself causes the problem. In the simulation, the seriousness of the congestion that occurs is caused primarily by the specified headway times (which are shorter than headway times without ACC).

8.5.4 Shock waves

Figure 8.24 also indicates the shock waves that develop during various degrees of penetration. It is impossible to conclude from the simulations that the shock waves become smoother. It must also be noted that – in contrast to ACC – human drivers have an outstanding ability to anticipate. This does not only occur by looking beyond the vehicle immediately ahead, but also by observing other cues (e.g. signals, vehicles in other lanes, etc.).

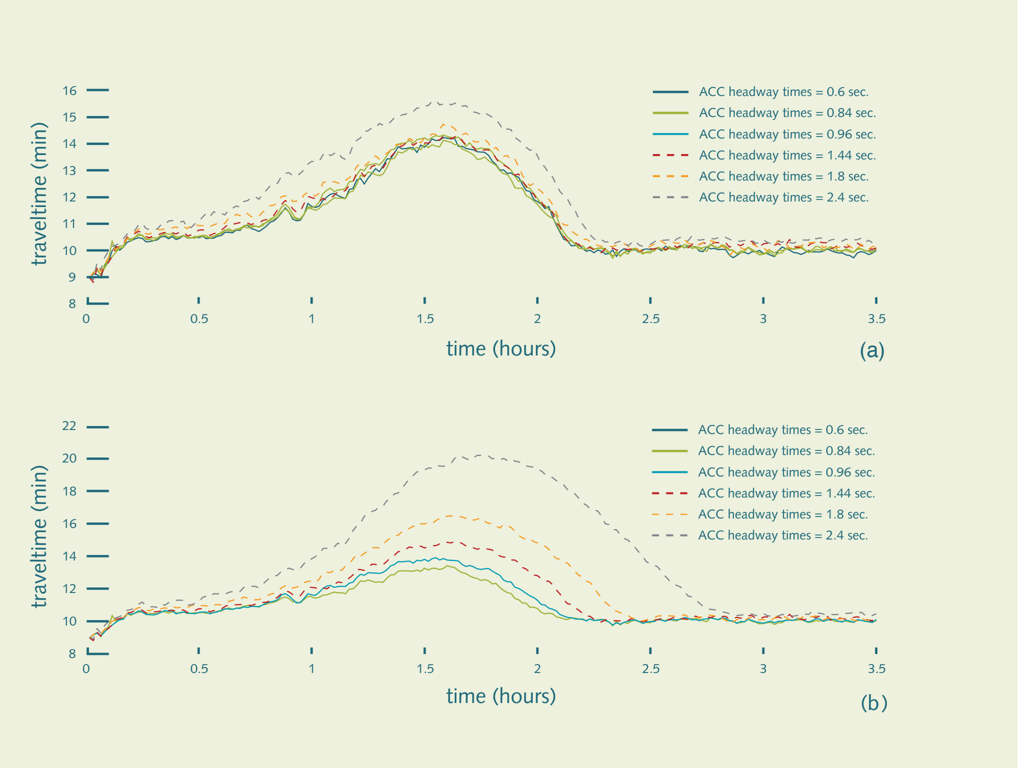


Figure 8.25 Effect on journey time from various hypotheses on headway times with ACC. In figure (a), the system is deactivated automatically for speeds below 30 km/h. In figure (b), ACC is active at all speeds.

8.5.5 Distribution of capacity

Given the reduction in the distribution of minimum headway times, it is natural to assume that the distribution in (free) capacity will decrease. The increase is limited, however, because there will still be a substantial distribution in attained headway times due to differences in used headway time settings. Incidentally, the data analysis has revealed that most drivers use the same headway time setting of 1.0 s. Only one driver selected a longer headway time.

8.5.6 Effect of deactivation on driving speed and journey time

A key aspect when determining the effects of the system are the circumstances under which the system deactivates itself/is deactivated. The system examined here functions at speeds of 30 km/h or higher. This specific feature has a major effect on traffic flow throughput.

Figure 8.25 indicates the journey times of the access ramp scenario for various headway times at a penetration level of 10%, with and without deactivation. The figure reveals that the effects of the system on throughput are exceptionally limited in the event of deactivation at speeds of 30 km/h or lower.

8.5.7 Conclusions and summary of effects of ADA on traffic flow throughput

This section will examine the effects of ADA systems on traffic flow throughput (capacity and journey times in particular). The model study revealed that this effect largely depends on the following facets:

- Headway time settings.
- Degree of penetration (or relative use) of ACC.
- Conditions under which the system switches off or is switched off.

On the basis of empirical results (increase in headway time with ACC active in relation to ACC off/inactive; average headway times in the post-period are identical to average headway times in the pre-period), the use of ACC (particularly in free traffic and heavy traffic) and the functionality of the system (ACC functional from 30 km/h onwards), we can conclude that the direct effect of ACC on traffic flow throughput will be neutral. This is further endorsed by the finding that drivers select their headway time setting in accordance with their standard driving behavior.

We expect that this ACC will have an explicit effect on throughput during extremely high degrees of penetration only. Throughput can be positively influenced indirectly as a result of an increase in road safety and the corresponding decrease in the number of accidents.

Finally, we must point out that these findings are limited to the ACC tested here. In the case of full range ACC, the effect on throughput can be completely different on occasion. In this context, the model study revealed that with full range ACC, the effect of the selected headway time setting is far more significant. With the currently selected settings, this would entail a negative effect for throughput, even at relatively low degrees of penetration. However, it is not self-evident that drivers would choose the same headway times if they were using another ACC system.

8.6 Analysis of road safety

In the preceding sections, we examined to what extent ACC and LDW will influence driving behavior and throughput. We saw to what degree the considered systems influence vehicle tracking behavior and lane changing behavior.

In this section we will endeavour to translate the effects of driving behavior into changes in road safety. We will do so by analysing indirect safety indicators and answering the following sub-questions:

a. To what extent is the risk of an accident involving one vehicle/party influenced?
b. To what extent does ADA influence the risk of a rear-end collision?
c. Will the likelihood of a sideways collision change due to ADA?

Before we do this, we will provide a brief impression of the safety potential of ADA, especially of the systems under consideration here.

The rest of this section will use the aforementioned data to give an estimation of the effect of ACC and LDW on road safety. We will focus in particular on:

- Changes in the number of sudden braking movements.
- Changes in speed.
- Changes in the percentage of short headway times.
- Number of line crossings.
- Increase in the use of direction indicators.

Due to ACC, there may be a change in the frequency of "overtaking on the right".
However, no judgement can be made on the basis of available measurement data.

Using the changes the aforementioned indicators, we will offer a (cautious) judgement in relation to the change in road safety.

8.6.1 Increase in the number of sudden braking movements

Table 8.41 indicates the percentage of time that drivers braked hard during various periods and for different road types . N.B.: this therefore involves the relative duration of hard braking, thus including periods when the vehicle is standing at traffic lights and the brake pedal is pressed. The table includes all traffic regimes together.

We can conclude from the table that the number of cases involving hard braking on provincial roads and motorways has not increased during the post-period in relation to the pre-period: there is even a decrease of about 35%. If we compare ACC off/inactive, we see a much stronger decrease in the number of abrupt braking movements (over 90%!).

[8] This can be explained in part by an increase in the use of direction indicators.

André Vits from the European Commission: "Transport must be safe, clean and smart."

"The three keywords for the future of our transport system are "safe, clean and smart". New developments must play a role in this regard. A project such as 'The Assisted Driver' dovetails perfectly." The person responsible for these comments is André Vits, head of the ICT for Transport unit of the European Commission. He notes that ADA systems already offer a wide range of possibilities from a technical perspective and that it is now especially important to make drivers aware of new technologies.

André Vits was one of the panel members during the demonstration day held on May 24th 2005. He indicates that he is following 'The Assisted Driver' pilot with great interest. "ADA systems offer a way to change the driving behavior of motorists. This can have a positive effect on fuel consumption and road safety. I think that these types of systems, which serve more than one purpose, have a future."
André Vits is aware of the counter-argument that drivers want to remain in charge within their own car and would not be open to ADA systems. He responds: "That is the situation now. I certainly believe that the perception of drivers can change. In the future, ADA systems will be more widely accepted." He states that there are roughly two visions for the future of driving assistance technology: equip cars with intelligent systems or allow them to be controlled by an intelligence control centre. "The truth is somewhere between the two."

Generate support
Another positive aspect of 'The Assisted Driver' pilot, according to André Vits is the fact that the dissemination of information is deeply "ingrained" in the project. "As a result, it is discussed more and the topic will catch the public's attention. That is crucial. The European Commission is doing its bit by financing research. Ultimately, however, it will be the motorist who has to choose these types of systems. In that case, support for such systems will have to be generated first. I have the feeling that this pilot will play an outstanding role in achieving this."

Table 8.41 Percentage of time that drivers brake hard (pre-period) Results only relate to free traffic and heavy traffic.

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	4.1%	2.0%	0.2%	3.4%
ACC active	1.9%	0.2%	-	0.3%
ACC active (inc. accel.)	1.9%	0.2%	-	0.3%
Total	**4.0%**	**1.5%**	**0.2%**	**2.8%**

Table 8.42 Percentage of time that drivers brake hard (post-period) Results only relate to free traffic and heavy traffic.

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	4.2%	2.5%	2.5%	4.7%
ACC active	0.7%	0.2%	0.2%	0.3%
ACC active (inc. accel.)	0.7%	0.2%	0.2%	0.3%
Total	**2.5%**	**1.0%**	**0,9%**	**2.6%**

If we look at the percentage of time that considerable deceleration (acceleration < -3.0 m/s2) is applied, we see a similar picture. Tables 8.43 and 8.44 show the percentage of time that there is considerable deceleration for the pre- and post-measurement. On the basis of the differences between the tables, we can conclude that there is also a reduction of about 35% here.

Table 8.43 Percentage of time that there is considerable deceleration (pre-period) Results only relate to free traffic and heavy traffic.

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	3.4%	2.0%	0.3%	3.1%
ACC active	1.1%	0.1%	-	0.2%
ACC active (inc. accel.)	1.1%	0.1%	-	0.2%
Total	**3.3%**	**1.7%**	**0.3%**	**2.7%**

Table 8.44 Percentage of time that there is considerable deceleration (post-period) Results only relate to free traffic and heavy traffic.

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	3.5%	2.8%	1.6%	4.4%
ACC active	0.7%	0.2%	0.3%	0.3%
ACC active (inc. accel.)	0.8%	0.2%	0.3%	0.3%
Total	**2.3%**	**1.2%**	**0.9%**	**2.5%**

To sum up, we can therefore state that the number of sudden braking movements decreased substantially during the post-period.

8.6.2 Speed and safety

It is sufficiently well known that driving speed has a major effect on road safety. On the basis of our findings, we cannot conclude, however, that there is a significant change in speed.

8.6.3 Percentage of shorter headway times

Section 8.4 already demonstrated that the headway time distribution with ACC off/inactive is different compared to when ACC is active. With regard to road safety, it is particularly interesting to look at the percentage of shorter headway times (h < 0,7 s).

We can conclude from table 8.45 that the percentage of shorter headway times with ACC on is significantly smaller than when ACC is off or inactive: when ACC is active, this percentage is smaller than 0.8%. When ACC is off or inactive, this percentage is substantially higher, approximately 3%. The difference remains significant for motorways in particular: in this case, the percentage of shorter headway times with ACC off/inactive ranges between 4.0% and 7.5%. Including ACC active + acceleration, the percentage of shorter headway times is obviously higher.

We also see differences between the pre- and post-measurement that point to a reduction (between 8% and 9% for motorways and provincial roads).

Table 8.45 Percentage of time that is driven with a short headway time (< 0.7 s) (pre-measurement))

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC inactive	1.3%	5.4%	2.6%	2.3%
ACC active	0.0%	0.5%	-	0.4%
ACC active (incl. accel.)	0.0%	0.8%	-	0.7%
Total	**1.3%**	**4.5%**	**2.6%**	**2.1%**

Table 8.46 Percentage of time that is driven with a short headway time (< 0.7 s) (post-measurement)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC inactive	1.5%	6.1%	2.5%	2.4%
ACC active	0.1%	0.7%	0.2%	0.6%
ACC active (incl. accel.)	0.2%	1.1%	0.5%	1.0%
Total	**1.2%**	**4.1%**	**1.8%**	**2.1%**
Change in % in relation to pre-measurement	-7.7%	-8.9%	-30.8%	0.0%

We can therefore conclude from the above that driving with ACC significantly reduces the percentage of short headway times.

In the comparison between the pre-and post-measurement, this difference is approximately 8% to 9%. It must be noted that the percentage of short headway times on motorways in the pre-period with ACC off (5.4%) is greater than the total (4.5%) because a number of test subjects also used ACC during the pre-period. If we look at the reduction in the post-period in relation to the pre-period for ACC off, we see a decrease (in terms of percentage) in short headway times of 2.4%.

If we compare ACC off/inactive with ACC on (incl. acceleration), we see a far more substantial reduction (nearly 60%). This is the value that will be used from now on to determine the change in the number of accidents.

8.6.4 Percentage of short TTCs

With regard to road safety, it is also interesting to look at the percentage of short Time-To-Collisions (TTC < 1.5 s). We can conclude from table 8.47, as in the case of short headway times, that the percentage of short TTCs with ACC active is smaller than when ACC is off or inactive.

The differences are less pronounced, however. This is partly due to the large relative error for determining the relative speed, which is required to calculate the TTC. This also explains the large percentage of small TTCs (around 20%). In view of this limitation, the headway time is more suitable for determining road safety effects.

Table 8.47 Percentage of time that is driven with a short TTC (< 1.5 s) (pre-measurement)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	19.6%	25.3%	24.3%	20.9%
ACC active	6.2%	20.4%	-	20.4%
ACC active(incl. accel.)	6.2%	20.2%	-	20.3%
Total	**19.0%**	**24.0%**	**24.3%**	**20.0%**

Table 8.48 Percentage of time that is driven with a short TTC (< 1.5 s) (post-measurement)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	20.8%	25.6%	16.7%	21.6%
ACC active	14.5%	23.4%	12.1%	22.8%
ACC active (incl. accel.)	14.3%	23.7%	11.9%	23.0%
Total	**19.7%**	**24.4%**	**15.9%**	**22.0%**

From the above can be concluded that driving with ACC leads to a decrease of the fraction of short TTCs.

8.6.5 SDLP and safety

A reduction in SDLP and the number of unintentional line crossings can increase safety. After all, roughly 6% of accidents on road sections occur because drivers keep to the right too much or too little (depending on the road type).

On the basis of the results referred to earlier relating to the distribution in lateral position and a reduction in the number of unintentional line crossings, we can conclude that SDLP does indeed decrease while the average distance to line markings increases.

If we only consider the decrease in the number of unintentional line crossings, we see an average reduction of roughly 20%

8.6.6 Change in the use of direction indicators

Section 8.4.4 demonstrated that there is a small increase in the (correct) use of direction indicators (about 20%). This has a small positive effect on road safety. After all, the primary circumstance for roughly 0.5% of the total number of accidents (on road sections) is the failure to indicate.

8.6.7 Estimation of impact on road safety

The effectiveness of ACC and LDW has been estimated on the basis of the changes in the various indicators reported here.

8.6.7.1 Estimation of effectiveness

To start off, we see a 90% decrease in the number of sudden braking movements due to ACC (comparison with ACC off/inactive and ACC on (incl. acceleration)). Apart from this, ACC also provides a warning effect: in the event of excessive speed differences/required deceleration, ACC warns the driver so that he or she can assume the driving task. Since this effect cannot be identified on the basis of the perceived indicators, it is disregarded. The effectiveness of ACC in relation to the circumstance "traffic jam that suddenly appears" is therefore 0%.

If we look at the percentage of short headway times, we see a reduction of roughly 60%. Since we have already corrected for the use of ACC, we can also consider this 60% as the effectiveness.

Finally, we noticed a minor increase in the driven speed, but that this rise cannot be unequivocally attributed to the use of ACC. In addition, it could be assumed that there is an increase in overtaking frequency (on the left and/or right). Since this cannot be ascertained on the basis of measurements, the effect on road safety due to this is immediately zero.

On the basis of changes in the use of direction indicators (increase of roughly 20%, depending on the road type) and the number of unintentional line crossings (also 20% approximately), we discover an effectiveness of 20% for LDW.

Table 8.49 summarises the aforementioned effectiveness.

Table 8.49 Correlation table for circumstances and considered ADA systems

	Effectiveness	
Circumstance	**ACC**	**LDW**
Direction indicating		
05 Not indicating		20%
06 Indicating incorrectly		20%
Maintaining distance		
11 Maintaining an inadequate distance	60%	
12 Unexpected/sudden braking	90%	
13 Traffic jam that suddenly appears	0%	
Overtaking		
18 Overtaking on the left	0%	
Position on the road		
25 Not driving on the right enough		20%
26 Driving on the right too much		20%
Speed		
35 Driving too fast	0%	

8.6.7.2 Effectiveness and use

As indicated earlier, ACC is not used continuously. Depending on the road type (and traffic conditions), ACC is switched on 43.1% of the time on the motorway. For provincial roads, ACC is switched on approximately 22.5% of the time; in the city, this is only 4.1%.

Table 8.50 Effectiveness of ACC under the influence of duration of use (circumstances 11, 12, 13, 18 and 35)

	ACC		
Circumstance	**Through-roads**	**Distributor roads outside urban areas**	**Distributor roads inside areas**
Maintaining distance			
11 Maintaining an inadequate distance	26%	14%	2%
12 Unexpected/sudden braking	39%	20%	4%
13 Traffic jam that suddenly appears	0%	0%	0%
Overtaking			
18 Overtaking on the left	0%	0%	0%
Speed			
35 Driving too fast	0%	0%	0%

8.6.7.3 Estimated impact of ACC on number of accidents

To determine the safety effect of ACC, we assume that ACC is only used on through-roads and distributor roads. We assume that ACC has an effect on the number of accidents with the following primary circumstances:

- 11 Maintaining an inadequate distance
- 12 Unexpected/sudden braking
- 13 Traffic jam that suddenly appears
- 18 Overtaking on the left
- 35 Driving too fast

We also assume that ACC has no effect on the number of accidents at intersections. Accident-related figures reveal anyway that accidents involving the aforementioned circumstances occur relatively less at intersections (except at the intersection of distributor roads inside urban areas x distributor roads inside urban areas, also referred to as 3x3).

Table 8.51 indicates the results of the analysis. We see in the table that 12.9% of all accidents on through-roads can be avoided if all vehicles are equipped with ACC and are driven in the same manner as those in the full-traffic trial. For distributor roads outside urban areas and distributor roads inside urban areas, the percentages are lower, particularly because the use of ACC is considerably less there (for the sake of convenience, it has been assumed that "provincial roads = distributor roads outside urban areas" and "urban roads = distributor roads inside urban areas").

Table 8.51 Reduction in the number of accidents as a result of ACC

	ACC		
Circumstance	**Through-roads**	**Distributor roads outside urban areas**	**Distributor roads inside areas**
Maintaining distance			
11 Maintaining an inadequate distance	12.1%	3.3%	0.4%
12 Unexpected/sudden braking	0.8%	0.1%	0.0%
13 Traffic jam that suddenly appears	0.0%	0.0%	0.0%
Overtaking			
18 Overtaking on the left	0.0%	0.0%	0.0%
Speed			
35 Driving too fast	0.0%	0.0%	0.0%
Total ACC	**12.9%**	**3.4%**	**0.5%**

8.6.7.4 Estimated impact of LDW on number of accidents

Since no distinction needs to be made for LDW between various road types (LDW is switched on practically 100% of the time), the overall percentage of accidents caused by the following circumstances were used to estimate the safety effects of LDW:

- 05 Not indicating
- 06 Indicating incorrectly
- 25 Not driving on the right enough
- 26 Driving on the right too much

Table 8.52 indicates the estimated safety effects of LDW. We see an estimated reduction in the number of accidents of 0.9%, 2.7% and 2.3% for motorways, provincial roads and urban roads respectively.

Table 8.52 Estimated safety effect of LDW

	LDW		
Circumstance	**Through-roads**	**Distributor roads outside urban areas**	**Distributor roads inside areas**
Direction indicating			
05 Not indicating (LDW)	0.0%	0.1%	0.2%
06 Indicating incorrectly (LDW)	0.0%	0.0%	0.0%
Position on the road			
25 Not driving on the right enough (LDW)	0.4%	1.4%	1.0%
26 Driving on the right too much (LDW)	0.5%	1.1%	1.1%
Total LDW	**0.9%**	**2.7%**	**2.3%**
Total ACC	12.9%	3.4%	0.5%
Total	**13.8%**	**6.1%**	**2.8%**

For the sake of completeness, table 8.52 also indicates the total effect of ACC and LDW for various road types. For road sections, it appears that 13.8%, 6.1% and 2.8% of accidents could have been avoided on motorways, provincial roads and urban roads respectively. A reduction of 7.6% therefore applies on average.

8.6.8 Long-term effects of ADA on road safety

During the workshop, there was considerable speculation about the long-term effects of ADA on road safety (and traffic flow throughput). Particular reference was made to the loss of driving skill, decrease in attention levels, increased appeal of motorways, etc. In other words, this mainly involves aspects that we cannot measure directly. Accordingly, judgements about these hypotheses would be just as speculative as the hypotheses themselves and have therefore been omitted.

8.6.9 Conclusions of effects of ACC/LDW on road safety

On the basis of the analysis above, we can conclude that the ADA systems examined here primarily have a positive effect on road safety.

This positive effect cannot be attributed to changes in average speed (after all, these barely exist). Other safety indicators, however, indicate an increase in road safety:

- Decrease in the number of sudden braking movements (ACC)
- Decrease in the percentage of short headway times (ACC)
- Decrease in speed distribution (ACC)
- Decrease in SDLP and line crossings (LDW)
- Increase in the use of direction indicators (LDW)

8.7 Effects on fuel consumption and emissions

Finally, the effect of driving with ADA on fuel consumption and emissions were examined. Fuel consumption was measured to this end, while a model was used for emissions that calculates emissions on the basis of available speed profiles.

The central questions answered here are:

a. What effect does driving with ADA have an fuel consumption?
b. What effect does driving with ADA have on emissions?

8.7.1 Effect of ADA on fuel consumption

It is highly unlikely that LDW will influence fuel consumption. With regard to ACC, however, a change in consumption is expected. The reason for this is the relationship between fuel consumption, speed and acceleration.

Relationship between fuel consumption, speed and acceleration
Fuel consumption depends on numerous aspects: gradient, weather, use of air-conditioning, road surface, etc. In most cases, however, fuel consumption can be explained sufficiently on the basis of the driven speed and acceleration.

Rakha and Ding (2002) proposed the following model:

$$MOE(t) = \exp\left\{\sum_{i=0}^{3}\sum_{j=0}^{3}\right\} c_{ij}\, v(t)^{i}\, (a)^{j} \qquad (4)$$

In Eq. (4), v(t) is the speed at time t, and a(t) the acceleration at that time. In this case, MOE(t) is the fuel consumption (in ml/s), but a comparable relationship can also be used to describe emissions.

Eq. (4) clearly reveals that the relationship between fuel consumption, speed and acceleration is not linear. Consequently, fluctuations in speed and acceleration will influence consumption. Since ACC influences these fluctuations, this type of ADA will also have an effect on fuel consumption and emissions.

The model above has been fitted into this study by means of data available off-line about fuel consumption. The model was then applied to available speed and acceleration profiles, which is how fuel consumption was estimated.

8.7.2 Fuel consumption

Tables 8.53, 8.54, and 8.55 show fuel consumption per 100 km for the pre-period, post-period and all days respectively that ACC was not active, for all traffic regimes combined (free, busy and congested). From the comparison between the situation before and after, we can see a limited decrease in fuel consumption ranging between 2% and 3%, depending on the regime.

If we look at the differences between ACC off/inactive and ACC active, average fuel consumption is significantly lower if ACC is active: depending on the road type, there is a decrease in fuel consumption ranging between 15% to 32%.

Finally, it is interesting to look at the difference between the post-period (table 8.54) and the average of all days that ACC was not active (table 8.55). On the basis of the comparison between both situations, we can conclude that overall there is a decrease in fuel consumption (7% on average) if we compare the post-period with the "no ACC usage" period.

Table 8.53 Fuel consumption in litres per 100 km (pre-period)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	6.1	5.8	5.8	6.0
ACC active	5.3	5.0	-	5.0
ACC active (incl. accel)	5.3	5.1	-	5.2
Total	**6.0**	**5.6**	**5.8**	**5.8**

Table 8.54 Fuel consumption in litres per 100 km (post-period)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	6.5	6.0	6.3	6.4
ACC active	4.3	4.9	4.5	4.8
ACC active (incl. accel)	4.4	5.1	4.7	5.0
Total	**5.8**	**5.5**	**5.6**	**5.8**
Difference in % between ACC active vs. off/inactive	-32.3%	-15.0%	-25.4%	-21.9%
Difference in % between pre-measurement and post-measurement	-3.3%	-1.8%	-3.4%	0.0%

Table 8.55 Fuel consumption in litres per 100 km (average over all days during which ACC was not active)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	6.7	5.6	5.4	6.2
ACC active	-	-	-	-
ACC active (incl. accel)	-	-	-	-
Total	**6.7**	**5.6**	**5.4**	**6.2**
Difference in % with post-period	19.4%	3.6%	-3.7%	11.3%

It can be concluded from the previous that fuel consumption decreases if ACC is active. The average over all traffic conditions was examined, and the fact that in the category ACC off/inactive the contribution of congested traffic is significantly greater than when ACC is active was not taken into account.

If we look at free traffic and heavy traffic only (traffic conditions in which ACC is used), we notice a similar picture (see tables 8.56, 8.57 and 8.58), although the results are slightly less pronounced.

Table 8.56 Fuel consumption in litres per 100 km (pre-period, free traffic and heavy traffic)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	6.2	5.8	5.7	5.6
ACC active	5.5	4.9	-	4.9
ACC active (incl. accel)	5.5	5.1	-	5.0
Total	**6.1**	**5.5**	**5.7**	**5.5**

Table 8.57 Fuel consumption in litres per 100 km (post-period, free traffic and heavy traffic)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	6.1	5.8	6.1	5.9
ACC active	4.4	4.9	4.7	4.8
ACC active (incl. accel)	4.6	5.1	4.9	5.0
Total	**5.4**	**5.4**	**5.6**	**5.5**
Difference in % between ACC active vs. off/inactive	-24.6%	-12.1%	-19.7%	-15.3%
Difference in % in relation to pre-measurement	-11.5%	-1.8%	-1.8%	0.0%

Table 8.58 Fuel consumption in litres per 100 km (average over all days during which ACC was not active, for free traffic and heavy traffic)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	6.0	5.7	6.3	5.6
ACC active	-	-	-	-
ACC active (incl. accel)	-	-	-	-
Total	**6.0**	**5.7**	**6.3**	**5.6**
Difference in % with post-period	10.0%	5.3%	11.1%	1.8%

8.7.3 Emission predictions

Finally, environmental effects (especially emissions) were also examined. The predicted change in the emission of CO, HC and NOx was analysed. This prediction was made by applying a model (4), on the basis of the speed and acceleration profile of various drivers. The model parameters that were used originated from Ahn (1998).

The pre-period, post-period and baseline period have been determined once again in the tables below. The emissions are expressed in mg/s.

CO emissions
Tables 8.59, 8.60, and 8.61 show CO emissions in mg/s for the pre-period, post-period and all days respectively that ACC was not active, for free traffic and heavy traffic.

If we compare the predictions for CO emissions in the pre- and post-period, we see an average increase in predicted emissions (6% on average). The increase is apparent for all network types.

However, if we compare ACC off/inactive emissions and ACC active emissions in the post-period, we see – as with fuel consumption – an increase in CO emissions ranging between 9% and 18% (depending on the road type).

Table 8.59 Estimated CO emissions in mg/s (pre-period); average over free and heavy traffic

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	3299.5	3765.8	3988.3	3399.6
ACC active	3203.8	3886.9	-	3707.0
ACC active (incl. accel)	3204.1	3944.4	-	3764.6
Total	**3297.9**	**3782.7**	**3988.3**	**3425.4**

Table 8.60 Estimated CO emissions in mg/s (average over all days during which ACC was not active; average over free and heavy traffic)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	3713.4	4173.0	5243.8	3588.9
ACC active	2918.1	3646.3	4017.1	3526,8
ACC active (incl. accel)	3029.3	3797.9	4354.9	3676.1
Total	**3459.1**	**3971.2**	**4719.9**	3625.2
Difference in % in relation to pre-measurement	4.9%	5.0%	18.3%	5.8%
Difference in % between ACC active vs. off/inactive	-18.4%	-9.0%	-17.0%	2.4%

Table 8.61 Estimated CO emissions in mg/s (average over all days during which ACC was not active; average over free and heavy traffic)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	3561.0	4200.7	4376.3	3616.8
ACC active	-	-	-	-
ACC active (incl. accel)	-	-	-	-
Total	**3561.0**	**4200.7**	**4376.3**	**3616.8**
Difference in % with post-period	-2.9%	-5.5%	7.9%	0.2%

HC emissions
For HC emissions, the same conclusions can be drawn as for CO. The results are therefore not explicitly discussed

Table 8.62 Estimated HC emissions in mg/s (pre-period)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	92.4	105.4	111.7	95.2
ACC active	89.7	108.8	-	103.8
ACC active (incl. acceleration	89.7	110.4	-	105.4
Total	**92.3**	**105.9**	**111.7**	**95.9**

Table 8.63 Estimated HC emissions in mg/s (post-period)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	104.0	116.8	146.8	100.5
ACC active	81.7	102.1	112.5	98.7
ACC active (incl. accel)	84.8	106.3	121.9	102.9
Total	**96.9**	**111.2**	**132.2**	**101.5**
Difference in % in relation to pre-measurement	4.9%	5.0%	18.3%	5.8%
Difference in % between ACC active vs. off/inactiv	-18.4%	-9.0%	-17.0%	2.4%

Table 8.64 Estimated HC emissions in mg/s (average over all days during which ACC was not active)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	99.7	117.6	122.5	101.3
ACC active	-	-	-	-
ACC active (incl. accel)	-	-	-	-
Total	**99.7**	**117.6**	**122.5**	**101.3**
Difference in % with post-period	-2.9%	-5.5%	7.9%	0.2%

NOx emissions
For NOx emissions, the same conclusions can be drawn as for CO. The results are therefore not explicitly discussed.

Table 8.65 Estimated NOx emissions in mg/s (pre-period)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	52.8	60.3	63.8	54.4
ACC active	51.3	62.2	-	59.3
ACC active (incl. accel)	51.3	63.1	-	60.2
Total	**52.8**	**60.5**	**63.8**	**54.8**

Table 8.66 Estimated NOx emissions in mg/s (post-period)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	59.4	66.8	83.9	57.4
ACC active	46.7	58.3	64.3	56.4
ACC active (incl. accel)	48.5	60.8	69.7	58.8
Total	**55.3**	**63.5**	**75.5**	**58.0**
Difference in % in relation to pre-measurement	4.9%	5.0%	18.3%	5.8%
Difference in % between ACC active vs. off/inactive	-18.4%	-9.0%	-17.0%	2.4%

Table 8.67 Estimated NOx emissions in mg/s (average over all days during which ACC was not active)

	Prov.	Motorway	Motorway (80 km/h)	Total
ACC off/inactive	57.0	67.2	70.0	57.9
ACC active	-	-	-	-
ACC active (incl. accel)	-	-	-	-
Total	**57.0**	**67.2**	**70.0**	**57.9**
Difference in % with post-period	2.9%	5.5%	-7.9%	-0.2%

8.7.4 Key findings

With reference to fuel consumption, we can conclude that ACC results in a (small) reduction. This is a direct consequence of the fact that distribution in acceleration (and the percentage of substantial acceleration) decreases as soon as ACC is active. For motorways, the difference between ACC off/inactive and ACC active is about 15%. If we compare the situation from the post-period with a situation in which no ACC was used, we discover a reduction of approximately 4%. For provincial roads, these reductions in fuel consumption are more pronounced (32% for the difference between ACC active in relation to ACC off/inactive and 19% for the difference between post-measurement and all days during which ACC was not active).

If we consider the average use of ACC, we see a difference in fuel consumption of roughly 3%.

A similar conclusion can be drawn with regard to emissions. Emissions with ACC active are on average smaller than when ACC was not active or off. For motorways, the reduction in emissions ranges up until 10%. For provincial roads, the reduction is slightly more substantial.

SWOV response: “Eight percent is certainly very high.”

The Dutch National Road Safety Research Institute (SWOV) is an independent research institute. The institute responded to the results of ‘The Assisted Driver’ pilot with guarded optimism. Peter Morsink: “Expectations about the reduction in accidents is certainly very high. If these expectations prove to be correct, this will have a major effect on road safety.”

Peter Morsink’s work includes studying vehicle technology and intelligent transport systems. “That is why I examined this project with profound interest. It is good that the pilot involved people driving in traffic and not only a test environment.”
He continue: “If we consider the results of the study to be scientifically sound and the system helps increase traffic safety levels, we will definitely emphasise the usefulness of such systems. As it happens, we believe that ‘intelligent’ vehicles can have a major effect on road safety in the future. However, such vehicles must take the possibilities and limitations of humans into consideration and be geared to other measures such as education and road design.”

Uniform speed

Peter Morsink believes that a reduction of 8% is extremely high, especially if it applies to the entire road network. “An earlier project involving LDW revealed that it could have a minor positive effect or even a neutral effect. That could imply that much of the success is thanks to ACC. Advanced Cruise Control ensures uniform speeds on the motorway. It is plausible for uniform driving speeds to have a positive effect on road safety. Unfortunately we have not had an opportunity yet to look at the study in detail and have to remain non-committal. I hope that this pilot has a good follow-up that also advises drivers how to use ACC safely.”

8.8 Summary and conclusions

This final section will sum up the most important findings of the study. It will also briefly discuss directions for follow-up research.

8.8.1 Use of ADA

The LDW system was used more or less throughout the trial. ACC is used primarily on motorways (40% of the time) and to a lesser degree on provincial roads (22% of the time). The use thereof is limited to free traffic (50% of the time) and heavy traffic (35% of the time). The frequency with which ACC was used during the trial increased (decrease in average time between deactivation and reactivation).

Drivers need a while to find headway time settings that suit them. The period of familiarisation is rarely longer than a month. There is usually a relationship between the selected headway time setting and standard driving behavior, although the majority of drivers choose the minimum headway time of 1.0 s. Cruise control speed is selected in accordance with the applicable maximum speed. A relationship appears to exist between the specified headway times and the specified cruise control speed: drivers who select a shorter headway time generally choose a higher cruise control speed.

8.8.2 Effect of ADA on driving behavior

By and large, motorists do not appear to observe the applicable maximum speed limit more effectively with ACC. However, the differences between the average free speed (with ACC) and the applicable maximum speed do appear limited, namely 5 km/h on average.

The distribution in acceleration with ACC active is smaller than with ACC off/inactive. This can have a positive effect on comfort, fuel consumption and emissions.

Average headway times with ACC active are somewhat longer than with ACC off/inactive (increase of roughly 0.2 s). The variation in headway times is smaller with ACC active than with ACC off/inactive. The percentage of short headway times decreases substantially, which has a positive effect on road safety.

The number of unintentional line crossings decreases thanks to LDW (for provincial roads by 35% and for motorways by 30%). Drivers reduce the SDLP of their vehicles to avoid warnings. This has direct consequences for the driving task load of drivers (they have to concentrate better).

Direction indicators are used more often and more effectively. The changes between the pre- and post-measurement are minimal, however. We cannot conclude that there are fewer lane changes due to ACC/LDW. We do see, however, that drivers continue driving in the left lane and particularly in the middle lane for longer.

8.8.3 Effect of ADA on traffic flow throughput, safety and environment

The anticipated effects of the ADA systems examined are summarised in the tables below.

Table 8.68 Anticipated effects on traffic flow throughput

Throughput aspect	Effect (pos., neutral, neg.)	Cause
Headway time distribution	-	ACC
Lane distribution	-/0	ACC
Lane changes	+	ACC
Speed distribution	+	ACC
Smoother shock waves	0	ACC
Total	**Neutral (0%)**	

Table 8.69 Anticipated effects on traffic safety

Safety aspect	Effect (pos., neutral, neg.)	Cause
Sudden braking movements/ percentage of hard braking	+	ACC
Speeds	0	ACC
Use of direction indicators	+	LDW
Percentage of shorter headway times	+	ACC
Compliance with maximum speed	0	ACC
Lane changes	+	ACC
Speed distribution	+	ACC
Total	**Positive (8% reduction in accidents on road sections)**	**ACC/LDW**

Table 8.70 Anticipated effects on emissions and fuel consumption

Environmental aspect	Effect (pos., neutral, neg.)	Cause
Decrease in abs. acceleration	+	ACC
Increase in speed	0	ACC
Increase in congestion	0	ACC
Total	**Slightly positive (3% reduction in fuel consumption; decrease in emissions if ACC is active)**	**ACC**

8.8.4 Synergetic effects of LDW/ACC

One of the unique features of the underlying study is the fact that the vehicles were equipped with both an ACC and LDW system. However, the most important effects that were discovered can usually be attributed to one of both systems.

The synergetic effects between the systems appear to relate more to the attention levels of drivers: where ACC assumes part of the driving task and possibly weakens attention levels, or shifts the driver's focus to other tasks, LDW does the exact opposite to a certain degree.

8.8.5 Recommendations and follow-up research

The ACC system tested here has a positive effect on road safety and the environment, and a neutral effect on traffic flow throughput. Drivers perceive ACC to be comfortable and pleasant. Although drivers have a less positive attitude towards the LDW system, the effects thereof (particularly on road safety) are positive. The use of LDW and ACC can therefore be recommended from a road safety perspective in particular.

The results described here relate to a fairly specific (partial range) ACC system and a specific LDW system. It is important to determine to what extent these systems may be considered representative for other ADA systems. This also applies to the driver population (lease drivers with a wealth of experience).

Particularly in relation to the VW ACC, this appears to be crucial, especially since the model study revealed how significant the differences in the impact of a partial range system can be in comparison with a full-range system. In the case of the former, throughput effects are relatively impervious to specified headway times (at least in the case of penetration degrees of 50% or less), but this certainly does not apply to full-range ACC systems.

In order to estimate the effect of the latter systems, it is essential to acquire an insight into the choice of headway time settings. This choice will depend largely on the driver's experience with ACC (in terms of reliability, predictability, differences in the system's behavior and personal behavior, etc.). Further research is required to obtain a deeper insight into this.

ADA SYSTEMS IN THE FUTURE

Existing ADA systems are autonomous and reactive, meaning they are not dependent on other systems outside the vehicle. The system can only intervene when it detects a particular situation. By way of example: ACC only brakes the moment it detects that the vehicle ahead is also breaking. By definition, a driving assistance system can do this quicker than a person. The shorter response time helps save time.

Vehicle-to-vehicle communication and vehicle-to-infrastructure communication provides even further possibilities. This entails a shift from reactive to proactive. An example to illustrate this: an ACC system that communicates with one or more vehicles ahead and that can already start braking the moment the vehicle directly ahead of it intends to brake or when it detects that a vehicle in front of the vehicle ahead is braking. This technology can also provide assistance in other situations, such as when a vehicle has stopped in a sharp bend on the road. Vehicle-to-vehicle communication or vehicle-to-infrastructure communication can help prevent accidents. The former can enable the stranded vehicle to emit signals that are picked up by vehicles approaching from behind. The latter can see that a vehicle is stranded in a dangerous place using a detection system (camera, IR, radar, etc.), and transmit this information to all vehicles in the vicinity.

Since vehicle-to-vehicle communication and vehicle-to-infrastructure communication do not have to be limited to one-way (data) traffic, information from vehicles can also be used for dynamic traffic management (DTM). In theory, this will allow existing DTM measures to be implemented more effectively. The information that is obtained may also be ideal for developing new measures. After all, a relatively new vehicle has a wealth of information at its disposal nowadays such as: speed, friction, temperature, windscreen wiper status and signalling during hard braking. Friction-related data can be used to provide slippery road warnings or compile information about the resistance of road surfaces, for example, so that a special vehicle does not have to measure this every year. The status of the windscreen wiper can provide information about local showers and a signal emitted in the event of hard braking can be used for detecting incidents or hazardous situations.

The following three European projects, which started in 2006 and will end in 2010, are focusing on the developments outlined above:

- CVIS (Cooperative Vehicle-Infrastructure Systems): www.cvisproject.org
- SAFESPOT (cooperative vehicles and road infrastructure for road safety) www.safespot-eu.org
- COOPERS (cooperative systems for intelligent road safety): www.coopers-ip.eu

The Dutch Directorate for Public Works and Water Management is a participant in CVIS as well as SAFESPOT.


LS460

9 'The Assisted Driver' clinic

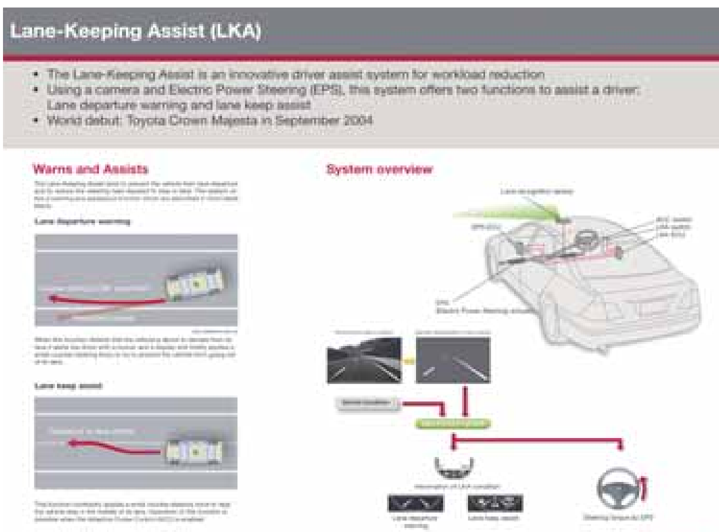
This chapter revolves around 'The Assisted Driver' clinic held over the course of three days. We will explain the aim of the field test and show how the study was set up. The chapter will conclude with the results and conclusions.

9.1 Introduction

Over three consecutive days, several people test drove a Lexus equipped with ACC (Adaptive Cruise Control), LDW (Lane Departure Warning) and LKA (Lane Keeping Assist) systems. ACC and LKA are two systems that actively intervene. It was first time that a combination of these systems could be tested. Participants in the full-traffic trial, who drive a Volkswagen Passat equipped with ACC and LDW, were also involved in the clinic. The aim of the clinic is to acquire an insight into the individual driver's experience with ADA systems with regard to driving comfort and safety. The key question is whether the combination of two active systems is not too much for the driver. Experiences with LDW (Passat) are also compared with LKA and LDW (Lexus).

Three systems

The Lexus used during the clinic is equipped with three ADA systems.
ACC automatically ensures that the car maintains a safe distance from the vehicle ahead by braking when required and accelerating when possible.
LDW warns the driver when the vehicle threatens to leave the lane it is travelling in unintentionally. The system in the Lexus emits an audio warning and corrects the steering briefly as soon as the car drifts too close to the lines. The system in the Passat only emits an audio warning and therefore only provides passive assistance. LKA provides active assistance. The system corrects the steering automatically when the car drifts away from the middle of the lane. Unlike LDW, LKA does not intervene once the car threatens to cross the lines of the lane, but immediately when it leaves the middle of the lane.



Differences between the Lexus and Passat
As mentioned above, the Volkswagen Passat is only equipped with ACC and LDW. These systems can be activated and deactivated independently of one another. The Lexus is fitted with all three systems. These cannot be activated and deactivated completely independently of one another. The following four options are available: only activate ACC or only LDW, activate ACC and LKA, or activate neither of the systems.

9.2 Set-up of the clinic

The clinic was held on May 30th, May 31th and June 1st 2006 on the premises of the distributor for Lexus and Toyota in the Netherlands, Louwman & Parqui in Raamsdonkveer. On each day, participants in the clinic took trips lasting approximately one hour. The seven participants involved in the study are driving a Volkswagen Passat and have experience with ACC and LDW. They drive between 25,000 and 60,000 km annually. They volunteered for the clinic. This reveals that the participants are generally positive about ADA systems.

Before the car trip began, an employee from Toyota Motor Europe (the manufacturer of Lexus) explained how the systems function. During the first part of the trip, the test subject watched from the passenger's seat while this employee explained how the systems functioned in greater detail. During the clinic the participants were seated behind the steering wheel.
After every trip, the participants were interviewed by the consultancies PRC and DHV.

9.3 Results

9.3.1 Overall impression

All participants indicated that the test drive was a pleasant and positive experience.
The majority found that they became accustomed to the systems quickly and thought the systems were configured nicely. All of them expect that these types of systems will have a future. The main reasons for this, in their opinion, are comfort and safety. According to them, ACC, LDW as well as LKA contribute to road safety (with LKA contributing the most and LDW the least). All participants found that ACC contributes significantly to comfort. LKA also contributes, but LDW only does so minimally. All participants preferred LKA to LDW.
The active steering corrections made by LKA appeared to appeal to the majority.

Incidentally, it must be emphasised here that this is the opinion of a small group.
The small-scale clinic is not intended as a representative study.

9.3.2 Lane Departure Warning (LDW)

LDW meets the expectations of practically all of the participants. The reason for this may be that at the time of the study they were driving a Passat also equipped with LDW.
The participants mentioned the following positive points about LDW: it increases the use of indicators (3x), you become accustomed to it (1x), the system warns you if you unintentionally leave the lane (2x), and the alarm and corrective steering function well (1x). They also pointed out various negative points about the system: the alarm can be irritating at times (3x), the LDW system in Passat responded too quickly (2x), lines were not always recognised properly, in the Passat lines on bicycle paths were also recognised in situations where the driver had to cross the lines (2x) and the audio warning in the Passat is insufficient (1x).

9.3.3 Lane Keeping Assistant

Five of the seven participants indicated that LKA performed better than expected. The other two said that the system met their expectations. The participants mentioned the following positive points about LKA: the steering correction occurs smoothly with the correct amount of power and is not disruptive (1x), the system keeps the vehicle within the lines via steering corrections (3x) and it enhances safety and comfort levels (2x). Negative points were as follows: it takes some time to get used to the system (2x), you do not feel that you are driving in the middle of the lane (2x), the system creates a sensation of crosswinds (2x), the car tends to drift slightly when you counter-steer too late (1x), the car tends to drift slightly due to prolonged correction if you release your hands (1x), and there is a risk that you will drive with less concentration (1x).

9.3.4 Comparison of systems in the Lexus with systems in the Passat

Overall, the ADA systems in the Lexus are considered more pleasant than those in the Volkswagen Passat.

Lexus

A positive aspect of the LKA system in the Lexus, according to the participants, is that it really does provide assistance and comfort. LDW does not offer a similar level of comfort. The participants also said that feedback from LDW to the steering is clearer than an audio warning only. They also commented that the ACC system in the Lexus responds gradually and enjoy the fact that they can see on the dashboard when the car brakes and the brake lights illuminate.

Passat

A positive point of the ACC system in the Passat, according to the drivers, is the availability of seven following distance settings. Here too, the system responds gradually. They also appreciated the clear display upon which the car ahead appears. This allows for proper anticipation when you wish to overtake, for example. According to the participants, the LDW system in the Passat boosts safety and emits a clear audio warning.

Points for improvement

When asked to mention points for improvement, the participants pointed out that LKA could be a bit more present by constantly keeping the car in the lane sooner and with more power. The system could also make steering corrections more smoothly. The detection of lines on the road could also be improved. One user would also like to see option that enables the following-distance control in the ACC system to be deactivated so that it can turn into a standard cruise-control system. ACC may also be more dynamic when the driver accelerates or decelerates while overtaking or merging.

9.3.5 Other activities while driving

Six of the seven participants in the clinic indicated a tendency to perform other activities in a car equipped with these systems. Examples of other activities include using a mobile phone more often, talking to passengers more, consulting one's diary, spending longer searching for CDs and looking at the navigation system. Various participants pointed out that they drive more respectably. Thanks to ACC, for example, they pay more attention to keep at an adequate distance from the vehicle ahead of them.

9.4 Conclusions

Active assistance more popular than warnings

Overall, the participants responded positively to the tested systems. They all indicated that the three systems help increase safety and comfort levels. With regard to the level of safety that was experienced, LKA and ACC are rated better than LDW and with regard to comfort, ACC and LKA are significantly better than LDW. This is primarily because ACC and LKA are systems that provide active assistance instead of only a warning. For drivers, LKA is more pleasing than LDW. Active corrective steering is considered an enjoyable aid. The participants in the clinic were therefore slightly more positive about the systems in the Lexus than those in the Passat.

Improvements

According to the drivers, all systems can be improved. These points for improvement are summarised below.

With regard to ACC, the participants recommend that the car be allowed to accelerate earlier when overtaking and that more settings be provided for the following distance and response speed when approaching a vehicle ahead. LDW should recognise road lines more effectively and it should be possible to drive closer to lines on the road (Passat). LKA must also recognise road lines better. It should also be possible to drive slightly to the left of the centre when driving in the left lane. Drifting (caused by steering corrections that are made too late or that are too prolonged) must be avoided. In general, the participants indicate that they wish to notice as little as possible when the systems intervene. This must proceed smoothly and feel natural.

Willingness to pay

The participants in the clinic believe that ADA systems have a future. The reasons they put forward relate to comfort and safety in particular. With regard to ACC and LKA, they are willing to pay (on average) between € 500,- and € 1.000,- per system.

Negative effects?

The results of the clinic reveal a clear contrast. One of the expected advantages of the systems is that drivers will focus more effectively on traffic. The answers provided by the participants indicated that six out of seven drivers use the available capacity for other activities (e.g. making phone calls). This would not be conducive to road safety. Nevertheless, the participants expect the systems to make a positive contribution towards safety. Further research can provide more clarity about this.

Jan van Honk: "The government can also promote awareness."

Jan van Honk from Toyota Motor Europe does not drive around using Advanced Cruise Control yet. "Because the system is not yet available in the model I drive", is the logical explanation provided by the engineer. "But I must admit that it will also depend on the price." Jan Van Honk believes that the government can play a role in this regard

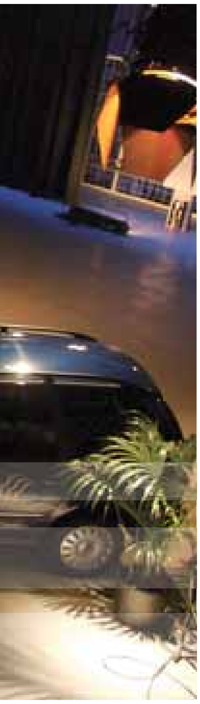
"The Netherlands has relatively high taxes", states Jan van Honk. "The Dutch government therefore has the opportunity to pull strings that could help ensure the penetration of these road safety systems into the market." Exactly how consumer demand for such devices will develop is difficult to say for the time being since they have not been on the market long enough. Jan van Honk: "It is tricky determining a demand for technology that has not been developed yet. What we do see, however, is a need for safety and comfort, the best selling of which is the latter. We are trying to link both factors."

Explaining systems properly

Toyota introduces customers to ADA systems in three ways. "Firstly, during the launch of new models of course. We have also noticed that specialist journals devote considerable attention to the technology. It is also important that sellers in the showroom can explain the systems properly. And it goes without saying that participating in projects such as 'The Assisted Driver' helps promote awareness. Thanks to the results of 'The Assisted Driver' pilot, our claim that ACC and LDW improve road safety has been corroborated by scientific research from the government."

10. Conclusions

This chapter lists the conclusions of 'The Assisted Driver' pilot. We offer a distinction between awareness, behavior and acceptance, and traffic effects.



Over the course of two years, the Dutch Directorate-General for Public Works and Water Management (Rijkswaterstaat) has been busy preparing and implementing this pilot. It has proven to be a success in various respects. Not only because the specified objectives were achieved, but also because the cooperation between the government and the business community was outstanding. For this reason, we would like to thank all partners who ensured this pilot was a success (see chapter 3).

10.1 Awareness

One of the two primary objectives of 'The Assisted Driver' pilot was to increase people's awareness of ADA systems. Many interested parties, such as policymakers and consumers, after all, are not sufficiently aware of what these systems actually are and what they can signify. In order to witness the potential positive effects of driving with these systems in practice, consumers must be able to purchase them at least. This will not or hardly occur if they unaware of the existence of such technology. Policymakers can help expedite this process by providing information and encouragement.

The demonstration day in particular made interested parties more aware of the existence of and opportunities provided by ADA systems, not only by seeing them but also by experiencing them. The international press praised this initiative and the European Commission was also enthusiastic. See:

- The Dutch "Road to the Future" shows the way to go:
  http://www.prevent-ip.org/en/news_events/news/the_dutch_road_to_the_future_shows_the_way_to_go.htm
- Dutch roads to the future demo day:
  http://www.ertico.com/en/news_and_events/ertico_newsroom/dutch_roads_to_the_future_demo_day.htm
- Impressive IV showcase at Dutch "Roads to the Future" event:
  http://www.ivsource.net/modules.php?name=IV_Archives&file=print&sid=148

The demonstration trips in a Volkswagen Passat equipped with ACC and LDW allowed those interested in the technology to experience ADA systems. After the first few trips, the decision was taken to remove vehicle number 20 permanently from the trial and use it for these demonstrations for the rest of the year. Journalists, colleagues, students, policymakers, consultants, the "Directorate-General of Public Works and Water Management" from China, the minister, the deputy mayor of Beijing and many others made use of this opportunity.

Effects
In order to create policies, it is essential that the government is well aware of the (anticipated) effects of such policies. With regard to ADA systems, relatively little is known, both nationally and internationally, about the effects thereof in practice. However, a wealth of literature is available that reveals the potential effects. This is usually based on theory: the opinions of experts and model studies (simulation as well as simulator). What is often lacking are "hard" results originating from demonstrations, pilot projects, field tests and (large-scale) use in practice. In the article "Quantified Effects of Advanced Driver Assistance Systems, the need for Field Operational Tests" by Alkim, Eijkelenberg, Malone and Bootsma (presented during the Transportation Research Board annual meeting in 2006), the need for field tests and demonstrations was substantiated and endorsed. (See http://www.trb.org/AM/IP/paper_detail.asp?paperid=10413).

'The Assisted Driver' pilot not only examined the effects of traffic flow on the basis of data obtained from data-loggers, but also focussed specifically on behavior and acceptance. How do participants experience driving with ADA systems, how do they think their driving behavior changes and do they have a need for such systems?

10.2 Behavior and acceptance

There different components, namely the VANpool pilot, the full-traffic trial and the clinic revealed that participants appreciate active assistance (intervention) more than warnings. This was unexpected given that people usually indicate beforehand that they would prefer to have an informative system in the car instead of a system that assumes part of the driving task. This, incidentally, is a "stated preference" that is not based on experience but on expectation.

Two warning systems were used in the VANpool pilot, namely LDW and HMW. Participants indicated a preference for LDW. This system issues warnings less often than HMW on average, including situations in which driving behavior has been adapted (more steady and maintaining a better distance). In the full-traffic trial, a warning (LDW) and intervention (ACC) system were used. Practically all participants prefer ACC and indicate that it is more pleasant and comfortable than LDW. The lack of warnings and active systems are the main reasons for this preference. During the clinic, a number of participants from the full-traffic trial, i.e. people who had experience with ACC and LDW, test drove a vehicle equipped with ACC and LKA: two active assistance systems. All participants agreed that LKA, in relation to LDW (same functionality, other approach: warning versus active assistance) was an improvement. Here too, a preference was indicated for intervention instead of warning. Driving with two active assistance systems was not considered "excessive".

The combination of ACC and LDW also appears to be complementary to a certain extent. Participants indicated that ACC facilitates driving and reduces the mental load. LDW does the opposite: the warnings issued by the system also increase the alertness of the driver. One of the consequences of a lower mental load is that people could start performing secondary tasks. In other words, they could observe other traffic but could also start using their phone, eating, smoking, navigating, making themselves up, etc. A number of participants did indeed indicate that they were more inclined to carry out secondary tasks. Since this was not measured in the trial, to what extent will this occur and what will the effects thereof be?

10.3 Traffic effects

A thorough analysis of the wealth of data compiled with the help of data-loggers during the full-traffic trial provided an insight into the effects of driving with ACC and LDW on traffic flow. The effects on road safety, throughput and the environment were examined.

Road safety increases due to the following effects in particular:
- less tailgating;
- fewer undesired line crossings;
- more uniform speed;
- more uniform acceleration;
- better use of direction indicators.

The pilot reveals that accidents on motorways and secondary roads would decrease by approximately 8% if everyone in the Netherlands were to use ACC and LDW.

All of this does not appear to go hand in hand with a reduced traffic flow. In a direct sense, there is little effect on traffic flow because the differences in average following distance are not that large and occur primarily in free traffic. The indirect effects on traffic flow are the most significant: fewer accidents lead to fewer traffic jams. Fuel consumption during the trial dropped by 3% on average and corresponding emissions could decrease by a maximum of 10% according to model calculations.

10.4 Finally

The compiled data attracted considerable interest at home and abroad. Various organisations and people enquired whether it would be possible to use this for their own research, such as TRANSUMO, SWOV and universities, and European projects such as CVIS, SAFESPOT and eIMPACT. Now that the project has finished, the Dutch Directorate-General for Public Works and Water Management will make this data available for relevant research, in principle.
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Whether or not the results of 'The Assisted Driver' pilot will be sufficiently convincing for policymakers remains to be seen. At any rate, a step forwards has been taken in revealing the potential of ADA systems for road safety as well as throughput and the environment. In the Netherlands, the pilot has undoubtedly helped make people far more aware of the possibilities and impossibilities of ADA systems.

11. Continuation

'The Assisted Driver' pilot has provided a deeper insight into the effects of driving with ADA systems. These results offer greater insights and information than was previously available in other literature, and are therefore more concrete. To acquire even more definitive results, additional tests are required involving more participants over a longer period of time. The results of such large-scale field tests can also be improved. The full potential of ADA systems will eventually be revealed through large-scale application in practice and long-term evaluation (analysing accidents, measuring throughput, monitoring driving behavior, etc.). However, stimulation is required to that end, through policy or otherwise, in view of the fact that the current pace of market penetration is low.

Other potential effects

The following other potential effects have been outlined on the basis of the positive results of 'The Assisted Driver' pilot:
- Further research
- Increasing awareness
- Personally purchasing the systems
- Fiscal encouragement
- Making such systems mandatory

The last two options are unrealistic at this point in time due to current legislation (abolition of fiscal incentives), inadequate support among political parties and a lack of "hard" evidence for making these systems mandatory.

The first three options could be fleshed out as follows:

Further research

The innovation programme of the AVV Transport Research Centre, part of the Dutch Directorate-General for Public Works and Water Management, is currently linking up with a number of European projects involving ADA systems. Existing activities can be continued or expanded in the coming round during which proposals will be made for new European research.

This will include the relationship between ADA systems and the development of communication between vehicles and roadside systems. The compiled data attracted considerable interest. Such information can be placed at the disposal of research institutes for relevant research. An agreement can be made to provide the data and receive the study results for free.
A request can also be made to the European Commission to set up large-scale pilot projects in Europe. Work is currently underway in this regard, incidentally.

Increasing awareness

An excellent instrument is participation in the eSafety forum, a European initiative geared towards raising awareness for ADA systems (see http://www.esafetysupport.org).
Communication channels, which reach a broad public, can also be approached, such as National Geographic and Dutch programmes such as Klokhuis, Jules Unlimited, Nationale Wetenschapsquiz, and Dutch publications such as Kampioen, Consumentengids, Kijk, Quest, etc. The results are also published in specialist journals and presentations are given at conferences.

Personally purchasing the systems

The Dutch Directorate-General for Public Works and Water Management can provide a good example by equipping (part) of its own fleet with ADA systems. These systems, which are available as an option, can be purchased as standard for new management vehicles. Naturally, this can also apply to the rest of the fleet. It is also possible to install the systems purchased from MobilEye (LDW, HMW) in company cars.

Research results presented on October 23rd 2006

LDW AND ACC HAVE A POSITIVE EFFECT ON ROAD SAFETY

Humour played a key role during the presentation of the research results of 'The Assisted Driver' pilot at the Mediapark in Hilversum. On October 23rd 2006, the Dutch actor Huub Stapel turned this event into an amusing spectacle, but the conclusions were serious: LDW and ACC have a positive effect on road safety.

Immediately after a flawless round of interviews conducted by Huub Stapel, a humorous awards ceremony was held in the TV studio. Consultant Walter Hagleitner, a key figure in the study of the Dutch Directorate-General for Public Works and Water Management thanks to his impressive network in the automobile industry, was awarded a Dumbo pendant by project leader Gerben Bootsma in front of the television cameras. "When we revealed our plans to combine two systems in one car, he said it was far too early to do so", declares Gerben Bootsma, explaining the symbolism of the Disney character. "He said we wanted to make elephants fly."

Positive results

Gerben Bootsma acknowledges it was possible to carry out the study in the end thanks in part to Toyota and Volkswagen of course. "They take risks by linking their name to a project like this one. Thankfully though, the results were extremely positive.
We demonstrated that when everyone drives vehicles equipped with ADA systems, the accident rate will decrease by as much as 8% and traffic congestion will diminish in turn. There are also significant, positive effects for traffic flow through-put and the environment. We now want to examine whether the ministry can provide a tax incentive via the tax on private motor vehicles and motorcycles to people who purchase vehicles equipped with such systems. This will allow manufacturers to also equip smaller and more affordable cars with ACC and LDW within the framework of road safety."

Cost compensation?

Abe van den Brink, Key Account Manager at Pon's Automobielhandel, does see advantages to this. "We are introducing the systems from the top down, starting with more expensive models. The Passat is one of the first medium-priced cars to offer ACC as an option. However, if the government is prepared to compensate part of the costs, we will also install the systems in the Golf, for example. The Dutch Ministry of Finance devised a similar scheme when cruise control was introduced." Jan van Honk from Toyota Motor Europe continues by referring to the high-tech Lexus: "This car costs € 133.000,- more than half which goes to the government. That is substantial, don't you think?" Driver and project participant Rudi Engelbertink has the final word. "It changed my driving style completely. I'm now calmer behind the wheel. I could never do without it."

Colophon

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