Behavioural impacts of Advanced Driver Assistance Systems–an overview

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The purpose of Advanced Driver Assistance Systems (ADAS) is that driver error will be reduced or even eliminated, and efficiency in traffic and transport is enhanced. The benefits of ADAS implementations are potentially considerable because of a significant decrease in human suffering, economical cost and pollution. However, there are also potential problems to be expected, since the task of driving a ordinary motor vehicle is changing in nature, in the direction of supervising a (partly) automated moving vehicle.

1. Introduction

There are a number of reasons why in recent years electronic driving aids are developed and implemented at an increasing rate and speed. The first and foremost reason is safety (i.e. the unacceptable number of accidents), but also economic principles (time is money, among others) are a compelling drive, while bringing comfort to the driver population is obviously a good sales argument. Last but not least, environmental arguments play a role of growing importance.

1.1. Accident causes

Safety is primarily a ‘human factors’ case. Driver impairment is the first cause of accidents on (European) motorways. Based on a literature survey, Smiley and Brookhuis (1987) stated that about 90% of all traffic accidents are to be attributed to human failure, for instance, through fatigue, inattention or drowsiness at the wheel. According to Vallet (1991) it is generally a loss of alertness, which is the principal cause of fatal accidents (34%). While some suggest that alcohol is in at least 20% of all accidents the “prime causative factor”, at least during the weekend, fatigue as “single factor” is estimated to be responsible for 7-10% of all accidents (Tunbridge et al., 2000). The costs of road traffic accidents for society are enormous in terms of both human suffering and economical loss. In Europe alone around 50.000 people are killed in traffic accidents each year, while more than 1.500.000 are injured. Traffic congestion, i.e. the regular ones and following traffic accidents, is a daily nuisance, predominantly present in the economically most sensitive places. At least 70 Billion Euro’s are spent each year on medical treatment of injured people, the cost of congestion is many times that amount, and many thousands of person-years of work are lost.

1.2 Accident causation

Tunbridge et al. (2000) argue that examination of accidents’ most prevailing factors shows, perhaps not surprisingly, the two most common “What happened?” factors being loss of control and failing to avoid a vehicle in the carriageway (i.e. a collision). The distribution of contributory factors is also interesting. These factors can be hierarchically categorised as representing Driver (error & impairment), Environment, and Vehicle factors contributing to accidents (Shinar, 1998). The incidence of these factors is revealing. The incidence of alcohol was established at 3.8%, which is very close to that for all accidents in England where a driver is known to be over the drink drive limit (4.2%). For the other impairment related factors the situation is not so straightforward. Impairment due to fatigue is recorded as a factor in only 0.8% of accidents, whereas in-depth studies and a large volume of anecdotal evidence shows that this factor is more like 7-10%. This under-representation of fatigue related accidents is now well recognised and results largely from the absence of direct evidence of sleepiness or tiredness being a factor. There is no quantitative measure of this effect on drivers. If drivers survive an accident caused by sleepiness they are unlikely to admit it; if they do not survive there is often very little direct physical evidence. Other factors e.g. vehicle defects, which are often erroneously cited as causes, usually need to be eliminated before fatigue becomes apparent.

1.3 Electronic aids

The prevention or reduction of traffic accidents requires countermeasures that have to be devised and introduced to prevent those behaviours contributing to accidents. In Europe, the USA and Japan, combined ergonomic and engineering approaches to both hazard assessment and the indication of drivers’ performance limits have developed into research and development of new and relevant (primary) safety measures. Brookhuis & Brown (1992) argue that an ergonomic approach to behavioural change via engineering measures, in the form of electronic driving aids, needs to be adopted in order to improve road safety, transport efficiency and environmental quality.

Driver comfort appears to be a strong impetus for the development of electronic driving aids as well, at least from a marketing point of view. Car manufacturers are keen on driver comfort and invest considerable effort in the development and improvement of comfort enhancing electronic aids. Well-known examples of this type of applications are navigation or route guidance systems and advanced cruise control systems. Though expensive, prototypes of this type of systems passed a number of tests (and improvements) and were successfully placed on the consumer market. Before the actual marketing, user needs research (or marketing research) is indispensable, but also studies on acceptance and certainly safety effects are still necessary after implementation. Consumer acceptance is dependent upon such requirements as system safety, validity (does the system function correctly) and benefit (is there a positive cost-benefit balance). Finally, environmental issues are not decisive in this area yet, but will gain weight in the future.

2. Advanced Driver Assistance Systems

What is now called ADAS (Advanced Driver Assistance Systems) is to be considered as the collection of systems and subsystems on the way to a fully automated highway system, if ever realised (ADASE project deliverables, 1998). Only when on a fully automated traffic lane, the vehicle can be operated under fully automated control, which is very similar to the automatic pilot in aeroplanes (Congress, 1994), bailing out the human factor. ADAS concepts include among others blind spot detectors, Adaptive Cruise Control, Autonomous Intelligent Cruise Control, platoon driving, etc., in general AVG (Automated Vehicle Guidance). Some of the technology is available on the market, or ready to be marketed, some is developed but as a prototype still under test. A prototype fully automated traffic lane exists in the USA near San Diego, including a limited number of vehicles running on the lane, for testing and demonstrating purposes. A similar demonstration including many more separate ADAS applications was organised in the Netherlands in 1998.

2.1 History

ADAS has a considerable history. In Europe several car manufacturers and research institutes started the Prometheus initiative, around 1986. A series of projects was carried out under this umbrella, most of them aiming at practical solutions to urban traffic problems. The European Union initiated the DRIVE (Dedicated Road Infrastructure for Vehicle safety in Europe) program shortly thereafter, in which a considerable number of projects tackled practical problems as well as fundamental issues. An example of the latter is the GIDS (Generic Intelligent Driver Support) project, the largest project in DRIVE 1, ahead of it’s time and still relevant (Michon, 1993). The overall objective of this ambitious project was “to determine the requirements and design standards for a class of intelligent driver support systems which will conform with the information requirements and performance capabilities of the individual drivers”. On the one hand this class of systems will aid the driver’s detection and assessment of road and traffic hazards, on the other they will provide guidance on the driver’s ability to deal with specific hazards.

2.2 Benefits and functionality

Thus, the purpose of ADAS is that driver error will be reduced or even eliminated and efficiency is enhanced. The benefits of ADAS implementations are potentially great because of a significant decrease in human suffering, economical cost and pollution, since (cf., Congress, 1994):

- driving safety will be considerably enhanced;
- many more vehicles can be accommodated, on regular highways but especially on dedicated lanes;
- high-performance driving can be conducted without regard to vision, weather and environmental conditions;
- drivers using ADAS can be safe and efficient drivers (cf. elderly, inexperienced drivers).

Primary functionality of ADAS is to facilitate the task performance of drivers by providing real-time advice, instruction and warnings. This type of systems is usually also described by the term “co-driver systems” or “driver support systems”. Driver support systems may operate in advisory, semi-automatic or automatic mode (e.g. Rosengren, 1995), all of which may have different consequences for the driving task, and with that on traffic safety. Although the purpose of a driver support system is to have a positive effect on traffic safety, adverse effects have been shown on driver behaviour, indicative of negative effects on traffic safety (Zwahlen, Adams and DeBald, 1988, Van Winsum, 1997). Firstly, the provision of information potentially leads to a situation where the driver's attention is diverted from traffic. Secondly, taking over (part of) the driving task by a co-driver system may well produce behavioural adaptation. As a result, either the driver might not (or too late) be aware of a sudden hazard, or, is not fit (anymore) c.q. not ready for an adequate reaction. Before introducing any driver support system, the consequences of system operation in this sense should be identified.

A specific source of problems with the development of driver support systems that are intended to reduce accidents is that it is very difficult, if not impossible, to forecast the savings of death and disability that might result from the introduction of such systems. Although there is an urgent need to know what the effects are of introducing a specific system before it enters the market, no data exist on which estimates of the benefits and the risks of system-specific traffic behaviour can be based. The only type of effects that can be studied is effects on behavioural aspects of the driving task per se. These aspects should be selected on the basis of known adverse effects on traffic safety, such as insufficient safety margins in lateral and longitudinal positioning (cf., Rumar, 1988). Hence, each individual IVIS application should be subjected to a test on behavioural effects before marketing, in order to pinpoint both beneficial and unwanted side effects at the behavioural level. For this, however, exact criteria still have to be developed (Brookhuis et al., submitted). Eventually, traffic safety effects are confined to an extrapolation from these test results then.

3. Problems with ADAS

User needs in road transport in a general sense stem from unsatisfactory conditions. The reason could be in (physical) working conditions, causing fatigue and health problems, or traffic safety. In the past many studies have been done in this area into the driving conditions of professional drivers. Ouwerkerk (1986), for instance, in a survey among studies as known at that time reported that more 50% of the professional drivers admitted falling asleep and/or having had near-accidents. These numbers were found for both lorry- and bus-drivers. In the present time of electronic driving aids, solving the need for support to avoid accidents is thought to be realised through ADAS.

However, there are also potential problems to be expected. For instance, increased complexity of the “cockpit” increases the likelihood of failure by the driver, and of at least one of the system’s components, either by ‘spontaneous’ failure or by design errors (Janssen, Wierda & Van der Horst, 1992). The latter requires additional alertness of the driver, while at the same time driver alertness in general and attention for the driving task per se is decreasing in case of automation of the driving task (Brookhuis & De Waard, 1993).

Electronic driving aids can be considered to operate in different modes, from noncommittal information supply via active support at driver’s will to leaving control to technology completely. Not surprisingly, acceptance varies with driver control (Bekiaris, Petica & Brookhuis, 1997); taking the driver out of the loop is considered a problem by many (potential) end-users. The views with respect to the different modes may well be different for different stakeholders such as the authorities, the general public and the end-users including professionals.

One of the most important characteristics of electronic in-car technologies is to provide information to drivers. Not only through different types of messages located in the road environment, but also by their integration inside the vehicle, through different types of devices. It is clear that a poorly designed system inside vehicles can adversely affect the different actors, or more generally, the social benefits associated with the system (Bekiaris, Petica & Brookhuis, 1997). However, ADAS devices that are limited to supplying information are most likely to meet a priori acceptance. Examples are route guidance systems, traffic jam warning systems, autonomous intelligent cruise control, driver monitoring systems and complete automatic highway systems.

Several reservations that have consequences for acceptance by the relevant stakeholders, hold for any of these modes. A few studies found support for compliance, i.e. excessive reliance on automated (ADAS) systems, others reported deterioration in driving performance. This and other forms of behavioural adaptation, or compensation as it is called in a wider field, are factors that should be taken into account when investigating the conditions for introduction of ADAS (Verwey, Brookhuis & Janssen, 1996).

3.1 Behavioural changes

Automation may increase reaction time. In case of continuous monitoring, reaction time to events in a driving task can be restricted to something like one second, while if more than one functions have to be monitored and other tasks are attended to, awareness of the situation has to be refreshed with increased frequency. At the same time, possible malfunction and its origin have to be determined which might take many seconds. In this way, an attempt to reduce workload is actually very likely to lead to increased workload (Hancock & Parasuraman, 1992). There are also several studies that have shown that monitoring of systems for malfunctions during prolonged periods of time induce high levels of workload, despite the fact that information processing requirements for these tasks are low in itself. Humans are poor ‘process monitors’ (e.g., Molloy & Parasuraman, 1996) and enforced vigilance in the operational environment is very stressful (Hancock & Parasuraman, 1992). An adaptable interface between human and machine is proposed that dynamically allocates tasks to these two and maintains an appropriate and tolerable load on the operator. Research on adaptive task allocation shows that temporarily returning control to the human operator at the right moment, i.e. when the driver is ready for it, has favourable effects on detection of automation failures during subsequent automation control (Parasuraman et al., 1996). Many of these aspects are subject to research in the early new millennium.

3.2 Human supervision

The classic goal of automation is to replace human manual control, planning and problem solving by automatic devices. However, these systems still need human beings for supervision and adjustment. It has been suggested that the more advanced a control system, the more crucial is the contribution of the human operator (Bainbridge, 1983).

The point made by Bainbridge (1983) is as follows: normal operation is performed automatically, abnormal conditions are to be dealt with manually. Unfortunately, as a result of automation, experience is limited, while in case of abnormal conditions (i.e., something is wrong with the process) unusual actions will be required. Also, human problem solving is not optimal under time-pressure.

Monitoring of (present) automatic processes is based on skills that formerly manual operators have, and that future generations of operators (/drivers) cannot be expected to have (Bainbridge, 1983). Pilots also indicated that although automation reduced workload, it also had a negative effect on flying skills. They considered manually flying of a part of every trip important to maintain these skills (McClumpha et al., 1991).

3.3 Complacency

When a system fails to work or is in a state that failure is possible, feedback should be provided in order to let the driver know that s/he can not rely on the system. The main reason for this is that automated systems can and will lead to what has been called ‘complacency’ (Wiener and Curry, 1980). Complacency is an attitude of (over)reliance on an automated system. In a test of reaction time to a system failure cue, Knapp and Vardaman (1991) found support for complacency, i.e. the reaction time to this cue increased compared to normal task performance. Ward et al. (1995) also found evidence for complacency, poor lane position control and failure to yield to other traffic was more frequently observed in drivers driving a car with AICC compared to drivers driving a normal car.

3.4 Acceptance/attitude towards ADAS

A basic question in ADAS implementation is acceptance of ADAS, i.e. giving up parts of the direct control over the vehicle. For instance, take-over of control in case of short headway to a lead car was less appreciated than warnings or suggestions of the appropriate action in a test of different types of Collision Avoidance Systems (Nilsson & Alm, 1991). Although drivers expect a positive safety effect by this type of anti-collision systems and other forms of ADAS, they have at the same time reservations against it. Handing over control to a device and the automated braking function are evaluated as negative aspects of ADAS systems (Hoedemaeker, 1996, Hoedemaeker & Brookhuis, 1999). Complete take-over in specific circumstances has been tested as well. The SAVE project (EU DG XIII TR1047) aimed to develop a system that takes over vehicle control in case of real emergency, such sudden illness. An international questionnaire survey carried out in the SAVE project indicated that the driver population is reluctant to release vehicle control, but is willing to accept it in emergency situations (Bekiaris et al, 1997). De Vos & Hoekstra (1997) focused on behavioural aspects of leaving the fully automated highway traffic lane. Apart from studying the exit procedure, they also found that a short headway was considered less comfortable and less accepted than a larger headway to vehicles-in-front. In follow-up projects funded by the EU, many of these aspects are tackled with the aim to help introducing ADAS (e.g. Wiethoff, 2001).

4. Conclusion

The potential of ADA systems is great, provided ADAS will be completely accepted and widely introduced in the (near) future. For this, the ADA (sub)systems will all have to be made as fail-safe as possible. Whenever the system fails, safety is to be determined by the provisions taken to avoid serious accidents and in case of an accident the measures to minimise the consequences for the passengers. Acceptability of ADAS is highly dependent upon solid demonstration of these features. Acceptability is also found to be dependent of the form in which ADAS applications are implemented. For the end-user the benefits should be clear and preferably directly noticeable. For this reason comfort enhancing features stand a better change than safety enhancement properties. Most drivers consider themselves at least better drivers with respect to safe behaviour than average. Strict requirements for ADAS applications by all stakeholders are safe (and valid) operation and reliability, false alarms are not acceptable for end-users particularly.

Introduction of a fully automated highway system is technically possible now, but public introduction on a large scale is at least waiting for the safety provisions and the public acceptance, and also on proper legislation that clearly establishes responsibility and liability. ITS America plans USA full deployment for 2005, comparable initiatives in Europe and Japan will certainly close in as soon possible. In the meantime many (current, at the moment of writing) projects such as the EU-projects ADVISORS and TRAVEL-GUIDE (both running from 2000 to 2003) try to pave the way for introduction of ADAS and above all acceptance of ADAS by stakeholders and community.

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