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Editorial

Advanced Driver Assistance Systems: Behavioural implications of some recent developments

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The application of Intelligent Transportation Systems (ITS), in particular Advanced Driver Assistance Systems (ADAS), is expected to improve the performance of road transportation significantly. Public policy makers, among others, are therefore increasingly interested in the implementation of these systems. Available knowledge on various implementation issues is growing, but still limited. This is due to the complex interactions between technological requirements, market introduction, impacts on driver behaviour and traffic performance and policy priorities. This article provides a framework for ADAS implementation, reviews recent developments in this field and introduces the contributions to this special issue.

Keywords: ADAS, behaviour, policy making.

1. Introduction

In the last decade, the interest in the development and implementation of Intelligent Transport Systems (ITS) has rapidly grown. ITS encompasses a large variety of technical devices and services based on the use of advanced information and communication technologies. One can

think of, for example, systems for the support of logistics management of a transport fleet, dynamic traffic management, as well as advanced driver support systems such as navigation support or speed headway control. The stage of development and the degree of application of these devices and services vary considerably. The effort in system development and innovation, especially by the automotive industry, is however huge and the technology is becoming increasingly mature. Transport policymakers therefore expect increasing positive influences of ITS on the reliability and effectiveness of transport services, traffic safety, traffic flow efficiency and possibly also fuel consumption and emissions.

Part of the discussion on ITS is focused on electronic devices for the intelligent support of driving tasks, generally referred to as Advanced Driver Assistance Systems (ADAS). This discussion is fuelled by the fact that, increasingly, various ADAS are introduced on the market. Furthermore, within the field of ITS, ADAS has probably the highest potential to improve road traffic performance as ADAS directly intervenes in the vehicle driving task. Most of the ADAS currently available offer informative or warning information (for example regarding forward obstacles, lane departure and route optimisation). However, today we also face market introductions of so-called assisting systems, which autonomously take decisions unless the driver overrules these decisions (e.g. advanced cruise control, collision avoidance systems, precise docking of busses). It is even generally expected that more advanced systems will gain market in the next future. Concepts based on integration of these advanced systems aim at full automation of driving tasks. First applications of such concepts can be found at various locations in the context of local public transport by automated people movers.

The dynamic developments in ADAS generate many questions, not only technically, but also (and perhaps even more) from the perspective of implementation. Who will be the users of such systems? How does the driver support concept match with driving behaviour? To what extent can the traffic performance improve due to ADAS? Which traffic and infrastructure conditions are necessary for a satisfactory application of various ADAS? Who is responsible in case of failure? In short: questions focus on a mixture of technological and functional requirements, the contribution of ADAS to policy goals and the formal and behavioural position of stakeholders regarding the development, introduction and large-scale use of ADAS. In the past decade various research programs have been initiated to study such questions in-depth. Nevertheless, broader pictures of ADAS implementation, in which the various ADAS, their possible consequences for transportation system performance, and societal conditions for implementation are treated in an integrated way, are seldom presented. Abele et al. (2005) present a recent overview of research progress in the development of Intelligent Vehicle Safety Systems (IVSS). The authors give an overview of several projects funded by EU, EU member states and automotive industries. The larger part of these projects focus on technological research and development. Only a minor number of studies (also) focus on innovation strategies for the transport system or the market implementation of safety systems. Although in this context some attention is paid to costs and benefits of this new technology, Abele et al. conclude that no systematic assessment and coherent analysis of the socio-economic impact of such systems is performed. Consequently, the value of reported results for transport policymaking on ADAS implementation has so far been limited due to the lack of such integrated policy analyses on ADAS (Marchau and Walker, 2003).

This special issue is triggered by recent Dutch research on behavioural implications of ADAS. It includes a number of articles dealing with behavioural aspects of ADAS development and use. This article summarises some recent developments related to the issue of

ADAS and behaviour. The goal is to indicate the trends in the actual discussion on ADAS development and application and identify underlying uncertainties in knowledge on behavioural impacts. This helps us to better understand the scientific issues addressed in the other articles in this special issue. First, a framework will be presented in section 2 to position ADAS within the broader context of intelligent transport system development. Next, section 3 will categorize behavioural aspects in interaction with ADAS. In section 4 we conclude this paper with some discussion and an introduction to the other articles.

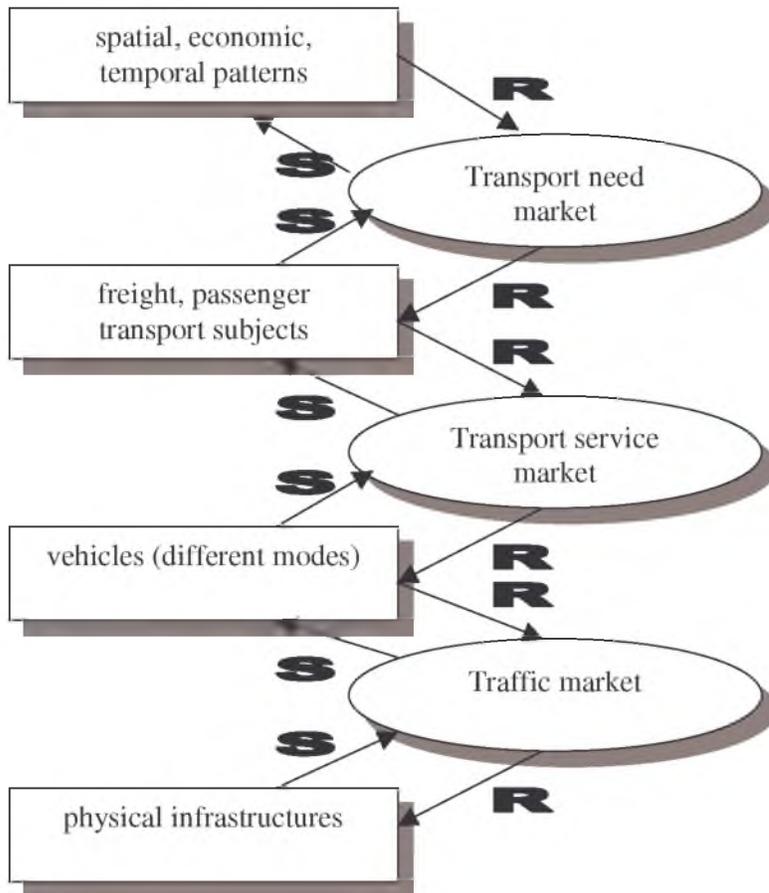
2. Positioning ADAS developments

To understand the various developments in ITS in general and within that context ADAS more specific, we need to understand the structure of the transport system in such a way that both the interactions among the physical elements of the transport system and the behavioural mechanisms underlying key processes in transport are integrated. Figure 1 presents a conceptual structure of the transport system, presented by Van der Heijden and Marchau (2002), that functionally distinguishes between seven subsystems: four physical subsystems (infrastructure, vehicles, cargo and passengers and spatial/economic patterns) and three 'market' subsystems (the traffic market, the transport service market and the transport needs market). Each subsystem is characterised by typical processes and issues and has characteristic stakeholder interactions. From an analytical point of view, it is valid to regard them as subsystems. From a synthesis point of view (e.g. in policymaking), it is important to pay special attention to the interactions between the subsystems. A lower subsystem facilitates (supports) the processes within the higher subsystems. A higher subsystem places functional requirements on services that are offered by the lower subsystem. We will first briefly discuss each subsystem in more detail before relating the ITS developments to the scheme.

The subsystem '*Physical infrastructure*' refers to the variety of infrastructure networks and facilities for different transport modes (road, rail, shipping, pipelines, air). These infrastructures are a necessary condition to facilitate traffic flows. Typical processes are the planning, design, construction and maintenance of infrastructure.

Increasingly, the road infrastructure capacity appears unable to handle total traffic demand, without congestion (e.g. Bovy, 2001). This is subject of intervention in the so-called '*Traffic market*'. Traffic managers intervene by using various operational traffic management strategies to cope with this problem. The nature and intensity of interventions can change due to e.g. the construction of more infrastructure capacity and/or the use of ITS applications to improve the use of available infrastructure capacity.

'*Vehicles*' refers to the fleet of vehicles that is available to transport passengers or freight from one place to another. The use of these vehicles asks for traffic rules and infrastructure capacity. The nature of this demand varies with the different functional characteristics of each transport fleet (e.g. maximum speed, professional drivers or not, use at dedicated lanes or in mixed traffic). Most of these fleets are subject to continuous technical improvements introduced by e.g. automotive industries, among which the introduction of ADAS.



S = support of processes at higher subsystems
R = requirements to subsystem's processes

Figure 1. Structure of the transport system

Choices regarding the use of certain modes to transport passengers or freight result from decision making by stakeholders operating in the subsystem called the 'Transport service market'. In this market, logistics providers, transport companies and individual travellers seek a match between the demand for trips and the available transport services. This process is sensitive to aspects such as costs, time or comfort. Various stakeholders involved focus on improving the quality of services and organising a good access to information for potential clients.

The development of transport services is an answer to actual 'Freight and passenger transport demand'. This demand is measurable in terms of the number of passengers and the freight volume to be transported at a certain time from a certain origin to a certain destination. This demand basically results from the 'Spatial, economic and temporal dynamics' related to production and consumption activities in society, the highest subsystem of the conceptual scheme. At this subsystem, decisions are taken and implemented on for instance the nature and spatial pattern of economic activities, the amount of free time for inhabitants and

on policies for urban development. The resulting societal structure generates a certain latent demand for transport. The degree, to which this latent demand results in actual transport behaviour, depends upon the operating of an intermediate market, here labelled the '*Transport needs market*'. The transfer from latent to actual transport needs heavily depends upon the trade-off made by individuals between the utility of a spatial movement and the level of resistance (time, money, effort). This is influenced by aspects such as the size of available time and financial budget, transport pricing policies and the possibilities to substitute physical trips by virtual trips.

Using this conceptual structure of the transport system, we are now able to make the step towards a functional classification of the variety of ITS technologies by linking the functionality of these technologies with the processes of the above-described subsystems. Table 1 shows such a classification. In this table, a link is made between the subsystems, the related public policy goals (deduced from Dutch national transport policy plans (V&W, 1989; 2004), the ITS functional category and indicative ITS applications. No comprehensiveness is intended.

Table 1. Indicative relationship between transportation subsystems, policy goals and ITS applications

Subsystem	policy goals	ITS functionality	possible ITS application
organisation of society	optimise mobility of people, goods and information		
transport need market	reduce unnecessary physical transport	systems for facilitating virtual mobility	electronic commerce; tele-working; tele-education
freight and passengers	optimise access to and use of transport system	information supply on transport services; booking of services	park and ride information; public transport services information; traffic information on radio or teletext; internet booking services
transport service market	improve logistical planning (modal split, route choice, time) in favour of safer, cheaper and environment-friendly transport	pre-trip planning support systems systems for logistic optimisation	(multi-modal) trip reservation; route planning systems; telecommunication for fleet management and operational control (tracking, tracing); trip matching systems (e.g. carpooling)
vehicles	improve driver's comfort, behaviour and vehicle control	smart motor technology driver support systems	self-diagnostic engine control systems; crash recorders; reverse parking aid; navigation systems; adaptive cruise/speed control; lateral/ longitudinal control; co-operative driving;
traffic flow market	maximise use of available infrastructure capacity; establish a smooth and safe traffic flow	dynamic traffic management systems	dynamic route information traffic information on radio; differentiated electronic payment; dynamic (directional) lane assignment; ramp metering; speed control (radar detection, cameras); variable message sign; incident detection; aid co-ordination systems
physical transport infrastructure	maximise capacity with limited physical extension; maintain quality	lane optimisation technology; infrastructure status control systems	dynamic lane configuration adaptation; surface measurement and deterioration detection

In the 'transport need market', some ITS developments focus on services to facilitate virtual mobility, aiming at a significant substitution for physical transport. Electronic services for distance working, commerce, learning or shopping, become increasingly popular (Banister and Stead, 2004). In the 'freight and passenger demand' subsystem, the focus is on ITS applications to improve pre-trip information (e.g. about transport mode options, expected travel time, delays, costs) and to collect transport service preferences. Logistic planning in the 'transport service market' uses a variety of supportive electronic tools, for example for route planning and navigation, for booking of multi-modal transport services, tracking and tracing, or fleet management. ITS developments related to the subsystem 'vehicles' focus on the development of systems to improve the operational performance of vehicles, such as improved motor performance, vehicle control or advanced driver support (ADAS). These ADAS helps the driver to perform basic driving tasks: lane keeping (roadway positioning), navigation, speed control, distance keeping, and front-obstacle and side-obstacle avoidance. The 'traffic market' is adopting a large variety of electronic systems for dynamic traffic management (Giannopoulos, 2004). ITS applications in this context focus on optimising infrastructure capacity use and assuring a safe and steady flow through networks. Examples are dynamic route information screens, lane assignment, real-time radio traffic information or ramp metering. Finally, in the 'infrastructure' subsystem, electronic systems can be used for road status measurement for e.g. maintenance planning or for certain activating traffic management measures such as speed advises.

A further focus on ADAS as a subset of ITS, learns us that some systems have been recently introduced on the market like adaptive cruise control, lane departure warning, or front-collision warning. Others are expected to be introduced in the market for soon, like lane departure avoidance or driver fatigue monitoring systems. On the other hand, various applications are still in a prototyping phase (e.g. intersection collision warning) or controversial (e.g. intelligent speed adaptation). In recent years, even integration of various ADAS in the concept of fully automated car driving has been demonstrated in the US, Japan and Europe (for an overview of recent ADAS developments see: Bishop, 2005).

The differences in speed of R&D and market introduction have to do with in general difficult to answer questions. A *first* issue concerns whether these systems can solely be based on in-vehicle technology or require (also) support from communication with other vehicles and/or infrastructure systems. Communication between vehicles and vehicles and infrastructure do overcome the limits of in-vehicle sensing devices: only the local environment is scanned and their provided lead time is short, in-vehicle sensors are mainly passive and they are relatively expensive (Morsink et al, 2003). Automotive industries prefer to develop applications as independent as possible from infrastructure facilities, since infrastructure adaptations usually take a long time. Moreover, public authorities often tend to act inconsistently and consequently constitute a risk for long-term co-operation. However, a sole in-car ADAS development seems difficult since, as mentioned above, extending the service level to the driver inevitably asks for links to infrastructure and traffic management related information. Public authorities dominate both. A *second* issue concerns the reliability of the technology: how sensible might the system performance be to disturbances, e.g. bad sensing due to temporary, degraded conditions (snow, fog), electromagnetic interferences, insufficient data processing capacity, and the like? For instance, unexpected interference between in-vehicle electronic systems has been reported resulting in accidents. The related liability issues are complex (Van Wees, 2004). Automotive industries put much effort in solving these issues to meet safety requirements for certification and enable market introduction of new ADAS. A *third*

issue concerns the applicability or functional scope of ADAS, an issue having strong relationships with gaps between market preferences and transport policy goals. Should these systems be designed to cope with the almost endless variety of road and traffic configurations or should specific groups (luxury vehicles) only be supported for convenience reasons within less complex traffic situations, notably the motorways? For the next decade for instance, only a limited applicability of overtaking support at secondary roads is expected as the sensing task is quite considerable and the decision rules to be implemented seem too complex to handle in the early development stage. In contrast, from a technical point of view there are no serious barriers to apply collision warning or intelligent speed control at secondary road networks. Experiments have revealed that intelligent speed adaptation and adaptive cruise control systems can perform satisfactorily in such a context of use.

Most of the technical developments are initiated by automotive industries. More safety, more driver comfort and better driving performance are claimed. The literature reports potentially significant positive impacts of ADAS. For instance, it has been estimated that the use of systems that support the driver in keeping a proper distance to the nearest vehicle ahead (adaptive cruise control) could increase road capacity by up to 25% (Minderhoud, 1999). The large-scale implementation of collision avoidance systems, which support the driver in case of imminent crash danger with vehicles or obstacles, could reduce collisions by up to 50% (Jagtman et al., 2001). Another type of ADAS measure involves the application of intelligent speed adaptation. These systems take into account the local speed restrictions and warn the driver in case of speeding or even automatically adjust the maximum driving speed to the posted maximum speed. The use of full-automatic speed control devices could lead to as much as a 36% reduction in injury accidents and a 59% reduction in fatal accidents (Carsten and Tate, 2005). The validity of these impact expectations, however, is often disputable. For instance, adaptive cruise control could contribute significantly to less head/tail crashes, but (dependent upon the specific operating characteristics of the system) could also reduce road capacity (Tabibi, 2004). Moreover, both intelligent speed adaptation and adaptive cruise control might generate unexpected driver behaviour (less alertness, over-expectations and compensation for freedom limitations) which could eliminate positive safety impacts (Hoedemaeker and Brookhuis, 1998; Dragutinovic et al., 2005). Finally, although indications can be found that the impacts of e.g. speed limitation and ACC on environmental performance are positive due to less fuel consumption (Antoniou et al., 2002), the question remains what happens when people adapt their travel-behaviour. One possibility is that car use increases because driving becomes more attractive due to the introduction of various driving support devices.

There is sufficient evidence that the introduction of dynamic traffic management systems has caused a significant (local) increase in road capacity, a better throughput and improved traffic safety. An increasingly important challenge is the attempt to link ADAS to traffic management systems and information on infrastructure status. Such information is then transferred to input for in-vehicle devices for e.g. traffic speed control, optimising flow assignment to different links in the road network or incident management. This so-called cooperation between vehicles and the infrastructure is generally considered as the next wave of ITS (Bishop, 2005). Examples like intersection collision avoidance, curve speed warning, cooperative-ACC and traffic-flow responsive-ACC are under heavy development.

From the brief explorations of ITS in this section, the conclusion can be drawn that different ADAS applications result in making the road 'smarter', making vehicle driving 'smarter' and making network management 'smarter'. Key players in this interacting game are the individ-

ual drivers, fleet owners, road managers, traffic managers, travel information providers and last but not least automotive industries.

3. Behavioural issues related to ADAS

In the previous section, we described a variety of services and devices for improving intelligence in transport. A subset of these systems is focused on the direct support of driver tasks: the advanced driver assistance systems. We memorised the widely felt expectation that these ADAS will increasingly be connected to systems providing travel information and traffic management information. The combination of systems in packages intends to significantly improve the performance of the transport system.

These packages and the expectations about their impacts are based on a set of assumptions on how these systems influence mobility behaviour and the performance of the transport system as a whole. Mobility behaviour is the result of individual driver's decision making. The performance of the transport system is the result of the dynamic interaction between decisions by a variety of stakeholders involved in the design, use and management of the transport system, including drivers, freight operators, traffic managers and policy makers. Hence, we deal with a large complexity and to understand this complexity we should at least distinguish between the following different types of decisions.

The first class of (basically strategic or long-term) decisions deals with the *development and selling* of certain ADAS applications. Hence, these decisions are linked to the transport service market as far as these concerns the potential users, but also influence the traffic market as far as this concerns the investments in and performance of the road infrastructure. This directly refers to the question which systems will be brought to the market in the future by the automotive industry? And what do automotive industries consider as their market in this context: commercial vehicles only or can we expect a similar development for ADAS as e.g. navigation devices which are becoming rapidly available for each vehicle today. Evidently, automotive suppliers will try to match the functionality of ADAS to *market preferences*. Different markets might however result in different preferences. Here several questions have not been answered yet in a fully satisfactory way: which kind of support do private and commercial drivers prefer and accept? Which systems will be purchased once they are brought to the market? When we do not really know the answers to these questions, there is a risk of the introduction of certain support systems that do not match market requirements. This might possibly have two effects: limited selling in case of voluntary systems or unintended use in case of compulsory systems (e.g. for in-vehicle speed limitation). In this context we also stress the potentially important impact of public policy strategies. These strategies will strongly influence *investments* in road infrastructure development in relation to public goals (e.g. in the field of traffic safety and urban accessibility). Long-term transport policy decisions are not only based on views with respect to traffic safety and traffic system efficiency but also on the interaction of transport with spatial organisation and economy. They are contextual for decisions regarding ITS in general and ADAS-development and implementation in particular. For example, a policy choice for stimulating interregional (including international) accessibility of economic centres by improving reliability and throughput of the main road network will most probably result in systems that optimise motorway use. In contrast, stimulating intra-urban accessibility might result in quite different strategies, such as for instance optimising P&R connected to a network for automated busses (see e.g. Argiolu et al. 2004).

The second class of (basically tactical or medium term) decisions has to do with the *ADAS use strategy* of drivers and traffic managers. Here we deal with decisions with a direct influence on the transport service market and traffic market. An underlying issue in this context from the perspective of the drivers is the *acceptance* and willingness to use a certain system. In case of obligatory systems, the acceptance is probably lower than in case of voluntary purchasing, as has e.g. been found in the case of intelligent speed adaptation (Marchau et al., 2005). When acceptance is low, drivers will find ways to avoid using the system or limit the impact on their normal behaviour (e.g. develop an attitude of neglecting warning signals) or try to compensate limitations by other types of behaviour. An example of compensating behaviour is that intelligent (in-vehicle) speed control in an urban area might generate more exceeding of speed limits on other roads (Várhelyi and Mäkinen, 2001). On the other hand, we cannot exclude the possibility that drivers develop a very positive attitude towards ADAS-equipped vehicles, because it gives them a feeling of safety and reliability, perhaps generating a trend of more car mobility. Such a behavioural effect might become reality for elderly and disabled people that are now more reluctant to participate in road traffic. From the perspective of traffic managers, decisions are important on *where* (different parts of different road networks) and *when* (day, night, extreme weather conditions) the use of certain systems should be obliged, encouraged or perhaps forbidden.

A third category of (basically operational or short-term) decisions refers to the direct use of the driver support systems by drivers. Here we enter the world of human machine interface (HMI) in interaction to situation awareness. At its turn, this is related to the issue of *product safety policy* and *liability law* (Van Wees, 2004). The behavioural impacts of the HMI design are of direct influence on the performance of car drivers and consequently indirect on the traffic system: number of incidents of accidents, flow disturbances, throughput in the network. One issue underlying this behaviour is whether or not drivers have sufficient understanding of the *intended use* and the limitations of the system. This has two important aspects. First the driver might not fully understand what the system does and how he/she should interact with the system. Secondly, the driver relies too much on the system and does not fully understand the limitations regarding the traffic circumstances he/she is allowed to use the system. For example the present advanced cruise control systems on the market do not work in case the speed is lower than about 40 km/h and cannot handle emergency stops. Relying on the use of certain support in a traffic situation, where the system has not been designed for, might generate dangerous situations. Another behavioural aspect of operational use of ADAS is the possible *information overload* to the driver in case of the simultaneous use of a series of different and not mutually connected driver support systems (e.g. speed level warning, lane keeping, speed headway control, route guidance, et cetera). On the other hand, ADAS taking over many operational driver tasks might cause a lack of certain skills and/or might cause more problems when switching from the network where ADAS is used towards a network where these systems are not applicable (e.g. from the motorway into the urban area).

Notwithstanding the growing amount of knowledge, the conclusion is that we cannot make simple, straightforward assumptions on how ADAS will influence driver behaviour, the interaction between traffic participants and the performance of the transport system as a whole. Many mechanisms and effects are still uncertain due to a lack of adequate behavioural theories and empirical research. More research is required, both focusing on increasing in-depth knowledge on the characteristics of specific ADAS, but certainly also focusing on the integrated use of different systems (the earlier mentioned packages). In the past decade in The

Netherlands different research groups have worked on these behavioural issues. Some results will be presented in the articles in this special issue. In the final section of this introductory article, we will suggest some priorities for research based on the preceding review and introduce the other articles.

4. Discussion and introduction to the special issue

In this article, we explored some recent development of ADAS, an important field of new technological devices within the broader context of the Intelligent Transport System (ITS) concept. We used a systems view to classify these developments. Attention was paid to the lack of sufficient conceptual and empirical knowledge about the links between decisions regarding the design and large-scale implementation on the one hand and user needs, user acceptance and traffic performance of ADAS on the other hand.

Improvement of knowledge is necessary to better develop efficient and effective driver assistance systems. Moreover, better knowledge improves the ex ante evaluation of the need for certain ADAS, the performance of these systems, the certification requirements and the allocation of liability to certain parties for system development, system application and system failure. The exploration in the previous sections provided various issues for a research agenda to actually work on the improvement of this knowledge infrastructure. It has been argued repeatedly in this and other articles that many research issues are not in the field of the technology itself. Many issues deal with the relationship between technological devices and the positions and attitudes of those who are supposed to design, to use or to accommodate these devices: the drivers, the road managers, the policy makers and the automotive industries.

What does this all mean for the research agenda? To contribute to the debate on this question, we mention the following three themes. *First*, we need more knowledge about the behavioural response of the potential users and other involved stakeholders to the technical developments discussed here. ADAS is something that is offered to drivers but is not only influencing their individual traffic behaviour. In the end ADAS will significantly change the performance of the transport system as a whole, in particular when good links with traffic management and travel information provision can be made. Therefore, exploring preferences, acceptance and behavioural responses to ADAS as input in automation efforts and as a conditioning factor for implementation strategies remains important. It seems evident that these investigations should be stimulated and performed by those who develop ADAS and bring them to the market. On the other hand, knowledge institutes are basically in a better position to independently study these aspects and, moreover, publish on the results without limitations.

Secondly, more effort should be put in (laboratory as well as real-world) experimenting with integrated ADAS applications, linking ADAS to the infrastructure and possibly also traffic management. Integrated approaches open a new future for indeed creating more intelligent transport systems. The challenge for society lies in reaching synergy between technological and management innovations that presently follow separate avenues. Some trend towards linking support devices is recognisable, but a strengthening of this development including testing on different road types, investigating individual responses and traffic impacts, would imply a major step forward. To perform such research a public-private partnership like the Dutch Transumo-project (Transition Sustainable Mobility), where knowledge institutes, public authorities work and knowledge users or industries work together in a setting of pre-

competition, might prove to be a productive way of knowledge development (see: www.transumo.nl). At a minimum, public authorities should co-operate with automotive industries in discussing the most promising avenues, exploring mutual contributions and increase mutual understanding.

A *third* issue is related to the previous one. It concerns the specification of contours of public policy in this field: what is allowed, what systems on what road types are preferred, which standards should be met, what public goals should not be violated, and the like. In other publications we pointed at the danger of a wait-and-see attitude of policy makers. Innovations might be blocked due to a lack of vision and a firm and stable related public action program. This is a major source of uncertainty that is presently reduced by automotive industry by merely focusing on developing in-vehicle systems and impacts for individual drivers. Consequently, the lack of a clear public policy strategy gives the technical and markets engineers more possibilities to take over the policy role. When this is a purposeful choice by politicians, then one should accept that. Unfortunately however, this lack of public goals seems much more the result of a lack of discussion. The time has come to change this situation.

The articles in this special issue mainly bear a relationship with the first theme: improving the knowledge on behavioural aspects related to ADAS. The next 3 articles in this special issue focus on the driver behavioural aspects for ADAS. The paper by Houtenbos et al. considers requirements for ADAS from a view of the driver's interaction with ADAS. Wrong expectations on this interaction might lead to uncommon driver behaviour and to unforeseen and dangerous responses by surrounding road users. An experiment is presented to understand the mechanisms of road users' expectations in interaction situations. Dragutinovic et al. focus on the danger of driving behavioural adaptation of ADAS, i.e. those behaviours which may occur following the introduction of ADAS but were not intended. The outcomes of existing studies about the effects ADAS have on driving behaviour are systematically assessed in order to assess the occurrence of potential behavioural adaptation changes in driving behaviour as a consequence of ADAS use. The third paper by Hegeman et al. considers to what extent ADAS could support overtaking manoeuvre performance. Therefore the overtaking task is divided in various subtasks and for each subtask available ADAS functionality is considered. It appears that for the more difficult subtasks of overtaking no ADAS is available yet.

The next two articles in this issue focus on the user needs regarding ADAS. The paper by Van Driel and Van Arem reports on the driver needs for ADAS based on a large Internet survey. In general drivers indicate a need for integrated ADAS, ADAS which exchange information with other vehicles and traffic operators, enabling driver support based on actual traffic conditions. Katteler reports the results of a study among test drivers of ISA. Although the attitude towards ISA appears positive, the support for ISA is frequently not associated with meeting a strong need. This weakens the permanence of the support in society for ISA implementation.

Walta et al. examine the viability of co-operative road-vehicle systems among crucial stakeholders. Five systems were recognised as potentially viable: Navigation systems, Intelligent Speed Adaptation (ISA), Traffic responsive Adaptive Cruise Control, Intersection support and Information systems. A deployment path for these systems was constructed based on the two main routes for deployment recognised that focused on Telematics and Advanced Driver Assistance Systems respectively.

Finally, Van Wees and Brookhuis link driving behaviouristic implications of ADAS to the field of legal liability. Potential liability of system developers and car manufacturers is often labelled as a barrier for the rapid deployment of new technology. They explain the role of

human factors expertise in product liability law. Furthermore, they explore the current state of knowledge in this field and assess its relevance for potential product liability for ADAS.

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References

Abele, J., Kerlen, C., Krueger, S., Baum, H., Geißler, T., Grawenhoff, S., Schneider J. and Schulz, W.H. (2005). *Exploratory Study on the potential socio-economic impact of the introduction of Intelligent Safety Systems in Road Vehicles*. VDI/VDE Innovation + Technik GmbH and Institute for Transport Economics, University of Cologne.

Antoniou, C. Yannis, G. and Golias, J. (2002). Road network efficiency and environmental impact assessment of Driver Assistance Systems. In: *Proceedings of the 9th World Congress in Intelligent Transport Systems ITS*, 14-17 October, Chicago.

Argioli, R., Van der Heijden, R. and Marchau, V. (2004). ITS policy strategies for urban regions; a creative exploration. *Proceedings of selected papers of the 10th WCTR Conference*, Istanbul, 4-8 July 2004.

Banister, D. and Stead, D. (2004). Impact of information and communications technology on transport. *Transport Reviews*, vol. 24, no. 5, pp. 611-632.

Bishop, R. (2005). *Intelligent Vehicle Technology and Trends*. Artech House Inc., Norwood.

Bovy, P.H.L. (2001). Traffic flooding the low countries: how the Dutch cope with motorway congestion. *Transport Reviews*, vol. 21, no. 1, pp. 89-116.

Carsten, O.M. and Tate, F.N. (2005). Intelligent speed adaptation: accident savings and cost-benefit analysis. *Accident Analysis and Prevention*, vol. 37, no. 3, pp. 407-416.

Dragutinovic, N., Brookhuis, K.A., Hagenzieker, M. and Marchau, V.A.W.J. (2005). ACC effects on driving speed - a second look. In: D. de Waard, L.A. Brookhuis, R. van Egmond and T. Boersma (eds.) *Human Factors in Design, Safety and Management*, Shaker Publishing, Maastricht, pp. 381-386.

Giannopoulos, G.A. (2004). The application of information and communication technologies in transport. *European Journal of Operational Research*, vol. 152, no. 2, pp. 302-320.

Hoedemaeker, M. and Brookhuis, K. (1998). Behavioural adaptation to driving with and adaptive cruise control (ACC). *Transportation Research Part F*, vol. 1, pp. 95-106.

Jagtman, E.J., Marchau, V.A.W.J. and Heijer, T. (2001). Current Knowledge on Safety Impacts of Collision Avoidance Systems. In: P.M. Herder, W.A.H. Thissen (eds.): *Critical Infrastructures – 5th International Conference on Technology, Policy and Innovation*. Lemma B.V., Utrecht.

- Marchau V. and Walker, W. (2003). Dealing with uncertainty in implementing Advanced Driver Assistance Systems: An Adaptive Approach. *Integrated Assessment*, vol. 4, no. 1, pp. 35-45.
- Marchau, V., Van der Heijden, R. and Molin, E. (2005). Societal desirability of advanced driver assistance from road safety perspective: the case of ISA. *Safety Science*, vol. 43, pp. 11-27.
- Minderhoud, M. (1999). *Supported driving: impacts on motorway traffic flow*. Delft University Press, Delft, the Netherlands.
- Morsink, P., Hallouzi, R., Dagli, I., Cseh, C., Schäfers L., Nelisse, M. and De Bruin, D. (2003). Cartalk 2000: development of a cooperative ADAS based on vehicle-to-vehicle communication. *Proceedings of the 10th World Congress and Exhibition on Intelligent Transport Systems and Services*, 16-20 November 2003, Madrid.
- Tabibi, M. (2004). *Design and Control of Automated Truck Traffic at Motorway Ramps*. TRAIL Thesis Series T2004/4, The Netherlands.
- Van der Heijden, R. and Marchau, V. (2002). Innovating road traffic management by ITS: a future perspective. *International Journal of Technology, Policy and Management*, vol. 2, no. 1, pp. 20-39.
- Van Wees, K. (2004). *Intelligente voertuigen, veiligheidsregulering en aansprakelijkheid. Een onderzoek naar juridische aspecten van Driver Assistance Systems in het wegverkeer*, TRAIL Thesis Series T2004/10, The Netherlands (In Dutch).
- Várhelyi, A. and Mäkinen, T. (2001). The effects of in-car speed limiters: field studies. *Transportation Research Part C: Emerging Technologies*, vol. 9, no. 3, pp. 191-211.
- V&W (1989). *National Transport Structure Plan II*. Ministry of Transportation and Public Works, The Hague, The Netherlands (in Dutch).
- V&W (2004). *National Policy Plan on Mobility*. Ministry of Transportation and Public Works, The Hague, The Netherlands (in Dutch).

