Alam A, Gattami A, Johansson K (2010). An experimental study on the fuel reduction potential of heavy duty vehicle platooning. Proceedings of the 13th International IEEE Conference on Intelligent Transportation Systems (ITSC), Funchal 306-311.

Vehicle platooning has become important for the vehicle industry. Yet conclusive results with respect to the fuel reduction possibilities of platooning remain unclear. The focus in this study is the fuel reduction that heavy duty vehicle platooning enables and the analysis with respect to the influence of a commercial adaptive cruise control on the fuel consumption. Experimental results show that by using preview information of the road ahead from the lead vehicle, the adaptive cruise controller can reduce the fuel consumption. A study is undertaken for various masses of the lead vehicle. The results show that the best choice with respect to a heavier or lighter lead vehicle depends on the desired time gap. A maximum fuel reduction of 4.7–7.7% depending on the time gap, at a set speed of 70 km/h, can be obtained with two identical trucks. If the lead vehicle is 10 t lighter a corresponding 3.8–7.4% fuel reduction can be obtained depending on the time gap. Similarly if the lead vehicle is 10 t heavier a 4.3–6.9% fuel reduction can be obtained. All results indicate that a maximum fuel reduction can be achieved at a short relative distance, due to both air drag reduction and suitable control.

Alam A (2011). Fuel-Efficient Distributed Control for Heavy Duty Vehicle Platooning. Licentiate Thesis in Automatic Control, KTH School of Electrical Engineering, Stockholm, Sweden. http://kth.diva-portal.org/smash/get/diva2:447050/FULLTEXT01 [accessed 09.04.2013]

Freight transport demand has escalated and will continue to do so as economies grow. As the traffic intensity increases, the drivers are faced with increasingly complex tasks and traffic safety is a growing issue. Simultaneously, fossil fuel usage is escalating. Heavy duty vehicle (HDV) platooning is a plausible solution to these issues. Even though there has been a need for introducing automated HDV platooning systems for several years, they have only recently become possible to implement. Advancements in on-board and external technology have ushered in new possibilities to aid the driver and enhance the system performance. Each vehicle is able to serve as an information node through wireless communication; enabling a cooperative networked transportation system. Thereby, vehicles can semi-autonomously travel at short intermediate spacings, effectively reducing congestion, relieving driver tension, improving fuel consumption and emissions without compromising safety. This thesis presents contributions to a framework for the design and implementation of HDV platooning. The focus lies mainly on establishing and validating real constraints for fuel optimal control for platooning vehicles. Nonlinear and linear vehicle models are presented together with a system architecture, which divides the complex problem into manageable subsystems. The fuel reduction potential is investigated through simulation models and experimental results derived from standard vehicles traveling on a Swedish highway. It is shown through analytical and experimental results that it is favorable with respect to the fuel consumption to operate the vehicles at a much shorter intermediate spacing than what is currently done in commercially available systems. The results show that a maximum fuel reduction of 4.7–7.7% depending on the inter-vehicle time gap, at a set speed of 70 km/h, can be obtained without compromising safety. A systematic design methodology for inter-vehicle distance control is presented based on linear quadratic regulators (LQRs). The structure of the controller feedback matrix can be tailored to the locally available state information. The results show that a decentralized controller gives good tracking performance, a robust system and lowers the control effort downstream in the platoon. It is also shown that the design methodology produces a string stable system for an arbitrary number of vehicles in the platoon, if the vehicle configurations and the LQR weighting parameters are identical for the considered subsystems. With the results obtained in this thesis, it is argued that a vast fuel reduction potential exists for HDV platooning. Present commercial systems can be enhanced significantly through the introduction of wireless communication and decentralized optimal control.

Alkim T, Bootsma G, Looman P (2007). The Assisted Driver: Systems that support driving. Ministry of Transport, Public Works and Water Management, Rijkswaterstaat, The Netherlands. http://www.mobileye.com/wp-content/uploads/2011/09/DutchMinistryReport1.pdf [accessed 04.04.2013]

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.

Arnaout GM, Bowling S (2013). A progressive deployment strategy for cooperative adaptive cruise control to improve traffic dynamics. International Journal of Automation and Computing. http://www.ijac.net/EN/article/downloadArticleFile.do?attachType=PDF&id=1397 [accessed 24.07.2013]

Cooperative Adaptive Cruise Control (CACC) vehicles are intelligent vehicles that use Vehicular Adhoc Networks (VANETs) to share traffic information in real time. Previous studies have shown that CACC could have an impact on increasing highway capacities at high market penetration. Since reaching a high CACC market penetration level is not occurring in the near future, this study presents a progressive deployment approach that demonstrates to have a great potential of reducing traffic congestions at low CACC penetration levels. Using a previously developed microscopic traffic simulation model of a freeway with an onramp - created to induce perturbations and trigger Stop-and-Go traffic, the CACC system's effect on the traffic performance is studied. The results show significance and indicate the potential of CACC systems to improve traffic characteristics which can be used to reduce traffic congestion. The study shows that the impact of CACC is positive and not only limited to a high market penetration. By giving CACC vehicles priority access to High-occupancy vehicle (HOV) lanes, the highway capacity could be significantly improved with a CACC penetration as low as 20%.

Arnaout G, Bowling S (2011). Towards reducing traffic congestion using cooperative adaptive cruise control on a freeway with a ramp. Journal of Industrial Engineering and Management 4(4), 699-717.

In this paper, the impact of Cooperative Adaptive Cruise Control (CACC) systems on traffic performance is examined using microscopic agent-based simulation. Using a developed traffic simulation model of a freeway with an on-ramp - created to induce perturbations and to trigger stop-and-go traffic, the CACC system's effect on the traffic performance is studied. The previously proposed traffic simulation model is extended and validated. By embedding CACC vehicles in different penetration levels, the results show significance and indicate the potential of CACC systems to improve traffic characteristics and therefore can be used to reduce traffic congestion. The study shows that the impact of CACC is positive but is highly dependent on the CACC market penetration. The flow rate of the traffic using CACC is proportional to the market penetration rate of CACC equipped vehicles and the density of the traffic.

Bartels A, Meinecke M-M, Steinmeyer S (2012). Lane change assistance. In Eskandarian A (Ed), Handbook of Intelligent Vehicles, Springer-Verlag London Ltd., 729-757.

More than 5% of all accidents involving injury to people take place as the result of a lane change. Therefore, it is sensible to provide the driver with a lane change assistant in order to provide support in this driving maneuver. ISO standard 17387 ''Lane Change Decision Aid System'' differentiates between three different types of system: The ''Blind Spot Warning'' monitors the blind spot on the left and right adjacent to the driver's own vehicle. The ''Closing Vehicle Warning'' monitors the adjacent lanes to the left and right behind the driver's own vehicle in order to detect vehicles approaching from behind. The ''Lane Change Warning'' combines the functions of ''Blind Spot Warning'' and ''Closing Vehicle Warning.'' Almost all major vehicle manufacturers are now offering systems that assist the driver to change lanes. Systems with ''Blind Spot Warning'' are available from Ford, Jaguar, Mercedes-Benz, Nissan/Infiniti, Peugeot, and Volvo. Systems with ''Lane Change Warning'' are available from Audi, BMW, Mazda, and VW. All vehicle manufacturers use an optical display in or near to the exterior mirrors in order to show information for the driver. The majority of vehicle manufacturers use radar sensors that are

installed in the rear of the vehicle. Two-level, escalating driver information is only offered in some of the systems. The type of escalation (optical, acoustic, tactile, lateral guidance intervention) usually differs from one vehicle manufacturer to another. The performance capability of the lane change assistants described above is already quite considerable. However, all of these systems have their limits, and the vehicle manufacturers need to inform drivers of these in the owner's manual, for example.

Belzowski BM, Ekstrom A (2013). Stuck in Traffic: Analyzing Real Time Traffic Capabilities of Personal Navigation Devices and Traffic Phone Applications. University of Michigan Transportation Research Institute Study for TomTom Group.

The global positioning system (GPS) market is a fast changing, highly competitive market. Products change frequently as they try to provide the best customer experience for a service that is based on the need for real-time data. Two major functions of the GPS unit are to correctly report traffic jams on a driver's route and provide an accurate and timely estimated time of arrival (ETA) for the driver whether he/she is in a traffic jam or just following driving directions from a GPS unit. This study measures the accuracy of traffic jam and ETA reporting by having Personal Navigational Devices (PNDs) from TomTom and Garmin and phone apps from TomTom, INRIX, and Google in the same vehicle programmed to arrive at the same destination. The ETA analysis focused only on the relationship between the devices and their ability to estimate arrival times while in traffic jams, not the typical ETA test ('Cat and Mouse' comparison) where devices are allowed to route drivers away from traffic. We found significant differences between the units in terms of their ability to recognize an upcoming traffic jam as well as how long it takes to get through a jam one encounters. We also found differences in how well the devices responded to jams when driving on surface streets versus highways, and whether the jams were shorter or longer in length. We see potential for auto manufacturers to employ real-time traffic in their new vehicles, providing potential growth for real-time traffic providers through access to new vehicles as well as the aftermarket.

Benmimoun M, Pütz A, Aust ML, Faber F, Sánchez D, Metz B, Saint Pierre G, Geißler T, Guidotti L, Malta L (2012). Final Evaluation Results. Deliverable D6.1 of the euroFOT ICT for Cooperative Systems European Project. http://www.eurofot-ip.eu/download/library/deliverables/eurofotsp620121207v11dld61_final_evaluation_results.pdf [accessed 03.04.2013]

The euroFOT project was the first large-scale Field Operational Test (FOT) of multiple Advanced Driver Assistance Systems (ADAS) in Europe. It evaluated the impact of eight different ADAS on safety, traffic efficiency, environment, driver behaviour and user-acceptance in real life situations by collecting data from instrumented vehicles. Offering valuable information for the short- and long-term impact of ADAS, the euroFOT project aimed to encourage their wide deployment. Altogether, about 1000 vehicles equipped with different ADAS technologies took part in the field operational test. The FOT was coordinated by five Vehicle Management Centres (VMC) and carried out at various operation sites across six European countries (France, Germany, Italy, Netherlands, Sweden and United Kingdom). Nevertheless, drivers could use their vehicles in different countries across Europe. The following functions were investigated: Longitudinal functions: Adaptive Cruise Control (ACC) and Forward Collision Warning (FCW) together in one bundle (together counted as one function) and Speed Regulation System (SRS) composed of Speed Limiter (SL) and Cruise Control (CC); Lateral functions: Lane Departure Warning (LDW) and Impairment Warning (IW) together in one bundle for passenger cars (together counted as one function for passenger cars) and Blind Spot Information System (BLIS); Other functions: Curve Speed Warning (CSW), Fuel Efficiency Advisory (FEA) and navigation systems (SafeHMI). The analysis was conducted at each VMC according to the data analysis plan previously elaborated in the project: this plan was based on a common framework for all the VMCs, but was also able to consider specific conditions within an experiment (e.g. availability of only CAN-data, use of video recording and presence of multiple functions). The data collection phase was conducted for 12 months at most VMCs. The first three months were used as a baseline phase when the tested functions were deactivated. In the remaining period the functions could be used by the drivers without restrictions (treatment phase). The impact assessment was conducted by comparing the relevant performance indicators between the baseline and treatment phase. Approximately 35 million km were driven during the data collection phase. The

gathered data was processed and finally used for data analysis. During the analysis a significant effort was dedicated to reduce the large quantity of raw data and extract only relevant data sets: for example car-following situations were needed for ACC, or specific conditions (such as road type, weather conditions, or length of travel) were required for testing certain hypotheses. Overall, the final results point to a positive effect on safety, a positive effect regarding fuel consumption and high levels of driver-acceptance.

Benmimoun M, Pütz A, Zlocki A, Eckstein L (2013). Impact assessment of adaptive cruise control (ACC) and forward collision warning (FCW) within a field operational test in Europe. Annual Meeting of the Transportation Research Board, Washington DC, USA.

The euroFOT project is the first large-scale Field Operational Test (FOT) of multiple Advanced Driver Assistance Systems (ADAS) in Europe. It will evaluate the impacts of ADAS on safety, traffic efficiency, environment, driver behaviour and user-acceptance in real life situations with normal drivers, by means of collected data from instrumented vehicles. By offering valuable information for the short- and long-term impact of ADAS the euroFOT project aims to encourage the deployment of ADAS. Altogether, about 1000 vehicles from different manufacturers and with different advanced driver assistance systems will take part in the FOT. The euroFOT fleet is coordinated by five Vehicle Management Centers (VMC). The Institute of Automotive Engineering (ika) of the RWTH Aachen University analysed the effects of ACC usage in combination with FCW under normal driving conditions of 100 passenger cars. The results of the data analysis show positive effects on traffic safety and fuel consumption. In terms of traffic safety a reduction in number of incidents, harsh braking and critical time-headways were determined. These reductions can be attributed to changed distance behaviour of the drivers. Moreover the analysis shows that the average time-headway was increased at about 16%, which is a further indication that ACC has a positive impact on traffic safety. In addition to the usage rate of 50% the analysis of acceptance rating revealed a positive perception of the ACC and FCW. Furthermore, a reduction in fuel consumption of 2.8% was observed which results in less CO2 emissions. Besides the analysis of the collected data, the complete process chain from the data collection to the analysis was defined and conducted at the ika.

Benz T, Christen F, Lerner G, Schulze M, Vollmer D (2003). Traffic Effects of Driver Assistance Systems - The Approach within INVENT. http://orbi.ulg.ac.be/bitstream/2268/102893/1/ITS%20Paper%20VRA%20V2.pdf [accessed 18.04.2013]

Within the German Research Initiative INVENT, the partial project „Verkehrliche Wirkung, Recht und Akzeptanz (VRA)“ deals with traffic effects, legal aspects, acceptance and economics of driver assistance systems. This presentation gives examples for the consulting services of VRA as well as for the early simulations of a driver assistance system. Such simulations vary in scale from basic functions over driving situations and traffic situations to traffic scenarios. Results are presented for the basic functions and driving situations for a stop-and-go extension of adaptive cruise control.

Bergenheim C, Shladover S, Coelingh E (2012a). Overview of platooning systems. Proceedings of the 19th ITS World Congress, Vienna, Austria. http://publications.lib.chalmers.se/records/fulltext/174621/local_174621.pdf [accessed 10.01.2014]

This paper presents an overview of current projects that deal with vehicle platooning. The platooning concept can be defined as a collection of vehicles that travel together, actively coordinated in formation. Some expected advantages of platooning include increased fuel and traffic efficiency, safety and driver comfort. There are many variations of the details of the concept such as: the goals of platooning, how it is implemented, mix of vehicles, the requirements on infrastructure, what is automated (longitudinal and lateral control) and to what level. The following projects are presented: SARTRE – a European platooning project; PATH – a California traffic automation program that includes platooning; GCDC – a cooperative driving initiative, SCANIA platooning and; Energy ITS – a Japanese truck platooning project.

Bergenhem C, Hedin E, Skarin D (2012b). Vehicle-to-Vehicle communication for a platooning system. Procedia - Social and Behavioral Sciences 48, 1222-1233.

This paper describes a vehicle-to-vehicle (V2V) communication system that is developed in the SARTRE project. The project vision is to develop and integrate technology that enables vehicles to drive in platoons. SARTRE defines a platoon (or road train) as a collection of vehicles where a manually driven heavy lead vehicle is followed by several automatically controlled (both laterally and longitudinally) following trucks and/or passenger cars. The V2V communication system enables forwarding of messages between vehicles to share data such as vehicle speed. In this paper, we present performance measurements of a first prototype of the V2V system. This is an important part of the platooning demonstrator that is being developed in the SARTRE project. We evaluate two antenna placements on the lead vehicle; in front on the driver cabin and in the rear on top of the container. Our results show that the rear placement provides superior results, especially for distances above 70 meters.

Biding T, Lind G (2002). Intelligent Speed Adaptation (ISA), Results of large-scale trials in Borlänge, Lidköping, Lund and Umeå during the period 1999-2002. Publication 2002:89 E, Swedish National Road Administration. http://publikationswebbutik.vv.se/upload/2636/2002_89_E_Intelligent_speed_adaption.pdf [accessed 02.04.2013]

During the period 1999-2002 the Swedish National Road Administration conducted a comprehensive road information project which included a large-scale trial involving Intelligent Speed Adaptation in urban areas. Several thousand vehicles have been equipped with voluntary, supportive and informative systems to help keep drivers from exceeding the speed limit. The systems were tested in Borlänge, Lidköping, Lund and Umeå, where the local authorities were responsible for running the trials in their respective municipalities. Over the three years of the project, the Swedish National Road Administration provided SEK 75 million in funding, and was also responsible for the overall co-ordination of the technology involved, as well as for evaluating the comparative advantages and disadvantages of the various systems. 1999 saw the planning of how the trial would be implemented and evaluated and in 2000 the systems started being installed in the vehicles. Most of the actual field trials were carried out in 2001. The submitted report documents the background, implementation and the results of the comparative evaluation of the individual systems, which were made centrally by the Swedish National Road Administration. The report is designed to provide information and guidance for the continued consideration of a possible introduction of a speed adaptation system on a large-scale.

Bishop R (2005). Intelligent Vehicle Technology and Trends. Artech House Inc, Norwood, USA. http://203.158.253.140/media/e-Book/Engineer/Automotive/Intelligent%20Vehicle%20Technology%20and%20Trends.pdf [accessed 18.04.2013]

Intelligent Vehicle Technology and Trends is intended to provide an overview of developments in the IV domain for engineers, researchers, government officials, and others interested in this technology. Readers will gain a broad perspective as to the overall set of activities and research goals; the key actors worldwide; the functionality of IV systems and their underlying technology; the market introductions and deployment prospects; the user, customer, and societal issues; and the author's prognosis for the future rollout of products and integrated vehicle-highway systems. The book opens with "big picture" considerations, introduces the major players in the IV domain, and then addresses key functional areas in-depth. The latter portion of the book is devoted to addressing some nontechnical issues, and a view toward the future is offered in conclusion. Intelligent Vehicle Technology and Trends endeavors to provide a thorough treatment of the topic, yet it is not intended to be completely comprehensive. The book is intended to provide perspective and, for readers new to the field, to provide a "jumping-off point" for deeper investigations. Projects described are illustrative, and, regrettably, many worthy projects could not be included due to space limitations. Further, it is not the intent of this book to offer significant depth as to the sensor technologies, subsystem designs, and processing algorithms—for this level of detail, the reader is referred to the voluminous technical literature available from a variety of sources. The obvious must be stated, as well. Significant private R&D to develop future products is

under way within automotive industry laboratories; while general information is available on some activities, large portions are kept confidential for competitive purposes. Nevertheless, I believe this book presents a reasonably accurate picture of industry activity. Many references refer to articles on http://www.IVsource.net, which is an informational Web site I publish. Videos of many of the systems and technologies in operation are available for download at the site, as well as additional supporting information.

Blum JJ, Eskandarian A, Arhin SA (2012). Intelligent Speed Adaptation (ISA). In Eskandarian A (Ed), Handbook of Intelligent Vehicles, Springer-Verlag London, 581-602.

Intelligent Speed Adaptation (ISA) systems are in-vehicle systems designed to improve driver compliance with safe speeds. These systems can provide information on safe speeds to driver, warn the driver when they are exceeding this limit, or control brakes or throttle to prevent speeding. Because of the link between excessive speeding and severe crashes, ISA systems have been called ''the most powerful collision avoidance system currently available'' (Carsten and Tate 2001). However, ISA systems do face challenges to their widespread deployment. Perhaps the most significant of these challenges is finding an appropriate balance between user acceptability and system effectiveness. The more effective that an ISA system is at reducing speeding, the less likely it is to be acceptable to drivers, particularly those who would benefit the most from ISA systems. In addition, some researchers have expressed concern about potential negative safety implications of ISA systems including driver unloading, driver distraction, negative behavioural adaptations, and negative interactions with other road users. This chapter presents an overview of ISA system configurations, potential benefits of ISA systems, and challenges faced by the systems. In addition, case studies, including large-scale field tests of ISA systems, are presented.

Bonnet C (2003). The platooning application, CHAUFFEUR Final Presentation. International Workshop on Vehicle Safety Communications (ARIB), Tokyo, Japan. http://www.itsforum.gr.jp/Public/E4Meetings/P01/fremont5_2_2.pdf [accessed 10.01.2014]

Presentation of the CHAUFFEUR project platooning application.

Boriboonsomsin K, Servin O, Barth M (2008). Selection of control speeds in dynamic intelligent speed adaptation system: A preliminary analysis. UCTC Research-Faculty papers, Summer 848, University of California Transportation Center (UCTC), USA. http://www.uctc.net/papers/848.pdf [accessed 12.08.2013]

Intelligent speed adaptation (ISA) has been shown to be an effective measure for road safety improvement. Recently, there has been an increasing interest in using ISA systems, particularly with the dynamic speed control, to manage congestion and reduce energy/emissions. The effectiveness of the dynamic ISA system relies on its speed control strategies. This paper presents the development of a preliminary method to determine control speeds of the dynamic ISA system. The initial results show reasonable control speeds under various levels of freeway congestion as categorized by freeway level of service.

Bose A, Ioannou P (1999). Analysis of traffic flow with mixed manual and semiautomated vehicles. California PATH Research Report UCB-ITS-PRR-99-14. California PATH Program, University of California, State of California Business, Transportation, and Housing Agency, Department of Transportation and United States Department of Transportation, Federal Highway Administration. http://www.path.berkeley.edu/PATH/Publications/PDF/PRR/99/PRR-99-14.pdf [accessed 27.04.2013]

During the last decade considerable research and development efforts have been devoted to automatic vehicles in an effort to improve safety and efficiency of vehicle following. While dedicated highways with fully automated

vehicles is a far in the future objective, the introduction of semi-automated vehicles on current highways designed to operate with manually driven vehicles is a realistic near term objective. The purpose of this paper is to analyse the effects on traffic flow characteristics and environment when semi-automated vehicles with automatic vehicle following capability (in the same lane) operate together with manually driven vehicles. We have shown that semi-automated vehicles do not contribute to the slinky effect phenomenon observed in today's highway traffic when the lead manual vehicle performs smooth acceleration maneuvers. We have demonstrated that semi-automated vehicles smooth traffic flow by filtering the response of rapidly accelerating lead vehicles. The smooth response of the semi-automated vehicles designed for passenger comfort significantly reduces fuel consumption and levels of pollutants of following vehicles when the lead manual vehicle performs rapid acceleration maneuvers. We have demonstrated using simulations that the fuel consumption and pollution levels present in manual traffic simulated using a car following model that models the slinky effect behavior observed in manual driving can be reduced during rapid acceleration transients by 7.3% and 3.8%-47.3% respectively due to the presence of 10% semi-automated vehicles. Due to the randomness and uncertainties in human driving, the numbers obtained are qualitatively valid and demonstrate the beneficial effect of semi-automated vehicles in mixed traffic in improving air quality and fuel consumption.

Bose A, Ioannou P (2001). Analysis of Traffic Flow With Mixed Manual and Intelligent Cruise Control Vehicles: Theory and Experiments. California PATH Research Report UCB-ITS-PRR-2001-13. California PATH Program, University of California, State of California Business, Transportation, and Housing Agency, Department of Transportation and United States Department of Transportation, Federal Highway Administration. http://escholarship.org/uc/item/2tw8q0h8.pdf [accessed 27.04.2013]

During the last decade considerable research and development efforts have been devoted to automating vehicles in an effort to improve safety and efficiency of vehicular traffic. While dedicated highways with fully automated vehicles is a future objective, the introduction of Intelligent Cruise Control (ICC) vehicles on current highways designed to operate with manually driven vehicles is a realistic near term objective. The purpose of this report is to analyze the effects on traffic flow characteristics and environment when ICC vehicles with automatic vehicle following capability (in the same lane) operate together with manually driven vehicles. We have shown that ICC vehicles do not contribute to the slinky effect phenomenon observed in today's highway traffic when the lead manual vehicle performs smooth acceleration maneuvers. We have demonstrated that ICC vehicles help smooth traffic flow by filtering the response of rapidly accelerating lead vehicles. The accurate speed tracking and the smooth response of the ICC vehicles designed for passenger comfort reduces fuel consumption and levels of pollutants of following vehicles. This reduction is significant when the lead manual vehicle performs rapid acceleration maneuvers. We have demonstrated using simulations that the fuel consumption and pollution levels present in manual traffic simulated using a car following model that models the slinky effect behavior observed in manual driving can be reduced during rapid acceleration transients by 28.5% and 1.5%-60.6% respectively due to the presence of 10% ICC vehicles. These environmental benefits are obtained without any adverse effects on the traffic flow rates. Experiments with actual vehicles are used to validate the theoretical and simulation results.

Bose A, Ioannou P (2003). Analysis of traffic flow with mixed manual and semiautomated vehicles. IEEE Transactions on Intelligent Transportation Systems 4(4), 173-188.

The introduction of semiautomated vehicles designed to operate with manually driven vehicles is a realistic near-term objective. The purpose of this paper is to analyze the effects on traffic-flow characteristics and environment when semiautomated vehicles with automatic vehicle following capability (in the same lane) operate together with manually driven vehicles. We have shown that semiautomated vehicles do not contribute to the slinky effect phenomenon when the lead manual vehicle performs smooth acceleration maneuvers. We have demonstrated that semiautomated vehicles help smooth traffic flow by filtering the response of rapidly accelerating lead vehicles. The accurate speed tracking and the smooth response of the semiautomated vehicles designed for passenger comfort reduces fuel consumption and levels of pollutants of following vehicles. This reduction is significant when the lead manual vehicle performs rapid acceleration maneuvers. We have

demonstrated using simulations that the fuel consumption and pollution levels present in manual traffic can be reduced during rapid acceleration transients by 28.5% and 1.5%–60.6%, respectively, due to the presence of 10% semiautomated vehicles. These environmental benefits are obtained without any adverse effects on the traffic-flow rates. Experiments with actual vehicles are used to validate the theoretical and simulation results

Brännström M (2013). Commercial Viability, Deliverable 5.1. SAfe Road TRains for the Environment project. http://www.sartre-project.eu/en/publications/Documents/SARTRE_5_001_PU.pdf [accessed 10.01.2014]

The SARTRE project aims at developing attractive customer products that make the traffic safer, decrease fuel consumption and enable drivers to perform other tasks than driving. This document is a commercial viability report for road trains which offer this type of functionality. Different business models are studied and conclusions are drawn on the commercial viability for each model.

Buscema D, Ignaccolo M, Inturri G, Pluchino A, Rapisarda A, Santoro C, Tudisco S (2009). The impact of real time information on transport network routing through intelligent agent-based simulation. Proceedings of the 2009 IEEE Toronto International Conference on Science and Technology for Humanity (TIC-STH), Toronto, ON, 72-77.

Advance Traveller Information Systems (ATIS) are considered a promising tool to alleviate traffic congestion and improve road network performance. They provide real time traffic information and route recommendation to road users, in order to increase their ability to choose the best alternative path. Though such systems have reached a high technical standard, their actual impact in traffic pattern and network performance is controversial. The methodology used is based on a Multi Agent Simulation to model how the presence of information influences the driver's reactive behavior and the network efficiency. The case study is the well known network of the Braess' paradox and the specific aim is to find the proper route recommendation strategy to avoid that adding a new road to traffic network may result in increasing the total travel time. Through a software platform able to simulate a virtual road network, where single drivers interact with each other and with the spatial environment according to a defined behavior, that is their reaction to external outputs, two behavioral patterns will be simultaneously considered. The first refers to the driver's path choice among those available for a fixed origin-destination pair; the second refers, once the path is chosen, to the microscopic motion of each vehicle as a function of the leader vehicle along each link of the network. To simulate the presence of drivers equipped with ATIS system and drivers who are not, or equivalently to simulate different reactive behavior to the information provided, it has been used a variable “probability of feedback”. Pattern arrival vehicle flow can be varied together with speed and acceleration of the vehicles. The general purpose of the paper is to contribute to the analysis of the impact of ITS (Intelligent Transport Systems) technology in traffic pattern and network performance. The specific objective is modelling driver's behavior in road networks when real time traffic information is- - provided. The results show that a proper rate of provided information is able to reduce the effect of the Braess' paradox and that network performance increases when drivers' behavior is affected by their ability to see local traffic conditions.

Carsten OMJ, Tate FN (2000). External Vehicle Speed Control, Final Report: Integration. Deliverable 17, External Vehicle Speed Control Project, Report prepared by the Institute of Transport Studies for the Vehicle Standards and Engineering Division of the Department of the Environment, Transport and the Regions, UK. http://www.righttoride.eu/virtuallibrary/warningcontrolsystems/del17.pdf [accessed 12.08.2013]

This report is the final report of the three-year External Vehicle Speed Control project. It does not attempt to summarise all the major findings of the project – that task will be accomplished by a separate executive summary of the project findings. The report concludes Phase III of the project. Other deliverables from this phase are D7.2 – Legal Implications of External Vehicle Speed Control Issues and D16 – Production Issues. The major objective of Phase III has been to prepare an implementation strategy for EVSC, taking into account system costs, predicted

benefits, any major disbenefits and timescales for introducing EVSC. This report draws on all the previous work of the project to review the case for moving forward with EVSC and to propose an implementation strategy by which EVSC could be rolled out if such a rollout can be justified. It presents the conclusions from the project concerning the technologies and system architecture for EVSC, the time required for implementation, and the predicted accident savings. The initial benefit-cost analysis carried out at the end of Phase I of the project in Deliverable 6 – Implementation Scenarios, has been revised in the light of the results from the simulation modelling carried out in Phase II on network effects on EVSC and in the light of the behavioural studies of user behaviour with EVSC. The costs of implementation have also been revised, drawing on more recent information about the future costs of the various sub-systems required.

Carsten OMJ, Tate FN (2005). Intelligent speed adaptation: accident savings and cost-benefit analysis. Accident Analysis & Prevention 37(3), 407-416.

The UK External Vehicle Speed Control (EVSC) project has made a prediction of the accident savings with intelligent speed adaptation (ISA), and estimated the costs and benefits of national implementation. The best prediction of accident reduction was that the fitting on all vehicles of a simple mandatory system, with which it would be impossible for vehicles to exceed the speed limit, would save 20% of injury accidents and 37% of fatal accidents. A more complex version of the mandatory system, including a capability to respond to current network and weather conditions, would result in a reduction of 36% in injury accidents and 59% in fatal accidents. The implementation path recommended by the project would lead to compulsory usage in 2019. The cost–benefit analysis carried out showed that the benefit-cost ratios for this implementation strategy were in a range from 7.9 to 15.4, i.e. the payback for the system could be up to 15 times the cost of implementing and running it.

Davila A (2013). Report on Fuel Consumption. Deliverable 4.3. SAfe Road TRains for the Environment project. http://www.sartre-project.eu/en/publications/Documents/SARTRE_4_003_PU.pdf [accessed 10.01.2014]

This report set out to validate the developed end to end system and comment on the fuel consumption of the vehicles in the system. It did this by carrying out aerodynamic simulations of the entire platoon to create an estimated fuel consumption. This was done using an Openfoam CFD simulation and the results were quite promising. The gap in between the vehicles was altered and the behaviour of the air between the cars was interesting to analyse as it showed that the optimum distance was 6m – 8m and not 3m or 4m. Track tests were then made to analyse the actual fuel consumption. At a gap of 8m all of the vehicles achieve fuel savings from 7 to 15%. All of the results from this work package show that platooning provides significant potential improvements for the efficient use of fuel.

Davis LC (2004). Effect of adaptive cruise control systems on traffic flow. Physical Review E 69(6), 066110.

The flow of traffic composed of vehicles that are equipped with adaptive cruise control (ACC) is studied using simulations. The ACC vehicles are modeled by a linear dynamical equation that has string stability. In platoons of all ACC vehicles, perturbations due to changes in the lead vehicle's velocity do not cause jams. Simulations of merging flows near an onramp show that if the total incoming rate does not exceed the capacity of the single outgoing lane, free flow is maintained. With larger incoming flows, a state closely related to the synchronized flow phase found in manually driven vehicular traffic has been observed. This state, however, should not be considered congested because the flow is maximal for the density. Traffic composed of random sequences of ACC vehicles and manual vehicles has also been studied. At high speeds (~30 m/s) jamming occurs for concentrations of ACC vehicles of 10% or less. At 20% no jams are formed. The formation of jams is sensitive to the sequence of vehicles (ACC or manual). At lower speeds (~15 m/s), no critical concentration for complete jam suppression is found. Rather, the average velocity in the pseudojam region increases with increasing ACC concentration. Mixing 50% ACC vehicles randomly with manually driven vehicles on the primary lane in onramp simulations shows only modestly reduced travel times and larger flow rates.

Davis LC (2006). Effect of cooperative merging on the synchronous flow phase of traffic. Physica A: Statistical Mechanics and its Applications 361(2), 606-618.

Cooperation in merging is introduced by adding interactions between pairs of vehicles in opposite lanes. Simulations with an improved version of the modified optimal velocity model are done for two lanes merging into a single lane. For 30 s prior to reaching the merge region, vehicles in both lanes adjust their headways to create safe distances in front of and behind the merging vehicle. Cooperation prevents the transition from free flow to synchronous flow that occurs for normal merging, provided the merge region is sufficiently large and the total incoming flow does not exceed the maximum possible single-lane flow. No long-range vehicleto-vehicle communication is required for the type of cooperation considered.

Davis LC (2007). Effect of adaptive cruise control systems on mixed traffic flow near an on-ramp. Physica A: Statistical Mechanics and its Applications 379(1), 274-290.

Mixed traffic flow consisting of vehicles equipped with adaptive cruise control (ACC) and manually driven vehicles is analyzed using car-following simulations. Simulations of merging from an on-ramp onto a freeway reported in the literature have not thus far demonstrated a substantial positive impact of ACC. In this paper cooperative merging for ACC vehicles is proposed to improve throughput and increase distance traveled in a fixed time. In such a system an ACC vehicle senses not only the preceding vehicle in the same lane but also the vehicle immediately in front in the other lane. Prior to reaching the merge region, the ACC vehicle adjusts its velocity to ensure that a safe gap for merging is obtained. If onramp demand is moderate, cooperative merging produces significant improvement in throughput (20%) and increases up to 3.6km in distance traveled in 600 s for 50% ACC mixed flow relative to the flow of all-manual vehicles. For large demand, it is shown that autonomous merging with cooperation in the flow of all ACC vehicles leads to throughput limited only by the downstream capacity, which is determined by speed limit and headway time.

Delling D, Sanders P, Schultes D, Wagner D (2009). Engineering route planning algorithms. In Lerner J, Wagner D, Zweig KA (Eds) Algorithmics of Large and Complex Networks (Lecture Notes in Computer Science Vol. 5515), Springer, 117-139.

Algorithms for route planning in transportation networks have recently undergone a rapid development, leading to methods that are up to three million times faster than Dijkstra's algorithm. We give an overview of the techniques enabling this development and point out frontiers of ongoing research on more challenging variants of the problem that include dynamically changing networks, time-dependent routing, and flexible objective functions.

Delling D, Wagner D (2009). Time-dependent route planning. In Ahuja RK, Möhring RH, Zaroliagis CD (Eds) Robust and online large-scale optimization (Lecture Notes in Computer Science Vol. 5868), 207-230.

In this paper, we present an overview over existing speed-up techniques for time-dependent route planning. Apart from only explaining each technique one by one, we follow a more systematic approach. We identify basic ingredients of these recent techniques and show how they need to be augmented to guarantee correctness in time-dependent networks. With the ingredients adapted, three efficient speed-up techniques can be set up: Core-ALT, SHARC, and Contraction Hierarchies. Experiments on real-world data deriving from road networks and public transportation confirm that these techniques allow the fast computation of time-dependent shortest paths.

Doecke S, Woolley JE (2010). Cost Benefit Analysis of Intelligent Speed Assist. Prepared by the Centre for Automotive Safety Research for the Department of Transport and Main Roads (QLD),
Australia. http://s3.amazonaws.com/zanran_storage/www.tca.gov.au/ContentPages/25059 89266.pdf [accessed 09.04.2013]

This report examines the potential costs and benefits of Intelligent Speed Adaptation (ISA) in Australia. Quantitative results from ISA trials reported in the literature were reviewed and the benefits of ISA in terms of reducing the quantities such as mean speed, 85th percentile speed and reduction in speeding identified. The literature also revealed a high variability in these benefits from trial to trial. An analysis of speeding crashes was conducted using mass crash data collected by the six Australian states from 2004 to 2008. This analysis was hampered by inadequate identification of speed as a factor in this data set and inconsistencies between states. Despite these shortcomings, segregation of this data allowed some general conclusions to be drawn. Speed related crashes occurred in metropolitan and rural areas therefore ISA should be operational in both areas. Curves were over represented suggesting ISA incorporating curve speeds should be considered. Young drivers and motorcyclists were also over represented highlighting the need to ensure these groups of road users benefit from ISA. A more detailed analysis was conducted to determine the benefits of advisory, supportive and limiting ISA. This analysis suggested advisory ISA would reduce injury crashes by 7.7% and save $1,226 million per year. These figures were 15.1% and $2,240 million for supportive ISA and 26.4% and $3,725 million for limiting ISA. The costs associated with mapping and the cost of the ISA devices available were investigated. Mapping the Australian states was estimated to cost $15.6 million with a further $2.4 million per year required for updating. Only two states have completed maps with another state currently undertaking the process. Dedicated ISA devices that are currently available in Australia cost between $800 and $1,800 for a single unit although this could reduce to as little as $200 in two years if a high volume order were placed. A navaid that has advisory ISA functionality is also available. This costs just under $30 for a year subscription. A cost benefit analysis was conducted considering different implementation scenarios including: all vehicles, new vehicles, fleet vehicles, market driven, heavy vehicles, young drivers and navaid devices. The cost benefit analysis was heavily influenced by the unit price of the ISA devices causing the cost benefit ratios (BCRs) to vary from as low as 0.29 to 4.03 over a 20 year timeframe. Payback periods were also calculated to give an indication of economic benefit independent of a set timeframe and break even price was calculated to give an indication of economic benefit independent of a set unit price. Payback periods ranged from 3 to over 100 years and break even prices from $341 to $2,164 per unit. The “all vehicles” and “new vehicles” scenarios produced the greatest BCRs although it was thought that, taking into account the elevated risk of young drivers, a combination of implementing ISA on young driver’s vehicles and new vehicles may be the most cost effective implementation scenario. The navaid scenario suggested that even if these devices are only infrequently used and less effective than dedicated devices they may still prove a cost effective option. Limiting ISA generally produced the highest BCRs therefore this level of ISA should be implemented wherever possible.

Eby DW, Kostyniuk LP (1999). An on-the-road comparison of in-vehicle navigation assistance systems. Human Factors: The Journal of the Human Factors and Ergonomics Society 41(2), 295-311.

We compared system performance and driver opinion of 3 in-vehicle navigation aids – two advanced traveler information systems (ATISs; Ali-Scout and TetraStar) and written instructions – when used on the road concurrently under identical conditions. Few drivers in the study had difficulty finding initial routes or became lost. Users of Ali-Scout, an ATIS that utilizes traffic information in routing, drove longer-distance routes, got lost more frequently, and gave their system less positive ratings than did TetraStar users. Users of the 2 ATISs traversed routes that were significantly shorter in duration than those driven by users of written instructions. The time savings benefit of the advanced technology systems over written instructions was greatest during peak traffic conditions. Drivers who were familiar with the road network, overall, had less difficulty finding destinations and drove shorter-duration routes than drivers who were unfamiliar with the road network. Actual or potential applications of this research include improving the design of technologies that provide navigation assistance to travelers.

Ehmanns D, Spannheimer H (2004). Roadmap. Deliverable D2D of ADASE (Advanced Driver Assistance Systems in Europe) European IST project. http://www.esafetysupport.org/download/working_groups/Implementation_Road_Maps/Related_documents/ADASE2Roadmap.pdf [accessed 18.04.2013]

The roadmap shows the future research activities of Advanced Driver Assistance Systems in Europe. It bases on discussions between the experts of the ADASE 2 project partners and results of the ADASE2 thematic workshops and concertation meetings. This process leads to a matrix, which shows the research projects and the interdependencies between system functionality and complexities concerning different aspects. The derived matrix reveals the complexities of the technological, societal and legal aspects related to the various systems. The contribution to the guessed safety enhancement is mentioned. Thus, technological gaps and future research needs can be identified in the given overview.

Fancher P, Ervin R, Sayer J, Hagan M, Bogard S, Bareket Z, Mefford M, Haugen J (1998). Intelligent Cruise Control Field Operational test, Final Report No. DOT HS 808 849 prepared by the University of Michigan Transportation Research Institute for the National Highway Traffic Safety Administration U.S. Department of Transportation. http://www.google.com/url?sa=t&rct=j&q=Intelligent+Cruise+Control+Field+Operational+test%2C+Final+Report&source=web&cd=1&cad=rja&ved=0CCkQFjAA&url=http%3A%2F%2Fwww.nhtsa.gov%2FDOT%2FNHTSA%2FNRD%2FMultimedia%2FPDFs%2FCrash%2520Avoidance%2F1998%2Ficc1998.pdf&ei=ZQrVUajBCsrmswabsYHYBA&usg=AFQjCNEEqMAfp8n4x7IU5CKPml9T1WRJqg&bvm=bv.48705608,d.Yms [accessed 03.07.2013]

This document reports on a cooperative agreement between NHTSA and UMTRI entitled Intelligent Cruise Control (ICC) Field Operational Test (FOT). The main goal of the work is to characterize safety and comfort issues that are fundamental to human interactions with an automatic, but driver-supervised, headway-keeping system. Volumes I and II of this report describe the work done to prepare and instrument a fleet of 10 passenger cars with infrared ranging sensors, headway-control algorithms, and driver interface units as needed to provide an adaptive-cruise-control (ACC) functionality, and these volumes present results and findings deriving from operational testing lasting from July 1996 to September 1997. The vehicles were given to 108 volunteer drivers to use for two or five weeks as their personal cars. An extensive data base covering objective and subjective results has been assembled and analyzed. The central finding presented here is that ACC is remarkably attractive to most drivers. The research indicates that, because ACC is so pleasing, people tend to utilize it over a broad range of conditions and to adopt tactics that prolong the time span of each continuous engagement. Notwithstanding having some concerns, field test participants were completely successful at operating ACC over some 35,000 miles of system engagement. In examining the results, the researchers observe that the role played by the driver as the supervisor of ACC entails subtle issues whose long-term safety and traffic impacts are unknown. These issues pertain to the shared control nature of ACC driving requiring a fine match to the perceptual and cognitive behavior of drivers in a safety-central task that affects others driving nearby. Thus, while offering great promise for improving the quality of the driving experience, ACC implies an inherent necessity for human-centered design. Volume III of the report covers the operation of a serial string or dense cluster of passenger cars equipped with an ACC system (see separate documentation page in Volume III).

Flinsenberg ICM (2004). Route Planning Algorithms for Car Navigation. PhD Thesis, Technische Universiteit Eindhoven, The Netherlands.

Car navigation systems are being offered as a special feature of new cars of an increasing number of car-brands. These car navigation systems are capable of taking over some of the tasks that are performed by the driver such as reading the map and determining the best route to the destination. They should also take daily congestion patterns into account. Because a car navigation system uses a built-in computer to determine a route, it can compare many different routes and the user expects the system to determine the best possible, or optimum route fast. This thesis is concerned with route planning algorithms that enable a car navigation system to plan optimum routes on very large real-world networks in very little time, taking daily congestion patterns into account.

General Motors Corporation (2005). Automotive Collision Avoidance System Field Operational Test (ACAS FOT) Final Program Report. Report No DOT HS 809 886 prepared for

the Office of Impaired Driving and Occupant Protection, National Highway Traffic Safety Administration, U.S. Department of Transportation, Washington, USA. http://www.nhtsa.gov/DOT/NHTSA/NRD/Multimedia/PDFs/Crash%20Avoidance/2005/ACAS%20FOT%20Final%20Program%20Report%20DOT%20HS%20809%20886.pdf [accessed 02.04.2013]

The Automotive Collision Avoidance System field operational test (or ACAS FOT) program was led by General Motors (GM) under a cooperative agreement with the U.S. Department of Transportation. This report summarizes the activities of the entire program, with an emphasis on efforts that occurred after the last program Annual Report. The ACAS system consisted of Adaptive Cruise Control (ACC) and Forward Collision Warning (FCW) systems that were developed and integrated by GM and Delphi Corporation in preparation for the FOT conducted by the University of Michigan Transportation Research Institute. The FOT involved exposing a fleet of 11 ACAS-equipped Buick LeSabre cars to 12 months of naturalistic driving (137,000 miles of driving were accumulated). The 96 test participants were lay drivers from southeastern Michigan who drove these cars as their personal vehicles for several weeks. Data gathered included over 300 data signals, including video samples of the forward driving scene and driver's face. ACC was found to be benign from a traffic safety perspective. Both ACC and FCW reduced the occurrence of short (e.g., <1 sec) headways, with the ACC reductions being substantially more marked and robust across driving conditions. While incidents were found during manual driving in which the FCW may have contributed to a timely driver response to an emerging rear-end crash conflict, the frequency or magnitude of such conflicts were unaffected by FCW presence. Questionnaire, interview, and focus group data indicated that ACC was widely accepted, whereas FCW acceptance was mixed. These data have suggested numerous methods for reducing the occurrence of FCW false alarms that should lead to broader FCW customer acceptability.

Godbole DN, Hagenmeyer V, Sengupta R, Swaroop D (1997). Design of emergency manoeuvres for automated highway system: obstacle avoidance problem. Proceedings of the 36th IEEE Conference on Decision and Control.

In this paper, we analyse the problem of obstacle avoidance in an Automated Highway System (AHS). For a given scenario (traffic state, obstacle location, etc.), we synthesize the best possible avoidance maneuver for each vehicle. Our aim is to obtain a distributed strategy so that the obstacle avoidance maneuvers can be executed be vehicle based controllers (with some intervehicle communication) as opposed to a roadside controller making decisions and communicating it to the individual vehicles.

Grumert E, Ma X, Tapani A (2013). Effects of a cooperative variable speed limit system on traffic performance and exhaust emissions. Annual Meeting of the Transportation Research Board, Washington DC, USA.

Variable Speed Limit Systems (VSLS) where variable message signs show speed limits based on traffic or road conditions exist on motorways in many countries. The purpose of the VSLS is to decrease the number of accidents while increasing efficiency of traffic system. Cooperative systems are a type of intelligent transport system that has received increasing interest lately. The central part of a cooperative system is communication between vehicles and/or vehicles and the infrastructure. In this paper, a cooperative systems extension of a VSLS is proposed and evaluated by means of microscopic traffic simulation. In the proposed cooperative VSLS, communication between the vehicles and the infrastructure is made available via a roadside unit communicating the speed limits to vehicles upstream on the road. Both aggregate and microscale emission models are used to estimate emission from vehicle states in traffic flow. The results of the study show that the cooperative VSLS has a potential to contribute to flow harmonization and to reduce environmental impacts. The emission estimates in the study are dependent on the emission models being applied.

Habenicht S, Winner H, Bone S, Sasse F, Korzenietz P (2011). A maneuver-based lane change assistance system. 2011 IEEE Intelligent Vehicles Symposium (IV), 375-

380. http://www.fzd.tu-darmstadt.de/media/fachgebiet_fzd/publikationen_3/2011_1/2011_Habenicht_Maneuverbased_Lane_Change_Assistance.pdf [accessed 07.11.2013]

Lane change is a very demanding maneuver. Therefore, a maneuver-based lane change assistance system has been developed which, by means of a single-task-combining assistance concept, supports the driver from the driver's first lane change intention through the final movement of the vehicle from the initial to the target lane, without automatization of the vehicle guidance. The maneuver recommendation covers lane change timing, lane change direction as well as the required acceleration or deceleration. The system architecture with its modules to estimate the maneuver recommendation is described as well as the HMI which presents the information to the driver on a display and by an additional steering-wheel torque. A core assistance module geared to the driver's needs and the detection of driver's intention based on motivators, inhibitors and indicators is explained in detail.

Hallé S, Chaib-draa B (2005). A collaborative driving system based on multiagent modelling and simulations. Transportation Research Part C: Emerging Technologies 13(4), 320-345.

Collaborative driving is a growing domain of intelligent transportation systems (ITS) that makes use of communications to autonomously guide cooperative vehicles on an automated highway system (AHS). In this paper, we address this issue by using a platoon of cars considered as more or less autonomous software agents. To achieve this, we propose a hierarchical driving agent architecture based on three layers (guidance layer, management layer and traffic control layer). This architecture has been used to develop centralized platoons, where the driving agent of the head vehicle coordinates other driving agents by applying strict rules, and decentralized platoons, where the platoon is considered as a group of driving agents with a similar degree of autonomy, trying to maintain a stable platoon. The latter decentralized model mainly considers an agent teamwork model based on a multiagent architecture, known as STEAM. The centralized and decentralized coordination models are finally compared using results from simulation scenarios that highlight safety, time efficiency and communication efficiency aspects for each model.

Hedrick J, Chen Y, Mahal S (2001). Optimized Vehicle Control/Communication Interaction in an Automated Highway System. California PATH Research Report UCB-ITS-PRR-2001-29, University of California at Berkeley, USA. http://www.path.berkeley.edu/PATH/Publications/PDF/PRR/2001/PRR-2001-29.pdf [accessed 10.01.2014]

One of the main goals of an Automated Highway System environment is to increase the throughput of vehicles traveling on the highway. By moving vehicles in a platoon (a group of tightly spaced vehicles), the traffic flow capacity can be greatly increased. The control law developed for vehicles to safely travel in a platoon is dependent on the lead and preceding vehicle's velocity and acceleration profiles. This information guarantees string stability (i.e. spacing errors between vehicles do not increase down the chain of vehicles). These profiles are transmitted to the vehicle via wireless communication. Unfortunately, a perfect wireless communication does not exist. In this paper, the effects of various communication delays on string stability will be analyzed. The concept of platooning in an Automated Highway System (AHS) allows a group of vehicles to share information across a wireless local area network (LAN). This sharing of information allows vehicles belonging to the same platoon to maintain a smaller intervehicular spacing that would otherwise be possible. Of course, once these platoon/LANs exist on the AHS, a method must exist to add vehicles to a platoon and also to remove vehicles from a platoon. This report also develops handshaking protocols that allow the LANs associated with each platoon to reconfigure themselves in response to any physical changes to the composition of the platoon. Since the LANs operate over a wireless communication system, these protocols are designed to be robust towards packet losses, as well as satisfying certain safety and liveness conditions.

Hegeman G (2002). Green light for ISA? The effect of intelligent speed adaptation on the traffic flow. ICTCT (International Co-operation on Theories and Concepts in Traffic Safety)

Workshop on intelligent speed adaptation, Nagoya, Japan. http://www.ictct.org/workshop.php?workshop_nr=16 [accessed 02.04.2013]

Intelligent Speed Adaptation (ISA) is a system that limits vehicles at the speed limit. Research in Sweden, England and the Netherlands has shown that it has a positive impact on safety. The current study compares traffic flows under ISA with those in the present of regular traffic lights. The model results show that ISA is able to replace traffic lights at crossroads with a clear major flow. This important positive effect will improve the support for ISA, which was originally designed for safety reasons.

Hoeger R, Zeng H, Hoess A, Kranz Th, Boverie S, Strauss M, Jakobsson E, Beutner A, Bartels A, To T-B, Stratil H, Fürstenberg K, Ahlers F, Frey E, Schieben A, Mosebach H, Flemisch F, Dufaux A, Manetti D, Amditis A, Mantzouranis I, Lepke H, Szalay Z, Szabo B, Luithardt P, Gutknecht M, Schoemig N, Kaussner A, Nashashibi F, Resende P, Vanholme B, Glaser S, Allemann P, Seglö F, Nilsson A (2011). The Future of Friving – Final Report. Deliverable D61.1 of HAVEit ICT for intelligent vehicles and mobility services European Project. http://haveit-eu.org/LH2Uploads/ItemsContent/24/HAVEit_212154_D61.1_Final_Report_Published.pdf [accessed 03.04.2013]

HAVEit is an essential step forward to the realization of the long-term vision of highly automated driving for intelligent transport. The project developed, validated and demonstrated important intermediate steps towards highly automated driving. The results offer a high potential for exploitation within 3-7 years from project end. In the longer term they also form the ideal basis to integrate further next generation ADAS and drive train components that offer highly automated functionalities. HAVEit significantly contributes to increased traffic safety and fuel efficiency for passenger cars, buses and trucks. The significant HAVEit safety, efficiency and comfort impact was generated by three aspects: (i) At first a layered approach has been realized for the interplay between driver and the co-driving system, which optimizes the task repartition between driver and co-driving system in monotonous driving situations like traffic jams or long distance driving as well as in demanding situations like road works. This approach for optimum task repartition between the driver and the co-driving system takes driver alertness into account and forms the basis for all HAVEit applications addressing the fact that 95 percent of all accidents are driver related and more than 22 percent are related to missing driver alertness. Therefore, it is of utmost importance to ensure that the driver is in the loop when required. It has to be ensured that he or she is able to react properly in a potentially critical situation. Within HAVEit, a approach was be developed that is relatively new in automotive, but has been successfully implemented in automation concepts of other domains like aviation: Instead of just switching off an ADAS system in case of an impending potentially critical situation, a progressive step-by-step-approach was used to transfer the driving task back from the automated system to the driver. The interaction starts quite early in the event chain, i.e. few seconds before a potentially critical situation occurs. It brings the driver back into the loop in advance of the critical situation and provides him or her with the optimum level of automation and assistance needed in critical situations. (ii) Secondly, a vehicle architecture scalable in terms of safety from fail silent to failure robust with advanced redundancy management was developed and successfully implemented. A further impor-tant focus of the architecture was enabling a rapid market introduction by usind technologies which are close to series development (CSC). Therefore, for less safety relevant system components a fail-safe ECU compliant with the Autosar standard and development methodology was developed and implemented (XCC). The aim of this development was to perfectly match the needs and require-ments of highly automated vehicle applications and to arrive at optimal system availability and reliability. Addressing safety issues in a proper way in particular represents a key issue in steer-by-wire (e.g. HAVEit Joint System demonstrator) and brake-by-wire vehicles (e.g. HAVEit brake-by-wire truck). In case of the brake by wire truck a pre homologation was done to prove the maturity of the HAVEit architecture approach. (iii) The third measure aimed at developing and validating a next generation advanced driver assistance systems (ADAS) directed towards a higher level of automation in comparison to the current state of the art by integration of hitherto independent ADAS functions. HAVEit implemented 7 pioneering vehicle applications for both passenger cars and trucks aiming at improved safety and comfort as well as improved fuel efficiency. The most important feature for support in terms of mental overload is represented by the automated assistance in roadworks. Key features for driver support in terms of mental

under load are the automated queue assistance and the temporary autopilot. Finally, the active green driving application based on the energy optimizing co-pilot contributes to safe and ecological driving (of trucks and buses) by considering hybrid drive train and digital maps. With these functionalities, HAVEit addressed the most important accident scenarios and ecological needs.

Hogema J, Schuurman H, Tampère CMJ (2002). ISA effect assessment: From driving behavior to traffic flow. ICTCT (International Co-operation on Theories and Concepts in Traffic Safety) Workshop on intelligent speed adaptation, Nagoya, Japan. http://www.ictct.org/workshop.php?workshop_nr=16 [accessed 02.04.2013]

This paper discusses two complementary methods for ISA effect assessment, and how to apply them in a coherent manner. The first level consists of the effects on individual driving behaviour, typically measured with an instrumented vehicle or a driving simulator. Results at this level form the starting point for the second level, which consists of microscopic traffic flow simulation. ISA system characteristics and behavioural effects should be incorporated in the traffic simulation model. The main focus of the paper is on an explorative case study, in which the MIXIC model was applied to study the effects of a dynamic ISA system. The ISA penetration level was varied as an independent variable. The in-car control unit consisted of a mandatory ISA The road configuration that was studied of consisted of a lane drop from 3 to 2 lanes, and the roadside part of the ISA system determined the actual ISA speed limit based on the traffic state. The driver model was adjusted to take into account the set speed of the in-car ISA system, but otherwise, no strategic changes in driving behaviour were assumed. Results shows a decrease in throughput (volume) combined with positive effects on safety (shock waves, speed variance) when ISA is introduced. For the validation of these results more research into the driver's behaviour in the presence of ISA is recommendable.

iMobility Forum (2013). Roadmap Automation in Road Transport. Draft Version, April 2013.

Highly or full automation will contribute to the enhancement of traffic safety by reducing the driver‘s workload, in terms of driving, and minimizing the human errors and incidents due to the driver‘s distraction or reduced vigilance. Another important impact will be the reduction of congestion, mainly in urban areas and on motorways by ensuring an optimal driving, minimizing speed variations and avoiding cases of stop and go. This will reduce vehicle emissions and fuel consumption per kilometre driven and will therefore have a positive impact on the environment. Driving highly or fully automated on public highways could become acceptable within the next ten to fifteen years, once thorny legal issues have been sorted out. Navigating automated in the urban areas requires additional technological development in order to make the cars extremely safe. This document explains the research needs in the area and connects them to its possible benefits and an implementation roadmap. Due to time restrictions automation in dedicated areas has not been included.

Ioannou P, Wang Y, Chang H (2007). Integrated Roadway/Adaptive Cruise Control System: Safety, Performance, Environmental and Near Term Deployment Considerations. California PATH Research Report UCB-ITS-PRR-2007-8, California PATH Program, Institute of Transportation Studies, University of California, Berkeley. http://www.path.berkeley.edu/PATH/Publications/PDF/PRR/2007/PRR-2007-08.pdf [accessed 12.07.2013]

In this project, we present the design, analysis and performance evaluation of the Integrated Roadway/Adaptive Cruise Control System (IRAC) proposed in Task Order (TO) 4242 and studied further in the continuation of TO4242 under TO5501. The IRAC system is a highway traffic control system which integrates ramp metering strategies and a speed control strategy by taking into account highway to vehicle communication, and adaptive cruise control (ACC) system technologies on board of the vehicles. The IRAC system closes the loop of an almost open loop highway traffic system by controlling both the ramps and the speed distribution along the highway lanes. The speed control and the ramp metering strategies are both extended and generalized versions of ALINEA and are designed based on the fundamental flow-density relationship. Available communication technologies such as Dedicated Short Range Communication (DSRC) systems are shown to be adequate to communicate to

vehicles the desired speed limit commands generated by the IRAC system. The IRAC system is evaluated using the I-80 as a site for possible implementation. Real traffic data from the I-80 are used to validate a traffic flow simulation model developed using the software package VISSIM. The validated simulation model is then used to evaluate the IRAC system under different traffic scenarios involving mixed traffic ranging from 0% to 100% ACC vehicles, different traffic flow demands, recurrent and non recurrent disturbances. The results demonstrate that the IRAC system could lead to a better managed traffic flow system where travel times are improved and the flows are smoother leading to potential improvements in safety and environment. While the magnitude of these improvements depends on the traffic situation and traffic disturbances, our results demonstrate consistent improvements under all scenarios considered. The report concludes by suggesting a stretch of the I-80 as a possible site for implementation due to the existence of traffic sensors as part of the Berkeley Highway Laboratory which minimizes changes to the existing infrastructure.

Ioannou PA, Zhang J (2005). Roadway/vehicle integrated transportation system. Workshop on Modeling and Control of Complex Systems, Ayia Napa, Cyprus, June 30 - July 1. http://seacorn.cs.ucy.ac.cy/pub/bscw.cgi/d39710-1/*/MCCS%20Ioannou.pdf [accessed 30.07.2013]

In this paper, we investigate the complexity of a roadway/vehicle integrated transportation system, which might be implemented in the near future. The vehicles are equipped with the Adaptive Cruise Control (ACC) system which allows automatic following in the longitudinal direction. The ACC system proposed in this paper is designed based on traffic, safety, performance and environmental considerations and is integrated with the roadway controller that coordinates the variable speed limits along the freeway and ramp metering. The roadway controller is designed using the Model Predictive Control (MPC) methodology. Its performance is evaluated using a microscopic model, which is constructed and validated with field data from the Berkeley Highway Laboratory (BHL). Our simulation results demonstrate the proposed roadway controller performs well at dissipating traffic congestions and reduces the total travel time (TTT) in the network by up to 12%. The preliminary results motivate several modeling and control issues associated with the complexity of traffic networks.

Jahn O, Möhring RH, Schulz AS, Stier-Moses NE (2005). System-optimal routing of traffic flows with user constraints in networks with congestion. Operations Research 53(4), 600-616.

The design of route guidance systems faces a well-known dilemma. The approach that theoretically yields the systemoptimal traffic pattern may discriminate against some users in favor of others. Proposed alternate models, however, do not directly address the system perspective and may result in inferior performance. We propose a novel model and corresponding algorithms to resolve this dilemma. We present computational results on real-world instances and compare the new approach with the well-established traffic assignment model. The essence of this study is that system-optimal routing of traffic flow with explicit integration of user constraints leads to a better performance than the user equilibrium, while simultaneously guaranteeing superior fairness compared to the pure system optimum.

Jiang R, Wu Q-S (2006). The adaptive cruise control vehicles in the cellular automata model. Physics Letters A 359(2), 99-102.

This Letter presented a cellular automata model where the adaptive cruise control vehicles are modelled. In this model, the constant time headway policy is adopted. The fundamental diagram is presented. The simulation results are in good agreement with the analytical ones. The mixture of ACC vehicles with manually driven vehicles is investigated. It is shown that with the introduction of ACC vehicles, the jam can be suppressed.

Jula H, Kosmatopoulos EB, Ioannou PA (2000). Collision avoidance analysis for lane changing and merging. IEEE Transactions on Vehicular Technology, 49(6), 2295-2308.

One of the riskiest maneuvers that a driver has to perform in a conventional highway system is to merge into the traffic and/or to perform a lane changing maneuver. Lane changing/merging collisions are responsible for one-

tenth of all crash-caused traffic delays often resulting in congestion. Traffic delays and congestion, in general, increase travel time and have a negative economic impact. In this paper, we analyze the kinematics of the vehicles involved in a lane changing/merging maneuver, and study the conditions under which lane changing/merging crashes can be avoided. That is, given a particular lane change/merge scenario, we calculate the minimum longitudinal spacing which the vehicles involved should initially have so that no collision, of any type, takes place during the maneuver. Simulations of a number of examples of lane changing maneuvers are used to demonstrate the results. The results of this paper could be used to assess the safety of lane changing maneuvers and provide warnings or take evasive actions to avoid collision when combined with appropriate hardware on board of vehicles.

Kaparias I, Bell MGH (2009). Testing a reliable in-vehicle navigation algorithm in the field. IET Intelligent Transport Systems 3(3), 314-324.

The results of a field experiment carried out to assess the accuracy and efficiency of a new in-vehicle navigation algorithm, whose aim is to incorporate and consider travel time reliability and route the guided vehicle along uncongested roads, in the absence of real-time traffic information are presented. Using historical travel time profiles deduced from floating vehicle data, the algorithm is implemented in a purpose-developed software tool and tested in the London Congestion Charging Zone. The experiment consists of driving a vehicle along routes computed by the algorithm and comparing the outcome with that of a conventional navigation system installed in a second vehicle. The results indicate that the new algorithm outperforms the conventional system in most cases, thus suggesting that it is a step forward towards a more intelligent navigation system.

Kaparias I, Bell MGH (2010). A reliability-based dynamic re-routing algorithm for in-vehicle navigation. Proceedings of the 13th International IEEE Annual Conference on Intelligent Transportation Systems, Madeira Island, Portugal, 974-979.

This paper presents a new algorithm for a car navigation system, whose purpose is to offer a reliable re-route to the driver in case he/she deviates from the route he/she has been following, or if a traffic incident is reported en route. A reliable route is defined as one that has a low probability of being congested. The new method makes use of the A* route finding algorithm and introduces a link penalizing procedure to avoid unreliable (i.e. potentially congested) and incident affected links in order to re-route the driver from his/her current position to his/her destination, while constraints are imposed on the route output by the algorithm so as to ensure driver acceptability. The new algorithm, called RDIN-R, is first described and then tested through a simulation experiment on the road network of Munich, Germany.

Kaparias I, Bell MGH, Chen Y, Bogenberger, K (2007). ICNavS: a tool for reliable dynamic route guidance. IET Intelligent Transport Systems 1(4), 225-233.

The aim of the study is to devise a new reliable dynamic route guidance approach by integrating the A algorithm, the concept of reliability and an existing route guidance method into a single package. A new purpose-developed software tool, the Imperial College Navigation Software (ICNavS), is presented, so as to implement and demonstrate the new approach on a real road network, using simulated data. A summary of the background of the program is given, followed by a procedure developed in order to model the features of real road networks as well as missing data. Then, a simulation experiment on a part of West London's road network is carried out and the results are presented.

Kavathekar P (2012). Cognitive Vehicle Platooning in the ERA of Automated Electric Transportation. MSc Thesis in Electrical Engineering, Utah State University, USA. http://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=2396&context=etd [accessed 09.04.2013]

Vehicle platooning is an important innovation in the automotive industry that aims at improving safety, mileage, efficiency, and the time needed to travel. This research focuses on the various aspects of vehicle platooning, one of the important aspects being analysis of different control strategies that lead to a stable and robust platoon.

Safety of passengers being a very important consideration, the control design should be such that the controller remains robust under uncertain environments. As a part of the Department of Energy (DOE) project, this research also tries to show a demonstration of vehicle platooning using robots. In an automated highway scenario, a vehicle platoon can be thought of as a string of vehicles, following one another as a platoon. Being equipped by wireless communication capabilities, these vehicles communicate with one another to maintain their formation as a platoon, hence are "cognitive". Autonomous capable vehicles in tightly spaced, computer-controlled platoons will lead to savings in energy due to reduced aerodynamic forces, as well as increased passenger comfort since there will be no sudden accelerations or decelerations. Impacts in the occurrence of collisions, if any, will be very low. The greatest benefit obtained is, however, an increase in highway capacity, along with reduction in traffic congestion, pollution, and energy consumption. Another aspect of this project is the automated electric transportation (AET). This aims at providing energy directly to vehicles from electric highways, thus reducing their energy consumption and CO2 emission. By eliminating the use of overhead wires, infrastructure can be upgraded by electrifying highways and providing energy on demand and in real time to moving vehicles via a wireless energy transfer phenomenon known as "wireless inductive coupling". The work done in this research will help to gain an insight into vehicle platooning and the control system related to maintaining the vehicles in this formation.

Kessler C, Etemad A, Alessandretti G, Heinig K, Chalmers S, Brouwer R, Cserpinszky A, Hagleitner W, Benmimoun M (2012). Final Report. Deliverable D11.3 of the euroFOT ICT for Cooperative Systems European Project. http://www.eurofot-ip.eu/download/library/deliverables/eurofotsp120121212v11dld113_final_report.pdf [accessed 03.04.2013]

The European project euroFOT developed the first large scale Field Operational Test, with a focus on Intelligent Vehicles equipped with Advanced Driver Assistance Systems (ADAS) and used by ordinary drivers in real traffic. Its motivation was to evaluate different on-board functions with regard to traffic safety, efficiency and the environment. Also usability and acceptance were exhaustively evaluated. Participants either owned their test vehicles, leased them during the experiment or took part as professional drivers employed by freight companies. Data acquisition techniques ranged from questionnaires to continuous recording of vehicle signals, and also, in some cases, additional instrumentation with video and extra sensors. The following functions have been considered for passenger cars and trucks: longitudinal control functions: Forward collision warning (FCW), adaptive cruise control (ACC), speed regulation system (SRS); lateral control functions: Blind spot information (BLIS), lane departure warning (LDW), impairment warning (IW); advanced applications: Curve speed warning (CSW), fuel efficiency advisor (FEA), , safe human machine interface (SafeHMI). The project started in May 2008 and ended with a Final Event at the Autoworld Museum in Brussels, Belgium in June 2012. Several hundred Terabyte of data have been collected from around 1200 drivers driving for more than 35 million km. This deliverable summarizes the three major phases of the project: specification/piloting, execution and data analysis. Field tests are a well-known method for manufacturers to look into the way their products are used by the consumer. For the first time euroFOT has brought together major European vehicle manufacturers and research institutes in order to collect data from different ADAS equipped vehicles in different countries but all with the same task: ordinary driving on real roads. Participants drove vehicles which did not look very different from standard vehicles and could be driven without special instructions. It was therefore necessary to assemble complex computer and sensor hardware, flying wires, instrument brackets or even maintenance intensive software into a nice and clean package, requiring low maintenance and worthy of the newly acquired customer vehicle. The results achieved are now available and summarised in a number of public deliverables. They can be used by research organizations, public bodies and other stakeholders in Europe and elsewhere to support the wider deployment of ADAS. The analysis first focused on system performance and user aspects, especially in dangerous situations which could potentially lead to accidents (which have been defined as 'incidents'). This was followed by impact studies on traffic safety, efficiency and environment. Finally, the project considered a Cost Benefit Analysis (CBA).

Kesting A, Treiber M, Helbing D. (2010). Enhanced intelligent driver model to access the impact of driving strategies on traffic capacity. Philosophical Transactions of the Royal Society A 368, 4585-4605.

With an increasing number of vehicles equipped with adaptive cruise control (ACC), the impact of such vehicles on the collective dynamics of traffic flow becomes relevant. By means of simulation, we investigate the influence of variable percentages of ACC vehicles on traffic flow characteristics. For simulating the ACC vehicles, we propose a new car following model that also serves as the basis of an ACC implementation in real cars. The model is based on the intelligent driver model (IDM) and inherits its intuitive behavioural parameters: desired velocity, acceleration, comfortable deceleration and desired minimum time headway. It eliminates, however, the sometimes unrealistic behaviour of the IDM in cut-in situations with ensuing small gaps that regularly are caused by lane changes of other vehicles in dense or congested traffic. We simulate the influence of different ACC strategies on the maximum capacity before breakdown and the (dynamic) bottleneck capacity after breakdown. With a suitable strategy, we find sensitivities of the order of 0.3, i.e. 1 per cent more ACC vehicles will lead to an increase in the capacities by about 0.3 per cent. This sensitivity multiplies when considering travel times at actual breakdowns.

Kesting A, Treiber M, Schönhof M, Helbing D (2007a). Extending adaptive cruise control to adaptive driving strategies. Transportation Research Record: Journal of the Transportation Research Board 2000, 16-24.

An adaptive cruise control (ACC) strategy is presented in which acceleration characteristics, that is, driving styles, automatically adapt to different traffic situations. The three components of the concept are the ACC itself, implemented in the form of a car-following model; an algorithm for the automatic real-time detection of the traffic situation based on local information; and a driving strategy matrix to adapt the driving characteristics—that is, the parameters of the ACC controller—to the traffic conditions. As an option, intervehicle and roadside-to-car communication can be used to improve the accuracy for determining the local traffic states. The complete concept was simulated microscopically on a road section with an on-ramp bottleneck by using real loop-detector data for an afternoon peak period as input for the upstream boundary. A small percentage of traffic-adaptive ACC vehicles, a relatively modest local change in the maximum free flow, improves traffic stability and performance significantly. Although the traffic congestion in the reference case was completely eliminated when a proportion of 25% of ACC vehicles was simulated, travel times for the drivers were reduced in a relevant way for much lower penetration rates. The presented results are largely independent of details of the model, the boundary conditions, and the type of road inhomogeneity.

Kesting A, Treiber M, Schönhof M, Helbing D (2008). Adaptive cruise control design for active congestion avoidance. Transportation Research Part C: Emerging Technologies 16(6), 668-683.

We present an adaptive cruise control (ACC) strategy where the acceleration characteristics, that is, the driving style automatically adapts to different traffic situations. The three components of the concept are the ACC itself, implemented in the form of a car-following model, an algorithm for the automatic real-time detection of the traffic situation based on local information, and a strategy matrix to adapt the driving characteristics (that is, the parameters of the ACC controller) to the traffic conditions. Optionally, inter-vehicle and infrastructure-to-car communication can be used to improve the accuracy of determining the traffic states. Within a microscopic simulation framework, we have simulated the complete concept on a road section with an on-ramp bottleneck, using empirical loop-detector data for an afternoon rush-hour as input for the upstream boundary. We found that the ACC vehicles improve the traffic stability and the dynamic road capacity. While traffic congestion in the reference scenario was completely eliminated when simulating a proportion of 25% ACC vehicles, travel times were already significantly reduced for much lower penetration rates. The efficiency of the proposed driving strategy even for low market penetrations is a promising result for a successful application in future driver assistance systems.

Kesting A, Treiber M, Schonhof M, Kranke F, Helbing D (2007b). Jam-avoiding adaptive cruise control (ACC) and its impact on traffic dynamics. In Traffic and Granular Flow 2005, Springer, 633-643.

Adaptive-Cruise Control (ACC) automatically accelerates or decelerates a vehicle to maintain a selected time gap, to reach a desired velocity, or to prevent a rear-end collision. To this end, the ACC sensors detect and track the vehicle ahead for measuring the actual distance and speed difference. Together with the own velocity, these input variables are exactly the same as in car-following models. The focus of this contribution is: What will be the impact of a spreading of ACC systems on the traffic dynamics? Do automated driving strategies have the potential to improve the capacity and stability of traffic flow or will they necessarily increase the heterogeneity and instability? How does the result depend on the ACC equipment level? We discuss microscopic modeling aspects for human and automated (ACC) driving. By means of microscopic traffic simulations, we study how a variable percentage of ACC-equipped vehicles influences the stability of traffic flow, the maximum flow under free traffic conditions until traffic breaks down, and the dynamic capacity of congested traffic. Furthermore, we compare different percentages of ACC with respect to travel times in a specific congestion scenario. Remarkably, we find that already a small amount of ACC equipped cars and, hence, a marginally increased free and dynamic capacity, leads to a drastic reduction of traffic congestion.

Kianfar R (2013). On Control Strategy and Safety Verification of Automated Vehicles. Thesis for the Degree of Licentiate of Engineering, Department of Signals and Systems, Chalmers University of Technology, Göteborg,
Sweden. http://publications.lib.chalmers.se/records/fulltext/173698/173698.pdf [accessed 09.04.2013]

Over the last few decades, congested traffic network have become a serious problem in many countries. Congestions result in time losses, increase of fuel consumption, increase of CO2 emissions and also raise the risk of accidents. While developing the road networks is not a feasible solution in many countries, intelligent transportation systems (ITS) may contribute to mitigate such problems. It is known that human errors or the delay in human's reactions is the main cause of many of the problem in current transportation systems. Hence, cooperative driving or in particular vehicle platooning is an example of an ITS which exploits advanced technology like, on-board vehicle sensors, wireless communication and control engineering to improve the traffic situation. However, development of such complex system requires a reliable control algorithm which can guarantee passenger safety and comfort while satisfying certain specifications. This thesis deals with the development of a distributed control strategy for a vehicle platoon. The aim of the control strategy is to enable platooning with a short inter-vehicle distance while fulfilling the so called string stability criterion and maintaining the safety and comfort. The control design is divided into longitudinal and lateral control of vehicle. Simulation and experimental results indicate that string stability in longitudinal and lateral direction can be achieved using the proposed control strategy. Furthermore, a safety verification method based on reachability analysis technique and invariant set theory is proposed for safety analysis of such autonomous systems for a given cooperative controller. The safety verification method is extended to account for model uncertainty and measurement noises. The findings in this thesis are verified through simulations and field tests.

Knake-Langhorst S, Löper C, Schebitz N, Köster F (2013). Merge and exit support for the driver. ATZ worldwide 115(4), 82-87.

The Institute of Transportation Systems of the German Aerospace Center has developed an advanced driver assistance system which supports the driver in performing merge and exit processes. Thus, the system helps to prevent critical situations and accidents. The support ranges from information und warning strategies to the automation of longitudinal control.

Lavien T, Oron-Gilad T, Meyer J (2011). Aesthetics and usability of in-vehicle navigation displays. International Journal of Human-Computer Studies 69, 80-99.

This research evaluates the aesthetics and usability of various in-vehicle electronic navigation map configurations. Study 1 adapted the aesthetics scale (Lavie and Tractinsky, 2004) to accommodate evaluations of map displays. Study 2 examined map displays that vary in the amount of data presented, their abstraction level and color schema, using objective and subjective usability measures. Maps with minimal detail produced best performances and highest evaluations. Abstractions were found to be advantageous when combined with reduced amount of detail and specific color schemas. Moderate abstractions were sufficient for obtaining the desired benefits. The color schema mainly affected the objective measures, pointing to the importance of good contrast between the cursor and the map colors. Study 3 further examined map schemas. Color schemas again had no effect on the perceptions of aesthetics and usability. Overall, similar results and high correlations were found for the perceived aesthetics and usability scales, indicating the connection between perceived aesthetics and usability. Lower correlations were found between the actual usability (performance) and the aesthetics scale. Finally, users' usability evaluations were not always in line with their actual performance, pointing to the importance of using objective usability measures.

Lee J, Forlizzi J, Hudson SE (2008). Iterative design of MOVE: A situationnally appropriate vehicle navigation system. International Journal of Human-Computer Studies 66, 198-215.

Drivers need assistance when navigating an unfamiliar route. In-vehicle navigation systems have improved in recent years due to the technology advances, but are sometimes problematic because of information overload while driving. To address the attentional demands of reading a map while driving, we have developed the maps optimized for vehicular environments (MOVE) in-car navigation display, which provides situationally appropriate navigation information to the driver through optimization of map information. In this paper, we describe the iterative design and evaluation process that shaped the MOVE system. We describe early map reading and navigation studies that led to early designs for our system. We present a study on visual search tasks that refined the renditions used for the system. Finally, we present a study on the effectiveness of several variations of a contextually optimized route map visualization with a desktop steering system. The result of this study shows that MOVE's contextually optimized navigation information can reduce the driver's perceptual load significantly. Our laboratory experiment shows that the total map display fixation time was decreased six-fold, and the number of glances to interpret the map display were decreased about threefold, when comparing the contextually optimized display to a static display.

Lee J, Yang J (2012). A fast and scalable re-routing algorithm based on shortest path and genetic algorithms. International Journal of Computers Communications & Control 7(3), 482-493.

This paper presents a fast and scalable re-routing algorithm that adapts to dynamically changing networks. The proposed algorithm, DGA, integrates Dijkstra's shortest path algorithm with the genetic algorithm. Dijkstra's algorithm is used to define the predecessor array that facilitates the initialization process of the genetic algorithm. Then the genetic algorithm keeps finding the best routes with appropriate genetic operators under dynamic traffic situations. Experimental results demonstrate that DGA produces routes with less traveling time and computational overhead than pure genetic algorithm-based approaches as well as Dijkstra's algorithm in large scale routing problems.

Lee GD, Kim SW (2002). A longitudinal control system for a platoon of vehicles using a fuzzy-sliding mode algorithm. Mechatronics 12(1), 97-118.

Recently much interest has been concentrated on the development of intelligent vehicle highway systems (IVHS) since they are considered to have the ability to effectively handle the traffic problems of the current industrialized society. In this context, this paper presents a control algorithm for a platoon of vehicles, which is one of the most important research areas of IVHS. The suggested control algorithm consists of a headway controller and a velocity/acceleration controller. The headway distance to the preceding vehicle and its changing rate along with the velocity of the leading vehicle are used to derive the headway control laws without using headway information from other vehicles. The velocity/acceleration controller, which controls the throttle and the brake of the controlled vehicle according to commands from the headway controller, is designed by using a

fuzzy-sliding mode control (FSMC) algorithm, which does not require exact models of vehicles. It is shown that the proposed control algorithm guarantees string stability under several conditions even when each vehicle has different performance. The good performance of the suggested control algorithm is illustrated by simulations and road tests in which vehicles follow one another at 10-m spacings at a peak velocity of 80 km/h.

Li PY, Shrivastava A (2002). Traffic flow stability induced by constant time headway policy for adaptive cruise control vehicles. Transportation Research Part C: Emerging Technologies 10(4), 275-301.

This paper is concerned with the traffic flow stability/instability induced by a particular adaptive cruise control (ACC) policy, known as the ''constant time headway (CTH) policy''. The control policy is analysed for a circular highway using three different traffic models, namely a microscopic model, a spatially discrete model, and a spatially continuous model. It is shown that these three different modeling paradigms can result in different traffic stability properties unless the control policy and traffic dynamics are consistently abstracted for the different paradigms. The traffic dynamics will, however, be qualitatively consistent across the three modeling paradigms if a consistent biasing strategy is used to adapt the CTH policy to the various modeling frameworks. The biasing strategy determines whether the feedback quantity for use in the control, is taken colocatedly, downstream or upstream to the vehicle/section/highway location. For ACC vehicles equipped with forward looking sensors, the downstream biasing strategy should be used. In this case, the CTH policy induces exponentially stable traffic flow on a circular highway in all three modelling frameworks. It is also shown that traffic flow stability will be preserved for an open stretch highway if the entry and exit conditions are made to observe the downstream biasing strategy.

Liu R, Tate J (2004). Network effects of intelligent speed adaptation systems. Transportation 31(3), 297-325.

Intelligent Speed Adaptation (ISA) systems use in-vehicle electronic devices to enable the speed of vehicles to be regulated automatically. They are increasingly appreciated as a flexible method for speed management and control particularly in urban areas. On-road trials using a small numbers of ISA equipped vehicles have been carried out in Sweden, the Netherlands, Spain and the UK. This paper describes the developments made to enhance a traffic microsimulation model in order to represent ISA implemented across a network and the impact of this on the networks. The simulation modelling of the control system is carried out on a real-world urban network, and the impacts on traffic congestion, speed distribution and the environment assessed. The results show that ISA systems are more effective in less congested traffic conditions. Momentary high speeds in traffic are effectively suppressed, resulting in a reduction in speed variation which is likely to have a beneficial impact on safety. Whilst ISA reduces excessive traffic speeds in the network, it does not affect average journey times. In particular, the total vehicle-hours travelling at speeds below 10 km/hr have not changed, indicating that the speed control had not induced more slow-moving queues to the network. A statistically significant, eight percent, reduction in fuel consumption was found with full ISA penetration. These results are in accordance with those from field trials and they provide the basis for cost-benefit analyses on introducing ISA into the vehicle fleet. However, contrary to earlier findings from the Swedish ISA road trials, this study suggested that ISA is likely to have no significant effect on emission of gaseous pollutants CO, NOx and HC.

Ma R, Kaber DB (2007). Effects of in-vehicle navigation assistance and performance on driver trust and vehicle control. International Journal of Industrial Ergonomics 37, 665-673.

Driver trust in in-vehicle navigation systems may be an important factor influencing use of such automation. This research investigated the trust effect of in-vehicle navigation aiding performance that degraded over time and assessed differences in trust among automated versus human aids in a simulated driving task. Twenty participants drove through a suburb area following traffic signs and directions from one of the navigation aids, the human aid via a cell phone or the in-vehicle automation aid presented on a separate simulator display, with different levels of aid information accuracy in each trial (100%, 80% and 60%). A control condition was also investigated to assess any benefit of aiding in which participants were presented with a telemarketing survey instead of navigation information. A 2×4 mixed experimental design was used with the two levels of aid type

(manipulated between-subjects) and the four levels of information accuracy (manipulated within-subjects). Driver trust was measured using a subjective survey of initial trust expectations, as well as subjective ratings of trust at the close of each trial. Driving speed control deviations and the number of errors in driver conformance with posted signs and navigation instructions were recorded. In agreement with prior work in other domains, results demonstrated drivers had a higher initial trust expectation for the automated aid than the human aid. However, once the automated aid was used, trust declined dramatically across degrading aid performance conditions. In general, there was a trend for trust to decrease more sharply with the automated aid than the human aid, but there was no statistical difference among the aids. Trust declined as both aids degraded in performance. Driving errors also increased as the navigation aid performance decreased, and the control condition produced the highest number of errors. This study demonstrated the role of driver trust in in-vehicle navigation aid use and has implications for designing navigation systems that support trust and performance.

May A, Ross T, Osman Z (2005).The design of next generation in-vehicle navigation systems for the older driver. Interacting with Computers 17, 643-659.

It has been proposed that the current design of in-vehicle displays may not be appropriate for the older driver. This paper describes an empirical, road-based investigation of the benefits to older and younger drivers of providing landmarks within the instructions presented by an in-vehicle navigation system. Thirty two participants navigated a challenging urban route using either landmarks or distance information to identify the location of forthcoming manoeuvres. A range of driver behaviour measures were collected, including visual glance data, driving errors, driver workload, navigation errors, navigation confidence, and pre and post-trial driver attitudinal responses. Results show that, for older and younger drivers, landmarks reduced the time spent glancing to a visual display, reduced navigation and driving errors, and influenced driver confidence. There were some key differences between the older and younger drivers. The wider implications for the design of in-car interfaces for the older driver are discussed.

Marchau V, van Nes N, Walta L, Morsink P (2010). Enhancing speed management by in-car speed assistance systems. IET Intelligent Transportation Systems 4(1), 3-11.

Intelligent speed adaptation (ISA) systems support drivers to comply with the legal speed limits. This functionality is expected to become increasingly important in speed management if integrated well with more traditional speed management measures. Based on state-of-the-art scientific literature, this study describes the current knowledge on the effects of ISA and the willingness of stakeholders to adopt ISA. Although the expected effects of the various ISA types are promising and stakeholders are willing to adopt ISA, the large scale deployment of ISA is still lacking. The main challenges with respect to ISA deployment relate to its social and political feasibility. Overall, a more active role of public authorities is recommended on ISA deployment, especially for ISA systems that actively intervene in the driving task.

Maihöfer C, Brenzel C, Coletti L, Provera M, Nelisse M, Verburg D, Schulz WH, Tian J, Burmeister H (2004). Final Report 01.08.2001 – 31.07.2004. Deliverable D15 of CarTALK IST European
Project. http://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1066&context=csse_fac [accessed 21.04.2013]

The CarTALK 2000 consortium brought together the extensive knowledge of the leading European manufacturers of vehicles, vehicle components and communication systems, plus renowned research institutes. The seven partners DaimlerChrysler, CRF, BOSCH, Siemens, TNO, University of Stuttgart and University of Cologne focussed its research activities on safety related communication based driver assistance systems. All major work tasks ended up in deliverables, conference or journal publications, three patent applications and finally they all converged into the demonstrator system. In the final demonstration in July in Balocco, the CarTalk consortium has demonstrated its result with six probe vehicles and a comprehensive simulation environment for the three application clusters: Information & Warning Functions (IWF), Communication-Based Longitudinal Control (CBLC), and Co-operative Driver Assistance (CODA). Apart from technological goals, CarTALK 2000 actively addressed market introduction strategies in particular addressing the penetration problem, including cost/benefit analyses,

and legal aspects. The socio-economic assessment has been carried out for the basic warning function from the IWF class and for the early braking function from the CBLC class. In short, both systems, basic warning and early braking will lead to significant benefits by reducing accidents and hence are desirable from a societal point of view. The capacity effect as result of decrease of congestions caused by congestion is positive, but plays only a minor role for the total benefits. The consortium aimed at the standardisation and pave the way for bringing these systems to the European market. For standardization, the Car-to-Car Communication Consortium was founded including not only the CarTALK vehicle manufacturers DaimlerChrysler and Fiat but also BMW and VW/Audi. More European vehicle manufacturers and major equipment suppliers are supposed to join soon. The report summarises the project results.

McNally MG, Marca JE, Rindt CR, Koos AM (2003). TRACER: In-vehicle, GPS-based, Wireless Technology for Traffic Surveillance and Management. California PATH Research Report UCB-ITS-PRR-2003-23, California Partners for Advanced Transit and Highways. http://escholarship.org/uc/item/5sp425vb [accessed 13.11.2013]

The fundamental principle of intelligent transportation systems is to match the complexity of travel demands with advanced supply-side analysis, evaluation, management, and control strategies. A fundamental limitation is the lack of basic knowledge of travel demands at the network level. Modeling and sensor technology is primarily limited to aggregate parameters or micro-simulations based on aggregate distributions of behavior. Global Positioning Systems (GPS) are one of several available technologies which allow individual vehicle trajectories to be recorded and analyzed. Potential applications of GPS which are relevant to the ATMS Testbed are implementation in probe vehicles to deliver real-time performance data to complement loop and other sensor data and implementation in vehicles from sampled households to record route choice behavior. An Extensible GPS-based in-vehicle Data Collection Unit (EDCU) has been designed, tested, and applied in selected field tests. Each unit incorporates GPS, data logging capabilities, two-way wireless communications, and a user interface in an extensible system which eliminates driver interaction. Together with supporting software, this system is referred to as TRACER. The design and initial implementation tests Testbed are presented herein. This research is a continuation in PATH MOU 3006; selected portions of the interim report for that MOU are repeated here to provide a complete overview of the research effort.

Michael JB, Godbole DN, Lygeros J, Sengupta R (1998). Capacity analysis of traffic flow over a single-lane Automated Highway System (AHS). ITS Journal - Intelligent Transportation Systems Journal: Technology, Planning, and Operations 4(1-2), 119-122.

We calculate bounds on per-lane Automated Highway System (AHS) capacity as a function of vehicle capabilities and control system information structure. We assume that the AHS lane is dedicated for use by fully automated vehicles. Capacity is constrained by the minimum inter-vehicle separation necessary for safe operation. A methodology for deriving the safe minimum inter-vehicle separation for a particular safety criterion is presented. The inter-vehicle separation, which depends on the vehicle braking capability, control loop delays and operating speed, is then used to compute site-independent upper bounds on AHS capacity for a given mix of vehicle classes. The sensitivity of the capacity with respect to the degree of inter-vehicle cooperation, check-in policies (governing minimum acceptable vehicle-braking capability), highway speed limits, and lane-use policies (governing the sharing of a lane by multiple vehicle classes) is also investigated.

Minderhoud MM (1999). Supported Driving: Impacts on Motorway Traffic Flow. PHD Thesis, TRAIL Thesis Series T99/4, The Netherlands TRAIL Research School, Delft University Press, The Netherlands. http://repository.tudelft.nl/assets/uuid:2c3220ef-d60c-4a2a-8f05-89b09ab5b57b/ceg_minderhoud_19990907.PDF [accessed 02.04.2013]

Growing car use is one of today's major problems of economic centres all around the world. The users of the road transportation system in these regions suffer from daily congestion and long travel times, resulting in individual inconvenience and substantial economic losses. It is therefore a great challenge to both policy makers and researchers to seek for solutions which contribute to a more efficient transportation system. This thesis

investigates one of the possible solutions to enhance the traffic flow quality of the road transportation network in the near future. The thesis focusses on the effects that driver support systems may have on capacity and safety of motorway bottlenecks, which largely determine the road network performance. With this analysis, a better understanding of the impacts of driver support systems on traffic flows can be obtained, enabling conclusions about the design of support systems.

Nagaki K (2012). Evolution of in-car navigation systems. In Eskandarian A (Ed), Handbook of Intelligent Vehicles, Springer-Verlag London Ltd., 463-487.

In-car navigation systems do not consist of only navigation functions that are combinations of GPS and Map. Present in-car navigation systems are an integrated system that mainly consists of navigation function, Audio and Video function, and communication function. This chapter provides the introduction of in-car navigation system that has various functions and connects different devices, and also shows future incar navigation systems. Firstly, this chapter provides the basic knowledge of in-car navigation system by tracing back through the history of in-car navigation system and the system architecture. These explanations give insight into the main hardware and software components of in-car navigation systems. Further, explaining the architecture of Portable Navigation Device (PND), it shows the characteristic of PND. Secondly, this chapter briefly describes, showing trends for the future, the main software components of in-car navigation systems, i.e., navigation function, audio and video function, and communication function. Enhancement of navigation functions seems to be slowing down, but there is still considerable room for growth by linking to network. Voice recognition and speech synthesis, also covered in this chapter, would become more attractive function by linking to network. In-car navigation systems are designed to connect various devices, e.g., smart phone, portable audio device, camera, rear monitor, and ITS devices. This chapter also describes about two more devices: camera device to be connected to in-car navigation system and display device that takes center stage of front. Lastly, we look ‘‘green technology’’ application of navigation functions, and the in-car navigation system for electric vehicles, which functions would be different from previous in-car navigation system to provide the useful applications.

Pang GKH, Takahashi K, Yokota T, Takenaga H (2002). Intelligent route selection for in-vehicle navigation systems, Transportation Planning and Technology 25(3), 175-213.

Driving is a demanding task which requires constant concentration and appropriate maneuvers of a vehicle on the road. The introduction of in-vehicle navigation and route guidance system should be carried out with utmost care because of the abundant information that can be provided to a driver. In order to increase the acceptance level and lower the negative safety impacts of in-vehicle navigation systems, the psychological consideration and study of model of driver behavior is crucial. The focus of this article is on the design of a route selection function for an in-vehicle navigation system. The issue of route selection criteria and decision-making by drivers is discussed and an adaptive route selection algorithm presented. The objective is to develop a system function which can act as a driver’s assistant and helps in the evaluation of alternate routes. Such a system can help to filter and interpret information to lessen stress on drivers. In this article, the philosophical consideration of drivers’ route selection is discussed. The concept of primary attributes is introduced. Also, a review of route selection studies, together with the results from three previous surveys, are presented.

PATH (1997). Vehicle Platooning and Automated Highways. PATH Factsheet of California PATH-Partners for Advanced Transit and Highways, USA. http://www.path.berkeley.edu/PATH/Publications/Media/FactSheet/VPlatooning.pdf [accessed 02.04.2013]

Factsheet outlining the results of the eight-vehicle platoon demonstration at the National Automated Highway Systems Consortium Technical Feasibility Demonstration, held in San Diego, USA, from August 7-10, 1997. These results successfully demonstrated the technical feasibility of operating standard automobiles under precise automatic control at close spacing, at highway speeds. Riders experienced real travel in a fully automated AHS vehicle, and were shown that comfortable, high-capacity, automated travel is technically feasible in the near future. The platoon demonstration was designed by researchers at the California PATH program to show how vehicle automation technology can be used to make a major contribution to relieving traffic congestion. The

eight Buicks operating in tight coordination showed how an automated highway system can provide a significant increase in highway throughput (vehicles per lane per hour moving along the highway).

Popescu-Zeletin R, Radusch I, Rigani MA (2010). Vehicular-2-X Communication: State-of-the-Art and Research in Mobile Vehicular Ad hoc Networks. Springer-Verlag Berlin Heidelberg.

This book describes the various aspects of vehicular communication such as medium access control, routing, security, and accompanying standards along the ISO OSI reference model. Furthermore, future automotive applications such as cooperative driving maneuvers utilizing vehicular communication are introduced and described in detail. Moreover, orthogonal to this description of vehicular communication technologies, a novel testing and simulation approach combining current approaches for traffic and network simulations is introduced as a method for validating the introduced automotive applications. Research and development projects are also outlined.

Pueboobpaphan R, van Arem B (2010). Driver and vehicle characteristics and platoon and traffic flow stability - Understanding the relationship for design and assessment of cooperative adaptive cruise control. Transportation Research Record: Journal of the Transportation Research Board 2189, 89-97.

Advanced driver assistance (ADA) systems may change individual driver and vehicle characteristics and influence the overall traffic flow performance. An overview is presented of the relationship between individual driver and vehicle characteristics and platoon and traffic flow stability under manual, ADA, and mixed traffic. The factors that make traffic flow stable or unstable are reviewed and categorized, and how ADA systems influence traffic flow stability is reviewed. The definition of traffic flow stability, assessment methodologies, open issues that need further clarification, and implications for the development of ADA systems are discussed. The result of stability analysis depends not only on driver and vehicle characteristics but also on traffic stream characteristics and the method used to analyze stability.

Rajamani R (2006). Vehicle Dynamics and Control. Springer.

While a few different textbooks on ground vehicle dynamics are already available in the market, they do not satisfy all the needs of a control systems engineer. A controls engineer needs models that are both simple enough to use for control system design but at the same time rich enough to capture all the essential features of the dynamics. This book attempts to present such models and actual automotive control systems from literature developed using these models. The control system topics covered in the book include cruise control, adaptive cruise control, anti-lock brake systems, automated lane keeping, automated highway systems, yaw stability control, engine control, passive, active and semi-active suspensions, tire models and tire-road friction estimation. A special effort has been made to explain the several different tire models commonly used in literature and to interpret them physically. As the worldwide use of automobiles increases rapidly, it has become ever more important to develop vehicles that optimize the use of highway and fuel resources, provide safe and comfortable transportation and at the same time have minimal impact on the environment. To meet these diverse and often conflicting requirements, automobiles are increasingly relying on electromechanical systems that employ sensors, actuators and feedback control. It is hoped that this textbook will serve as a useful resource to researchers who work on the development of such control systems, both in the automotive industry and at universities. The book can also serve as a textbook for a graduate level course on Vehicle Dynamics and Control.

Rajamani R, Levinson D, Michalopoulos P, Wang J, Santhanakrishnan K, Zou X (2005). Adaptive Cruise Control System Design and its Impact on Traffic Flow. Report No CTS 05-01 prepared for the Intelligent Transportation Systems Institute, Center for Transportation Studies, University of Minnesota. http://nexus.umn.edu/Projects/ACC/CTS-05-01.pdf [accessed 27.04.2013]

This study resolves the controversy over the stability of constant time-gap policy for highway traffic flow. Previous studies left doubt as to the effectiveness of constant time-gap policies and whether they maintain stability in all traffic conditions. The results of this study prove that the constant timegap policy is in fact stable to a limit. At this limit, depending on the boundary conditions, conditions lose their stability. This study develops alternative ways to maintain the balance between safety and traffic flow for ACC vehicles that does not rely on constant time-gap policies. New spacing policies will create more stability, and therefore safer conditions, and allow for greater traffic capacity.

SARTRE (2013). Project Final Report. SAfe Road TRains for the Environment project. http://www.sartre-project.eu/en/publications/Documents/SARTRE_Final-Report.pdf [accessed 10.01.2014]

The SARTRE project is a FP7 project which aims to develop strategies and technologies to allow vehicle platoons to operate on normal public highways with significant environmental, safety and comfort benefits. The overall concept of SARTRE is to have a group of vehicles driving together with a lead vehicle, driven normally by a trained professional driver, and several following vehicles driven fully automatically by the system with small longitudinal gaps between them. Driving in this way in a platoon brings benefits in fuel consumption, safety and driver convenience. In addition to investigating the concept, a demonstrator system has been developed consisting of 5 vehicles: a lead truck, a following truck, and 3 following cars. An offboard system has also been developed to allow a potential SARTRE driver to find, and navigate to, a suitable platoon, although this has not been fully integrated into the vehicle system. The project has investigated the human factors aspects of platooning from the point of view of the lead driver, the following drivers, and the other road users. Safety analyses have been carried out on the system considering not only the effects of potential faults, but also the effects of potential misinterpretation by a driver as well as deliberate malicious actions by third parties. The demonstration system has been successfully tested on test tracks and public motorways, and demonstrated to industry stakeholders as well as members of the press. Using these vehicles, the fuel consumption benefits of platooning have been measured. The commercial viability of product offerings based on platooning has been studied, looking at the different range of options for trucks and for cars. The policies which would be affected by platooning of automated vehicles have been outlined.

Schultes D (2008). Route Planning in Road Networks. PhD Thesis, Fakultät für Informatik der Universität Fridericiana zu Karlsruhe (TH), Germany.

Computing optimal routes in road networks is one of the showpieces of realworld applications of algorithmics. In principle, we could use Dijkstra's algorithm—the 'classic' solution from graph theory. But for large road networks this would be far too slow. Therefore, there is considerable interest in speedup techniques, which typically invest some time into a preprocessing step in order to generate auxiliary data that can be used to accelerate all subsequent route planning queries. Following the paradigm of algorithm engineering, we design, implement, and evaluate three highly-efficient and provably accurate point-topoint route planning algorithms—all of which with different benefits—and one generic many-to-many approach, which computes for given node sets S and T the optimal distances between all node pairs $(s, t) \in S \times T$ in a very efficient way. The evaluation is done in an extensive experimental study using large real-world road networks with up to 33 726 989 junctions. Highway hierarchies exploit the inherent hierarchical structure of road networks and classify roads by importance. A point-to-point query is then performed in a bidirectional fashion—forwards from the source and backwards from the target—, disregarding more and more less important streets with increasing distance from source or target. Highway-node routing is a related bidirectional and hierarchical approach. Its conceptual simplicity and fast preprocessing allows the implementation of update routines that are able to react efficiently to unexpected events like traffic jams. Transit-node routing provides extremely fast query times by reducing most requests to a few table lookups, exploiting the observation that when driving to somewhere 'far away', the current location is always left via one of only a few 'important' traffic junctions. Our generic many-to-many algorithm can be instantiated based on certain bidirectional route planning techniques, for example, highway hierarchies or highway-node routing. It computes a complete $|S| \times |T|$ distance table, basically performing only $|S|$ forward plus $|T|$ backward queries instead of $|S|$ times $|T|$ bidirectional queries. Among all route planning methods that

achieve considerable speedups, we currently provide the one with the fastest query times, the one with the fastest preprocessing, and the one with the lowest memory requirements.

Shladover SE, Lu X-Y, Cody D, Nowakowski C, Qiu Z, Chow A, O'Connell J, Nienhuis J, Su D (2010). Development and Evaluation of Selected Mobility Applications for VII. California PATH Research Report UCB-ITS-PRR-2010-25. http://www.path.berkeley.edu/PATH/Publications/PDF/PRR/2010/PRR-2010-25.pdf [accessed 12.04.2013]

This report describes the development of two of the three mobility applications that PATH is developing and evaluating under the sponsorship of the FHWA Exploratory Advanced Research Program, with cost share funding provided by PATH TO 6224. These applications are intended to use DSRC wireless communications among vehicles and between vehicles and the roadway infrastructure to improve mobility on limited-access highways. The first application combines ramp metering with variable speed limits to enhance control of traffic so that traffic flow breakdowns can be deferred or avoided at bottleneck locations. The second application uses vehicle-vehicle communication to improve the performance of adaptive cruise control systems so that they can operate safely with smaller longitudinal gaps and vehicle-roadside communication to provide adjustments to their set speed and gap settings to adapt to changes in local traffic conditions.

Shladover SE, Lu X-Y, Nowakowski C, Su D (2011). Development and Evaluation of Selected Mobility Applications for VII. Report No CA11-2138 prepared for the California Department of Transportation, Division of Research and Innovation, Sacramento, USA. http://www.dot.ca.gov/newtech/researchreports/reports/2011/task_2138-tsm.pdf [accessed 12.04.2013]

This report describes the development of two of the three mobility applications that researchers have developed and evaluated under the sponsorship of the FHWA Exploratory Advanced Research Program, with cost share funding provided by Caltrans. These applications are intended to use Dedicated Short Range Communications (DSRC) wireless communications among vehicles and between vehicles and the roadway infrastructure to improve mobility on limited-access highways. The first application combines ramp metering with variable speed limits to enhance control of traffic so that traffic flow breakdowns can be deferred or avoided at bottleneck locations. The second application uses vehicle-vehicle communication to improve the performance of adaptive cruise control systems so that they can operate safely with smaller longitudinal gaps and vehicle-roadside communication to provide adjustments to their set speed and gap settings to adapt to changes in local traffic conditions. The Cooperative Adaptive Cruise Control (CACC) study showed that drivers preferred the shorter time gap settings enabled by the CACC technology when it was made available for their use. The trend of capacity with respect to CACC market penetration can be improved if the rest of the vehicles (the ones without CACC) are at least equipped with Vehicle Awareness Devices that broadcast their status information so that they can serve as leaders for CACC followers. The Variable Speed Limits (VSL) study showed in simulation that VSL has a strong potential for relieving bottleneck congestion by delaying the onset of the bottleneck condition and shortening the duration of the bottleneck congestion by increasing the effective throughput of the bottleneck.

Shladover SE (2012a). Recent International Activity in Cooperative Vehicle - Highway Automation Systems. Report No. FHWA-HRT-12-033 of the Office of Corporate Research, Technology, and Innovation Management, Federal Highway Administration, USA. http://www.fhwa.dot.gov/advancedresearch/pubs/12033/12033.pdf [accessed 03.04.2013]

This report summarizes the current state of the art in cooperative vehicle–highway automation systems in Europe and Asia based on a series of meetings, demonstrations, and site visits, combined with the results of literature review. This review covers systems that provide drivers with a range of automation capabilities, from driver assistance to fully automated driving, with an emphasis on cooperative systems that involve active

exchanges of information between the vehicles and the roadside and among separate vehicles. The trends in development and deployment of these systems are examined by country, and the similarities and differences relative to the U.S. situation are noted, leading toward recommendations for future U.S. action.

SINTEF, TRG, STRATEC (2004). STARDUST: Evaluation of Scenarios to Deployment of ADAS/AVG Systems in Urban Contexts. Deliverable 10 of the STARDUST (Contract Number: EVK4-CT-2000-00024) FP5 project. http://trg1.civil.soton.ac.uk/stardust/d10.pdf [accessed 20.09.2013]

The main focus in the STARDUST project has been to study ADAS/AVG systems in an urban context. The systems investigated are ACC, Stop&Go, Lane Keeping, ISA and Cyber cars. The STARDUST programme applies a wide range of methodology by combining analysis at behavioural, microscopic and macroscopic level, so that the final recommendations can be based on the actual driver behaviour, rather than on theoretical views exclusively. Further, the project includes integration of end user potential acceptance analysis (by means of stated preference surveys), investigation of the human factors issues (using data from instrumented vehicles, driving simulators, and microscopic modelling) and larger scale assessment of the impacts, at city-level (using semi-dynamic traffic assignment models).

Skog I, Händel P (2012). State-of-the-Art In-Car Navigation: An overview. In Eskandarian A (Ed), Handbook of Intelligent Vehicles, Springer-Verlag London Ltd., 435-462.

The basics around in-car navigation is discussed, including the principals of contemporary systems, global navigation satellite system basics, dead-reckoning, mapmatching, and strategies for information fusion. In-car navigation system are generally made out of three building blocks, an information source block, an information fusion block, and an user interface block. This chapter presents an overview of the information source block and the information fusion block. First, the ideas of operation and main characteristics of the four most commonly used information sources, global navigation satellite systems, vehicle motion sensors, road maps, and mathematical models of the vehicle dynamics, are reviewed. Thereafter, common techniques to combine the information from the different information sources into an estimate of the position, velocity, etc. of the car are reviewed.

Smith DL, Glassco R, Chang J, Cohen D (2003). Feasibility of modelling lane-change performance. NHTSA paper 2003-01-0280, Washington DC, USA. http://nhthqnlas187.nhtsa.dot.gov/DOT/NHTSA/NRD/Multimedia/PDFs/Crash%20Avoidance/2003/SAE2003-01-0280.pdf [accessed 14.11.2013]

This paper examines the feasibility of using four driving states (low risk, conflict, near crash, and crash imminent) to characterize lane-change driving performance. Data are analyzed from a test track study to estimate the boundaries between the states and to show that performance maps can be created for lane change events in two simple scenarios. The map structure is further investigated using naturalistic on-road data and the agreement between the test track and on road data models is discussed. Implications for crash counter-measure development and evaluation are discussed.

Swaroop D, Rajagopal KR (1998). Intelligent Cruise Control Systems and Traffic Flow Stability. California PATH Research Report UCB-ITS-PRR-98-36. California PATH Program, University of California, State of California Business, Transportation, and Housing Agency, Department of Transportation and United States Department of Transportation, Federal Highway Administration. http://www.path.berkeley.edu/PATH/Publications/PDF/PRR/98/PRR-98-36.pdf [accessed 27.04.2013]

In analogy to the flow of fuids, it is expected that the aggregate density and the velocity of vehicles in a section of a freeway adequately describe the traffic flow dynamics. The conservation of mass equation together with the

aggregation of the vehicle following dynamics of controlled vehicles describes the evolution of the traffic density and the aggregate speed of a traffic flow. There are two kinds of stability associated with traffic flow problems – string stability (or car-following stability) and traffic flow stability. We make a clear distinction between traffic flow stability and string stability, and such a distinction has not been recognized in the literature, thus far. String stability is stability with respect to intervehicular spacing; intuitively, it ensures the knowledge of the position and velocity of every vehicle in the traffic, within reasonable bounds of error, from the knowledge of the position and velocity of a vehicle in the traffic. String stability is analyzed without adding vehicles to or removing vehicles from the traffic. On the other hand, traffic flow stability deals with the evolution of traffic velocity and density in response to the addition and/or removal of vehicles from the flow. Traffic flow stability can be guaranteed only if the velocity and density solutions of the coupled set of equations is stable, i.e., only if stability with respect to automatic vehicle following and stability with respect to density evolution is guaranteed. Therefore, the flow stability and critical capacity of any section of a highway is dependent not only on the vehicle following control laws and the information used in their synthesis, but also on the spacing policy employed by the control system. Such a dependence has practical consequences in the choice of a spacing policy for adaptive cruise control laws and on the stability of the traffic flow consisting of vehicles equipped with adaptive cruise control features on the existing and future highways. This critical dependence is the subject of investigation in this paper. This problem is analyzed in two steps: The first step is to understand the effect of spacing policy employed by the Intelligent Cruise Control (ICC) systems on traffic flow stability. The second step is to understand how the dynamics of ICC system affects traffic flow stability. Using such an analysis, it is shown that cruise control systems that employ a constant time headway policy lead to unacceptable characteristics for the traffic flows.

SWOV (2010). Intelligent Speed Assistance (ISA). SWOV Fact sheet, Institute of Road Safety Research, Leidschendam, The Netherlands. http://www.swov.nl/rapport/Factsheets/UK/FS_ISA_UK.pdf [accessed 09.04.2013]

Intelligent Speed Assistance (ISA) is a promising type of advanced driver support system. From a technical point of view, large scale ISA implementation is possible in the short term. The different types of ISA are expected to have different effects on behaviour and traffic safety. The more intruding and controlling an ISA system is, the less it will be accepted by drivers. At the same time, however, the more intruding and controlling, the larger the effects on speed and on road safety in general. Successful implementation of ISA is largely dependent on the willingness of drivers to buy these systems and use them correctly, the public's attitude towards them, and the possibilities for a gradual implementation.

Tampère CMJ, Hogema JH, van Katwijk RT, van Arem B (1999). Exploration of the impact of Intelligent Speed Adaptation and Co-operative Following and Merging on Highways using MIXIC. TNO-report Inro/NK2003 prepared for the Transport Research Centre (AVV) of the Dutch Ministry of Transport, Public Works and Water Management, The Netherlands. http://www.utwente.nl/ctw/aida/research/publications/tampere_et_al.pdf [accessed 09.04.2013]

This study explores how and to what extent communication between vehicles or between vehicle and infrastructure can contribute to more stable traffic flow for better throughput and safer driving on highways. For this purpose the desired functionality of 3 systems has been determined: Intelligent Speed adaptation, Co-operative Following and Co-operative Merging. The former two have been implemented in the microscopic simulation model MIXIC and were used in an exploratory simulation experiment. The simulation of CF led to the identification of those elements in the design of the CF system that are crucial for adequate functioning: proper management and processing of different warning messages and integration of different functionalities into one single driver assistance system. The explorative simulation of ISA in traffic flows shows a decrease in throughput (volume) combined with positive effects on safety (shock waves, speed variance) when ISA is introduced. For the validation of these results more research into the driver's behaviour in the presence of ISA is recommendable.

Tapani A (2012): Vehicle trajectory effects of Adaptive Cruise Control. Journal of Intelligent Transportation Systems: Technology, Planning, and Operations 16(1), 36-44.

Adaptive cruise control (ACC) can potentially improve quality-of-service and safety and reduce the environmental effect of the road traffic system. This article uses vehicle trajectories from traffic simulation to study effects of ACC on vehicle acceleration and deceleration rates. The analysis is based on traffic simulations with car-following models including ACC functionality and driver behavior in ACC-equipped as well as standard nonequipped vehicles. The simulation results show that ACC can improve the traffic situation in terms of reduced acceleration and deceleration rates even though macroscopic traffic properties may remain uninfluenced. This supports the hypothesized positive road safety and environmental effects of ACC. It is also established that the results are largely dependent on the assumptions made regarding driver behaviour in ACC-equipped and standard vehicles. It is consequently crucial to include appropriate assumptions regarding driver behavior in traffic simulation–based analyses of ACC.

Tideman M, van der Voort MC, van Arem B, Tillema F (2007). A Review of lateral driver support systems. Proceedings of the 2007 IEEE Intelligent Transportation Systems Conference, Seattle, WA, USA, 992-999. http://doc.utwente.nl/60592/1/Tideman07review.pdf [accessed 07.11.2013]

Lateral driver support systems have the potential to reduce the number of accidents associated with – both intentional and unintentional - lane departures. Additionally, such systems may increase driving comfort and stimulate a more efficient traffic flow, thereby reducing traffic emissions and the costs associated with traffic delays. This paper provides a literature review to identify the current state of the art on lateral driver support systems. The emphasis is on sensor technology, detection algorithms and safety assessment algorithms.

Tientrakool P, Ho Y-C, Maxemchuk N (2011). Highway capacity benefits from using vehicle-to-vehicle communication and sensors for collision avoidance. Proceedings of the IEEE Vehicular Technology Conference (VTC Fall), San Francisco, CA, 1-5.

Several automobile manufacturers are offering assisted driving systems that use sensors to automatically brake automobiles to avoid collisions. Before extensively deploying these systems, we should determine how they will affect highway capacity. The goal of this paper is to compare the highway capacity when using sensors alone and when using sensors and vehicle-to-vehicle communication. To achieve this goal, the rules for using both technologies to prevent collisions are proposed, and highway capacity is estimated based on these rules. We show that both technologies can increase highway capacity. The increase in capacity is a function of the fraction of the vehicles that use a technology. If all of the vehicles use sensors alone, the increase in highway capacity is about 43%. While if all of the vehicles use both sensors and vehicle-to-vehicle communication, the increase is about 273%.

Tomar RS, Verma S (2012). Safety of lane change maneuver through a priori prediction of trajectory using neural networks. Network Protocols and Algorithms 4(1), 4-21.

Lane change (LC) is a maneuver that allows drivers to enter into a lane that suits their requirements and comfort. The LC process requires the driver to assess its neighborhood traffic in its original and target lanes before undertaking the maneuver. Other vehicles in the neighborhood also need to adjust for safe lane change. The LC trajectory is determined by the accuracy of these subjective assessments as well as the state of traffic. An erroneous assessment by LC vehicle or neighboring vehicles or an incorrect maneuver can cause collision. The collision can be prevented if the LC trajectory can be predicted and the feasibility of LC can be communicated to different vehicles involved in this process. . In the present paper, neural network is used for long term forecast of the lane change trajectory and for short term near future positions of the LC vehicle. The neural network is trained using past LC trajectories of different vehicles. The trained network is then used for long and short term forecast of the vehicle's positions during LC. Simulation results with actual filed data observed data indicates that

neural network is able to learn LC maneuvers and is able to perform short term prediction with sufficient accuracy.

Tsugawa S (2014). An automated truck platoon within the Energy ITS Project. Featured Article, IEEE ITS Society Newsletter 16(1), 11-14. http://sites.ieee.org/itss/files/2014/01/v16n1January2014.pdf [accessed 20.01.2014]

An automated truck platoon, its technologies and the effectiveness on the energy saving have been introduced. For the introduction, not only legal and institutional issues but also technological issues including the reliability of both the hardware and software of the automated driving system must be solved. The Energy ITS project was supported by the New Energy and Industrial Technology Development Organization (NEDO).

University of Michigan and General Motors Corporation (2005a). Automotive Collision Avoidance System Field Operational Test Methodology and Results Appendices. Report No DOT HS 809 901 prepared for the National Highway Traffic Safety Administration, U.S. Department of Transportation, Washington, USA. http://www.nhtsa.gov/DOT/NHTSA/NRD/Multimedia/PDFs/Crash%20Avoidance/2005/809901All.pdf [accessed 02.04.2013]

The Automotive Collision Avoidance System field operational test (or ACAS FOT) project was led by General Motors (with Delphi playing a major supporting role) under a cooperative agreement with the U.S. Department of Transportation. The work conducted by the University of Michigan Transportation Research under this project is the subject of this two-volume report. This work involved developing the FOT methodology, gathering the FOT data, and the analysis and interpretation of this massive dataset. The FOT involved exposing a fleet of 11 ACAS-equipped Buick LeSabre passenger cars to 12 months of naturalistic driving by lay drivers from southeastern Michigan. The ACAS system included both a forward crash warning (FCW) system and an adaptive cruise control (ACC) system. The goal of the FOT was to examine the suitability of the ACAS system for widespread deployment from the perspectives of both driving safety and driver acceptance. Ninety-six drivers participated in the project, with an accumulation of 137,000 miles of driving. Data included over 300 data signals collected at 10 Hz with corresponding samples of video of the forward driving scene and the driver's face. A set of subjective instruments were uses to capture information about the driver and their self-reported tendencies, as well as postdrive questionnaires, interviews (which included video replays of alert experiences), and focus groups. Results indicated that ACC was widely accepted by drivers, whereas the acceptance of FCW was mixed (due to false alarms) and was not found to be significantly related to FCW alert rate. ACC was found to be benign from a traffic safety perspective, with possible benefits resulting from the marked reduction in short (<1 second) headways and reduced passing behavior observed during ACC driving. While incidents were found in which the FCW may have contributed to a timely driver response to an emerging rear-end crash conflict, the frequency or magnitude of such conflicts in manual driving was unchanged when FCW was enabled. In addition, headways in manual driving with FCW enabled were found to increase on freeways and also during daytime driving.

University of Michigan and General Motors Corporation (2005b). Automotive Collision Avoidance System Field Operational Test Report: Methodology and Results. Report No DOT HS 809 900 prepared for the National Highway Traffic Safety Administration U.S. Department of Transportation, Washington, USA. http://deepblue.lib.umich.edu/bitstream/handle/2027.42/49539/99798.pdf?sequence=1 [accessed 04.04.2013]

The Automotive Collision Avoidance System field operational test (or ACAS FOT) project was led by General Motors (with Delphi playing a major supporting role) under a cooperative agreement with the U.S. Department of Transportation. The work conducted by the University of Michigan Transportation Research under this project is the subject of this two-volume report. This work involved developing the FOT methodology, gathering the FOT data, and the analysis and interpretation of this massive dataset. The FOT involved exposing a fleet of 11 ACAS-

equipped Buick LeSabre passenger cars to 12 months of naturalistic driving by lay drivers from southeastern Michigan. The ACAS system included both a forward crash warning (FCW) system and an adaptive cruise control (ACC) system. The goal of the FOT was to examine the suitability of the ACAS system for widespread deployment from the perspectives of both driving safety and driver acceptance. Ninety-six drivers participated in the project, with an accumulation of 137,000 miles of driving. Data included over 300 data signals collected at 10 Hz with corresponding samples of video of the forward driving scene and the driver's face. A set of subjective instruments were uses to capture information about the driver and their self-reported tendencies, as well as postdrive questionnaires, interviews (which included video replays of alert experiences), and focus groups. Results indicated that ACC was widely accepted by drivers, whereas the acceptance of FCW was mixed (due to false alarms) and was not found to be significantly related to FCW alert rate. ACC was found to be benign from a traffic safety perspective, with possible benefits resulting from the marked reduction in short (<1 second) headways and reduced passing behavior observed during ACC driving. While incidents were found in which the FCW may have contributed to a timely driver response to an emerging rear-end crash conflict, the frequency or magnitude of such conflicts in manual driving was unchanged when FCW was enabled. In addition, headways in manual driving with FCW enabled were found to increase on freeways and also during daytime driving.

Varhelyi A, Makinen T (2001). The effects of in-car speed limiters: Field studies. Transportation Research C 9(3), 191-211.

Field trials in three European countries, the Netherlands, Spain and Sweden were carried out in order to investigate the effects of an in-car speed limiter. The trials were carried out on urban and rural roads including motorways. A so-called unobtrusive instrumented car was used, where all the measuring equipment was hidden. All the speed limit categories in the respective countries, ranging from 30 to 120 km/h were included. The results showed that the effects of the limiter were greatest in free driving conditions outside platoons. However, the limiter also had effects in congested traffic. Momentary high speeds were suppressed effectively, which resulted in less variation of speeds. Approach speeds at roundabouts, intersections and curves became smoother, car-following behaviour became safer in the speed range of 30±50 km/h. On the other hand, in the speed range of 70±90 km/h a slightly higher number of short time-gaps suggested less safe car-following behaviour. Other negative behavioural effects were slightly increased travel time and the increased frustration and stress for the drivers caused by the limiter. The majority of the subjects accepted the speed limiter as a driver-operated system. Half of the drivers would accept the limiter voluntarily in their cars.

van Arem B, Driever H, Feenstra P, Ploeg J, Klunder G, Wilmink I, Zoutendijk A, Papp Z, Netten B (2007). Design and evaluation of an Integrated Full-Range Speed Assistant. TNO report 2007-D-R0280/B, Traffic and Transport, The Netherlands. http://rijkswaterstaat.nl/rws/corporate/Wegen%20naar%20de%20toekomst/rijassistent%20-%20design%20and%20evaluation%20of%20an%20integrated%20full%20range%20speed%20assistant.pdf [accessed 24.07.2013]

In the SUMMITS-IRSA project, TNO has developed and demonstrated the SUMMITS Tool Suite, which is an integrated tool set to allow developers of Advanced Driver Assistance (ADA) systems to assess issues regarding technical functioning, human factors and traffic flow in a consistent way. The Integrated Full –Range Speed Assistant (IRSA) was selected as a case to guide and test the development of the tool suite. The IRSA system is a collection of functions to support a driver in maintaining an appropriate speed in a number of selected traffic conditions, such as approaching a traffic jam, cut-in situation and leaving the head of the queue at a traffic light.Consistent results were guaranteed by the use of a common mathematical description of the IRSA system (the meta-model), traffic scenarios and selective coupling of tools. Several control models were used, varying from a common Adaptive Cruise Control (ACC) algorithm, to algorithms that also use vehicle-vehicle communication with the three closest downstream IRSA equipped vehicles taking into account the time headways (CACC1) and average speed (CACC2).

van Arem B, van Driel CJG, Visser R (2006). The Impact of Cooperative Adaptive Cruise Control on Traffic-Flow Characteristics. IEEE Transactions on Intelligent Transportation Systems 7(4), 429-436.

Cooperative adaptive cruise control (CACC) is an extension of ACC. In addition to measuring the distance to a predecessor, a vehicle can also exchange information with a predecessor by wireless communication. This enables a vehicle to follow its predecessor at a closer distance under tighter control. This paper focuses on the impact of CACC on traffic-flow characteristics. It uses the traffic-flow simulation model MIXIC that was specially designed to study the impact of intelligent vehicles on traffic flow. The authors study the impacts of CACC for a highway-merging scenario from four to three lanes. The results show an improvement of traffic-flow stability and a slight increase in traffic-flow efficiency compared with the merging scenario without equipped vehicles.

van Driel CJG, van Arem B (2008). Traffic flow impacts of a congestion assistant. Annual Meeting of the Transporation Research Board, Washington DC, USA. http://www.utwente.nl/ctw/aida/research/publications/CvD-TRB08.pdf [accessed 04.04.2013]

This paper presents the results from a microscopic traffic simulation study that was conducted to investigate the impacts of a so-called Congestion Assistant on traffic efficiency and traffic safety. The Congestion Assistant is an in-vehicle system that supports the driver with an Active pedal when approaching a traffic jam and a Stop & Go when driving in a traffic jam. Six variants of the Congestion Assistant with different equipment rates on a four-lane highway with a lane drop were assessed. The traffic simulation tool was calibrated and validated using measured loop data on a segment of the Dutch A12 highway. The Congestion Assistant was found to reduce the amount of congestion significantly, especially due to the Stop & Go. This function led to more efficient car-following behavior by adapting smaller headways and eliminating the reaction time of drivers. The Active pedal of the Congestion Assistant hardly influenced traffic efficiency; rather it affected traffic safety through a safer approach to a jam.

van Driel CJG, van Arem B (2010). The impact of a congestion assistant on traffic flow efficiency and safety in congested traffic caused by a lane drop. Journal of Intelligent Transportation Systems: Technology, Planning, and Operations 14(4), 197-208.

This article presents the results of a microscopic traffic simulation study conducted to investigate the impact of a Congestion Assistant on traffic efficiency and traffic safety. The Congestion Assistant is an in-vehicle system in which an active pedal supports the driver when approaching congestion and a stop-and-go function when driving in congestion. The authors used an Intelligent Transportation System (ITS) Modeller traffic flow simulation tool to study the effect of the Congestion Assistant in congestion caused by a lane drop. This article describes (a) how the Congestion Assistant operates and (b) the main features of the ITS Modeller. Furthermore, it examines the calibration and validation of the ITS Modeller for congestion caused by a lane drop using traffic flow measurements on a segment of the Dutch A12 highway. Simulation experiments of different penetration rates and system settings show that the stop and go leads to a 30% decrease in travel-time delay at a 10% penetration rate, while the active pedal leads to small reductions in travel-time delay. Compared with the stop-and-go function, the active pedal has fewer sharp accelerations and decelerations, which implies better traffic safety and driver comfort. The effect of the stop-and-go active pedal combination is similar to that of the stop-and-go function on its own. The authors further discuss the implications of the results.

van Driel CJG (2007). Driver Support in Congestion: An Assessment of User Needs and Impacts on Driver and Traffic Flow. CTIT Ph.D. thesis Series No. 07-106, TRAIL Thesis Series T2007/10, The Netherlands TRAIL Research School. http://doc.utwente.nl/58037/1/thesis_van_Driel.pdf [accessed 03.04.2013]

Mobility is a key factor for modern societies. However, it also brings about problems, such as congestion, accidents and pollution. High expectations rest on in-vehicle systems to contribute to solving these problems.

These so-called driver support systems use advanced information and communication technology to assist the driver in performing elements of the driving task, such as maintaining a proper speed or avoiding an accident. A variety of systems is under investigation or already commercially available. Most current systems are autonomous systems that do not communicate with other vehicles or the infrastructure. Recently, the development of driver support systems is more and more directed at cooperative systems that do communicate and therefore extend the driver's horizon. Despite the research and development efforts, the market introduction of driver support systems finds itself in an early stage. Car manufacturers employ a rather conservative strategy, because they are uncertain about the financial risks and the usability of these systems. Governments and road operators are uncertain about the actual impacts of driver support systems on traffic safety and traffic efficiency, which makes them hesitant to take measures to facilitate, stimulate or regulate the introduction of these systems. This thesis aims at reducing the above uncertainties by improving the knowledge of user needs for driver support systems and the impacts of one of such systems, the so-called Congestion Assistant, on the driver and the traffic flow.

VanderWerf J, Shladover S, Kourjanskaia N, Miller M, Krishnan H (2001). Modeling effects of driver control assistance systems on traffic. Transportation Research Record 1748, Paper No. 01-3475, 167-174.

A set of mathematical models is defined to predict the effects of emerging driver control assistance systems such as adaptive cruise control (ACC) on traffic flow dynamics and capacity. It is important to understand these effects in order to ensure that ACC systems are implemented in ways that improve, rather than degrade, traffic conditions. Existing traffic models were not designed for, and are not suitable for, this purpose, so it has been necessary to develop a new family of simulation models incorporating the key elements of driver behavior and control system design that will affect traffic flow dynamics and capacity. Example outputs from simulation validation test cases are illustrated and explained to show that the models are producing reasonable results.

VanderWerf J, Shladover S, Miller M A, Kourjanskaia N (2002). Effects of adaptive cruise control systems on highway traffic flow capacity. Transportation Research Record 1800, Paper No. 02-3665, 78-84.

The effects on traffic flow of increasing proportions of both autonomous and cooperative adaptive cruise control (ACC) vehicles relative to manually driven vehicles were studied. Such effects are difficult to estimate from field tests on highways because of the low market penetration of ACC systems. The research approach used Monte Carlo simulations based on detailed models presented in the literature to estimate the quantitative effects of varying the proportions of vehicle control types on lane capacity. The results of this study can help to provide realistic estimates of the effects of the introduction of ACC to the vehicle fleet. Transportation system managers can recognize that the autonomous ACC systems now entering the market are unlikely to have significant positive or negative effects on traffic flow. An additional value of studying ACC systems in this way is that these scenarios can represent the first steps in a deployment sequence that will lead to an automated highway system. Benefits gained at the early stages in this sequence, particularly through the introduction of cooperative ACC with priority access to designated (although not necessarily dedicated) lanes, can help support further investment in and development of automated highway systems.

VanderWerf J, Shladover S, Kourjanskaia N, Miller M, Krishnan H (2007). Modeling effects of driver control assistance systems on traffic. Transportation Research Record 1748, 167-174.

A set of mathematical models is defined to predict the effects of emerging driver control assistance systems such as adaptive cruise control (ACC) on traffic flow dynamics and capacity. It is important to understand these effects in order to ensure that ACC systems are implemented in ways that improve, rather than degrade, traffic conditions. Existing traffic models were not designed for, and are not suitable for, this purpose, so it has been necessary to develop a new family of simulation models incorporating the key elements of driver behavior and control system design that will affect traffic flow dynamics and capacity. Example outputs from simulation validation test cases are illustrated and explained to show that the models are producing reasonable results.

Visser R (2005). Co-operative Driving on Highways - An Assessment of the Impact of the Advanced Driver Assistance System 'Co-operative Adaptive Cruise Control' on Traffic Flow Using Microscopic Traffic Simulation. MSc Thesis, University of Twente, The Netherlands. http://www.utwente.nl/ctw/aida/education/Rapport_RV.pdf [accessed 02.04.2013]

During the last decades the western society is constantly confronted with problems caused by increasing road traffic. This increase in traffic demand leads to congestion and has a negative effect on traffic safety, environment and energy consumption. The expectations of the use of telematics technology in road traffic in this respect are high, since this technology could lead to system innovations, which in the long term can contribute to the problems faced. In the coming years motorists will have at their command a range of Intelligent Transport Systems (ITS). ITS that support the driver in performing the driving tasks are called Advanced Driver Assistance (ADA) systems. An ADA system that has been introduced on a small scale by the automotive industry is Autonomous Adaptive Cruise Control (AACC). AACC is a radar-based system which is designed to enhance driving comfort and convenience on highways by relieving the driver of the need to continuously adjust his or her speed to match that of the preceding vehicle while also maintaining a proper headway. Vehicle-to-vehicle communication is potentially boosting the development of ADA systems. Recently, vehicle-to-vehicle communication is added to the AACC system. This system is called Co-operative Adaptive Cruise Control, abbreviated CACC. Vehicle-to-vehicle communication could provide an ACC system with more and better information about the vehicle it is following, enabling the own vehicle to react faster and smoother on acceleration and deceleration of the predecessor. Since communication is quicker, more reliable and less noisy than autonomous sensing, significant closer headways (down to a time gap that could be as low as 0.5 second) can be postulated. Although CACC is primarily designed for giving the driver more comfort and convenience, the system potentially has effects on traffic flow and highway capacity when it is widely used. However, since CACC is in a very early stage of development, not much research into the traffic flow impacts of CACC has been done so far. This study aims at assessing the traffic flow impacts of CACC on a Dutch highway. Since CACC does not exist yet and therefore field tests on highways are not an option, research has been done with the microscopic traffic simulation model 'MIXIC'. MIXIC describes the behaviour of vehicles on highways in a very detailed way. The functionality of CACC has been elaborated in functional specifications for MIXIC and the model is extended with this functionality.

Visvikis C, Smith TL, Pitcher M, Smith R (2008). Study on lane departure warning and lane change assistant systems. Project Report PRR 374, Transport Research Laboratory. http://ec.europa.eu/enterprise/sectors/automotive/files/projects/report_ldwlca_en.pdf [accessed 07.11.2013]

Lane Departure Warning (LDW) Systems monitor the position of the vehicle with respect to the lane boundary. When the vehicle is in danger of leaving the lane unintentionally, the system delivers a warning to the driver. Lane Change Assistant (LCA) Systems monitor the adjacent lanes to assist drivers when changing lane. If the driver of the vehicle fitted with the LCA system initiates a lane change manoeuvre and the system detects a vehicle in the adjacent lane, the system will alert the driver to the presence of the other vehicle. The objective of this research was to gather and evaluate information regarding the performance standards of LDW and LCA systems and the likely costs and benefits of meeting these standards with respect to: Light vehicles (e.g. categories M1 and N1); Heavy goods vehicles (HGV) (e.g. categories N2 and N3); Large passenger vehicles (LPV) (e.g. categories M2 and M3). The study considers the potential casualty savings to occupants of both the vehicle to which the equipment is fitted as well as the occupants of other vehicles. The potential benefits for vulnerable road users (pedestrians, cyclists and motorcyclists) were also considered. Initial specifications for LDW and LCA assistance systems have been developed based on relevant standards and the safety requirements required to influence the target population of accidents.

Viti F, Hoogendoorn SP, Alkim TP, Bootsma G (2008). Driving behavior adaptation under ACC: results from a large Field Operational Test in the Netherlands. Preprints of the Intelligent

Vehicle Symposium, Eindhoven, The Netherlands, 745-750. https://www.mech.kuleuven.be/cib/verkeer/dwn/pub/PC2008E.pdf [accessed 09.04.2013]

A large Field Operational Test (FOT) was conducted in 2006 in the Netherlands to assess the impact of two Advanced Driver Assistance Systems (ADAS), namely Adaptive Cruise Control (ACC) and Lane Departure Warning (LDW) systems. The research goal was to estimate the effects of these systems in the traffic flow performance. More specifically, expectations on the changes in the road capacity, safety and emissions on a macroscopic scale were investigated. In this paper we focus on the interaction between driver and ACC system, i.e. the adaptation behavior of drivers under these systems. It was found that the system is often deactivated under dense traffic conditions. It is also observed from the data that the system, when de-activated, either automatically or manually, needs some time to become again active. These findings imply that, even with a 100% penetration rate of currently available ACC controls, road capacities will still be determined mainly by human factors.

Vlassenroot S, Marchau V, De Mol1 J, Brookhuis K, Witlox F (2011a). Potential for in-car speed assistance systems: results of a large-scale survey in Belgium and the Netherlands. IET Intelligent Transportation Systems 5(1), 80-89.

Speeding is generally considered to be a major cause of road traffic accidents. In-car speed assistance systems aim at reducing speeding. Several trials with different types of in-car speed assistance systems, in particular intelligent speed assistance (ISA), have shown that ISA can be an effective way to reduce speeding. A basic condition for achieving significant improvements in safety involves the adaptation of ISA among vehicle drivers on a large scale. This study focuses on the issue of acceptability of ISA. It is based on a large-scale survey of 6370 individuals in Belgium (Flanders region) and 1158 persons in the Netherlands. The respondents indicated that they believed that their own driving behaviour is of great influence on accidents and traffic safety, and that contextual issues like infrastructure or other drivers are less important. Almost 95% of the respondents are in favour of ISA: seven out of ten drivers state that they want to have some informative or warning system. Three out of ten drivers even wanted to go further; they indicated a preference for a restricting type of ISA. However, drivers would only choose for more restricting systems if the penetration rates of such systems in the vehicle market were high enough.

Vlassenroot S, van der Plas J-W, Brookhuis K, De Mol J, Marchau V, Witlox F (2011b). Easy going - Multilevel assessment of ISA. In Bekiaris E, Wiethoff M, Gaitanidou E (Eds) Infrastructure and Safety in a Collaborative World. Road Traffic Safety. Berlin-Heidelberg-New York, Springer Verlag, 215-232.

Intelligent Speed Adaptation (ISA) involves an in-vehicle system, which supports the driver in not exceeding the speed limit. Inappropriate speed or speeding is a major cause of road traffic accidents and strongly relates to the outcome of an accident (research indicates that in Europe 1/3 of all fatal accidents is caused by inappropriate speed). As such, ISA has the potential to substantially improve traffic safety and is recognized as a promising speed management policy. Over the past decades, a lot of research on ISA has been conducted across Europe. This research involved different ISA systems, ranging from simple information provision to keeping the car to the local speed limit, and a variety of different methodologies, ranging from pilots and trials, to driving simulator studies, computer simulations and expert elicitation of opinions. The central notion in this chapter is to describe which evolutions were found about ISA around the world to assess the effects of ISA on social, ecological, economical, political and technical level. By discussion and evaluation of some ISA studies and ISA developments, two main questions will be answered: what do we know and what is still do be done? This will result in an overview of barriers and issues that have been resolved and that still have to be resolved, to enable large-scale implementation.

Wan L, Raksincharoensak P, Maeda K, Nagai M (2011). Lane change behaviour modelling for autonomous vehicles based on surroundings recognition. International Journal of Automotive Engineering 2, 7-12.

This paper describes an algorithm that determines the reference vehicle trajectory for autonomous lane changing maneuver. The algorithm employs potentially acquired on-board vehicle sensing signals like the velocity of each vehicle, the relative distance between vehicles as variables and estimates the positions of host and surrounding vehicles after finishing lane change maneuver. The lane change timing and reference lateral/longitudinal acceleration are derived theoretically and compared with the data which is obtained from human driver experiments carried out in driving simulator. The longitudinal and lateral accelerations are determined as the reference model. The paper describes algorithm details, following by simulation results which show the feasibility of the proposed algorithm.

Wilmink I, Klunder G, van Arem B (2006). The impact of integrated full-range speed assistance on traffic flow. Proceedings of the 13th ITS World Congress, London, UK. ftp://218.22.27.69/%E6%99%BA%E8%83%BD%E4%BA%A4%E9%80%9A%E5%A4%A7%E4%BC%9A%E8%B5%84%E6%96%99/13%E5%B1%8AITS%E4%B8%96%E7%95%8C%E5%A4%A7%E4%BC%9A/papers/1372.doc [accessed 04.04.2013]

This paper discusses the assessment of the effects of Integrated full-Range Speed Assistance (IRSA), using the ITS modeller. The aim of IRSA is to assist drivers in their longitudinal driving task by providing speed advice or speed warnings and cruise control-like functionalities. The effects of the application of IRSA in two scenarios (Approaching a traffic jam and Approaching a reduced speed limit zone) are presented. In addition, general aspects of modelling vehicle and driver behaviour for co-operative systems are discussed, and how this is done in the ITS modeller.

Xiao L, Gao F (2010). A comprehensive review of the development of adaptive cruise control systems. Vehicle System Dynamics: International Journal of Vehicle Mechanics and Mobility, 48(10), 1167-1192.

It has been 15 years since the first generation of adaptive cruise control (ACC)-equipped vehicles was available on the market and 7 years since the ISO standard for the first generation of ACC systems was produced. Since the next generation of ACC systems and more advanced driver-assistant systems are at the verge of complete introduction and deployment, it is necessary to summarise the development and research achievements of the first generation of ACC systems in order to provide more useful experiential guidance for the new deployment. From multidimensional perspectives, this paper looks into the related development and research achievements to objectively and comprehensively introduce an ACC system to researchers, automakers, governments and consumers. It attempts to simply explain what an ACC system is and how it operates from a systematic perspective. Then, it clearly draws a broad historical picture of ACC development by splitting the entire history into three different phases. Finally, the most significant research findings-related ACC systems have been reviewed and summarised from the human, traffic and social perspectives respectively.

Yamada H, Ouchi H, Hirasawa T, Yamada K, Katayama Y, Horiguchi R, Oikawa M (2005). Applicability of AHS service for traffic congestion in sag sections. 12th World Congress and Exhibition on Intelligent Transport Systems and Services. http://www.nilim.go.jp/japanese/its/3paper/pdf/051201wc_1.pdf [accessed 02.04.2013]

Sag sections and tunnels cause 35% of the congestion on expressways in Japan. One of the factors in congestion is imbalance in traffic lane utilization such as traffic concentration in the passing lane and leeway in the cruising lane. Therefore the National Institute for Land and Infrastructure Management (NILIM) and the Advanced Cruise-Assist Highway System Research Association (AHSRA) have been studying AHS services that would optimize the traffic lane utilization rates by providing drivers with information before congestion occurs. This paper will report on our analysis of actual traffic conditions at a congestion location in a sag section (in the Tomei (Tokyo-Nagoya) Expressway). It will also report on the results from examination of the possibility of providing service, the algorithms for determining the timing for service.

Yi J, Horowitz R (2006). Macroscopic traffic flow propagation stability for adaptive cruise controlled vehicles. Transportation Research Part C: Emerging Technologies 14(2), 81-95.

Traffic flow propagation stability is concerned about whether a traffic flow perturbation will propagate and form a traffic shockwave. In this paper, we discuss a general approach to the macroscopic traffic flow propagation stability for adaptive cruise controlled (ACC) vehicles. We present a macroscopic model with velocity saturation for traffic flow in which each individual vehicle is controlled by an adaptive cruise control spacing policy. A nonlinear traffic flow stability criterion is investigated using a wavefront expansion technique. Quantitative relationships between traffic flow stability and model parameters (such as traffic flow and speed, etc.) are derived for a generalized ACC traffic flow model. The newly derived stability results are in agreement with previously derived results that were obtained using both microscopic and macroscopic models with a constant time headway (CTH) policy. Moreover, the stability results derived in this paper provide sufficient and necessary conditions for ACC traffic flow stability and can be used to design other ACC spacing policies.

Yuan Y-M, Jiang R, Hu M-B, Wu Q-S, Wang R (2009). Traffic flow characteristics in a mixed traffic system consisting of ACC vehicles and manual vehicles: A hybrid modelling approach. Physica A: Statistical Mechanics and its Applications 388(12), 2483-2491.

In this paper, we have investigated traffic flow characteristics in a traffic system consisting of a mixture of adaptive cruise control (ACC) vehicles and manual-controlled (manual) vehicles, by using a hybrid modelling approach. In the hybrid approach, (i) the manual vehicles are described by a cellular automaton (CA) model, which can reproduce different traffic states (i.e., free flow, synchronised flow, and jam) as well as probabilistic traffic breakdown phenomena; (ii) the ACC vehicles are simulated by using a car-following model, which removes artificial velocity fluctuations due to intrinsic randomisation in the CA model. We have studied the traffic breakdown probability from free flow to congested flow, the phase transition probability from synchronised flow to jam in the mixed traffic system. The results are compared with that, where both ACC vehicles and manual vehicles are simulated by CA models. The qualitative and quantitative differences are indicated.

Zhang J, Ioannou P (2004). Integrated Roadway / Adaptive Cruise Control System: Safety, Performance, Environmental and Near Term Deployment Considerations. California PATH Research Report UCB-ITS-PRR-2004-32, California PATH Program, Institute of Transportation Studies, University of California, Berkeley. http://www.escholarship.org/uc/item/4749164x [accessed 12.07.2013]

In this project, we design two new Adaptive Cruise Control (ACC) systems based on driver comfort, safety, vehicle following performance, environmental and traffic flow characteristics considerations. A new variable time headway rule is proposed and used to meet these considerations. Analysis and simulations are used to evaluate and compare the two designs. The first ACC system (referred to as ACC01) incorporates two controllers: one for speed tracking and one for vehicle following. The second ACC system (referred to as ACC02) treats the vehicle following task as a special speed tracking task and incorporates more intelligence in dealing with disturbance rejection, smooth response and safe vehicle following without affecting travel time. It provides better transient performance than ACC01, and can attenuate oscillations in the speed response of the preceding vehicle. It has also been shown that ACC02 provides better fuel economy and emission results than ACC01. The ACC02 design will be used for subsequent studies in a continuation project.

Zwaneveld P J, van Arem B (1997). Traffic Effects of Automated Vehicle Guidance System. A Literature Survey. TNO Report INRO-VVG 1997-17 Delft, The Netherlands. http://www.utwente.nl/ctw/aida/research/publications/zwaneveld_arem.pdf [accessed 27.04.2013]

Automated Vehicle Guidance (AVG) systems are systems in which driving tasks are supported or taken over partly or entirely by an automated system. The reported benefits of AVG systems involve improvements of road traffic performance, safety, and comfort. The research described in this report has the following objective: To describe

the existing state of knowledge with respect to the interaction between automated, AVG supported vehicles and manually driven vehicles. The description focuses on the traffic effects of the interaction between automated and manually driven vehicles, and more precisely on the effect of this interaction on the maximum achievable capacity. In order to structure the research and the presentation of results and to provide the reader with an overview, we defined three stages for the development for AVG systems. These three stages can be considered as a global chronological development path for AVG systems: (Stage 1) Early AVG in Mixed Traffic, (Stage 2) Introduction of AVG lanes, (Stage 3) Intelligent AVG infrastructure. The studies that were found in the literature were assigned to one of these stages. Each study was briefly described. At the end of the discussion of each stage, the results for that stage were summarized into a table. The main conclusions with respect to the stages were: (Stage 1) Introducing ACC systems in mixed traffic conditions is likely to result in a small capacity increase of a few percentages. This capacity increase may, however, turn out to be a capacity decrease if drivers set the target headway too large. As a consequence of this result, ACC is mostly presented as a comfort and safety device. (Stage 2) The capacity gains for introducing a lane exclusively dedicated to AVG vehicles seem to be marginal in comparison with the situation in which both automated and manually driven vehicles are allowed to use the lane. Introducing an AVG lane (without infrastructure intelligence) will probably be based on aspects other then capacity. Firm conclusions could, however, not be derived for this stage, since only a few studies investigate a situation that fits into Stage 2. (Stage 3) The anticipated capacity improvement for this stage are huge. Improvements of 100 to 200% are most frequently mentioned. These capacity estimates are based upon design parameters, and less on actual predictions of traffic behavior. Most future research on this stage will concern studies of the best design of infrastructure and (software) procedures. An important capacity issue is the connection of high capacity AVG lanes with local streets. This connection is necessary for feeding traffic onto an AVG lane and for dispersing traffic off the lane. The consistency of the design parameters is an important issue.