ACCEPTABILITY OF IN-VEHICLE INTELLIGENT TRANSPORT SYSTEMS TO VICTORIAN CAR DRIVERS

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ABSTRACT

The Monash University Accident Research Centre (MUARC) recently completed research for the Royal Automobile Club of Victoria (RACV) into the acceptability to car drivers of several in-vehicle Intelligent Transport Systems (ITS) with high estimated safety potential. The acceptability of seven technologies was assessed: Forward Collision Warning; Intelligent Speed Adaptation; Emergency Notification; Electronic Licence; Alcohol Interlock; Fatigue Monitoring; and Lane Departure Warning. Eight focus groups were conducted involving a total of 52 Victorian car drivers, ranging in age from 18 to 83 years. Participants belonged to sub-groups of car drivers (defined by age and sex) who, from examination of Victorian crash data, were either over-represented or involved most in crashes of the types addressed by the technologies under study. Hence, the sub-groups of car drivers selected were those who should derive the greatest safety benefits from the systems. To be acceptable to participants a system was defined as needing to be useful, effective, usable, affordable, and socially acceptable. The Alcohol Interlock and Electronic Licence were found to be least acceptable to drivers. They were also, along with Intelligent Speed Adaptation, the systems that were estimated to confer the greatest safety benefit. The implications of these findings for the successful deployment of in-vehicle ITS are discussed.

INTRODUCTION

The term ITS refers to the bringing together of advanced information processing, communications, sensing and computer control technologies to produce systems that are capable of addressing various surface transportation problems. ITS technologies have been designed, for example, to improve travel efficiency and mobility, enhance safety, conserve energy, provide economic benefits, and protect the environment (Regan, Oxley, Godley & Tingvall, 2001). It is estimated that many in-vehicle ITS technologies have great potential to enhance the safety of road users (Regan et al., 2001). Many such technologies are either currently available, or are entering the Australian market. In order for in-vehicle ITS technologies to be successful in reducing the incidence and severity of road crashes, the technologies must be deemed to be acceptable by the eventual users. The demand for many in-vehicle systems will be driven by road users, who will decide whether to purchase the systems or to purchase cars that are equipped with the technologies. ITS technologies that are not acceptable to drivers are unlikely to have the desired effect on driver behaviour. The acceptability of in-vehicle ITS technologies to drivers is thus a vital issue to address in the design, development and deployment of in-vehicle ITS.

RACV commissioned MUARC to assess the acceptability to car drivers of certain ITS technologies with high estimated safety potential. This paper provides an overview of the method and key findings of this study. Before doing so, a brief review of previous research into the acceptability of in-vehicle ITS is presented.

PREVIOUS RESEARCH INTO ITS ACCEPTABILITY

Over the past decade, an increasing number of studies have been conducted into the acceptability to car drivers of in-vehicle ITS technologies. For example, studies have been conducted in Europe investigating driver acceptability of the class of technologies designed to reduce speeding known as Intelligent Speed Adaptation (e.g. Almqvist & Nygård,1997; Brookhuis & de Waard,1999). Across studies, speed alerting systems, which simply warn the driver if he/she is exceeding the posted speed limit, have been found to be more acceptable to drivers than speed limiting systems, which are more aggressive than alerting systems in that they prevent the driver from speeding by limiting the speed of the vehicle to the posted speed limit (Várhelyi,2001).

In Australia, to date, only three studies have been completed that have investigated the acceptability to drivers of various in-vehicle ITS (Cairney, 1995; Gray, 2001; Harrison, Senserrick & Tingvall, 2000). Cairney's (1995) study involved the use of focus groups in which all participants considered seven in-vehicle technologies, including Route Guidance, Vehicle Monitoring, Emergency Notification, Adaptive Cruise Control and Congestion Avoidance systems. Participants perceived the Vehicle Monitoring system to be the most useful of all the systems discussed and the one that they would most like to have in their vehicle. Adaptive Cruise Control was the least liked and perceived to be the least useful. This latter finding contrasts with the findings of several European and US studies where participants' views on Adaptive Cruise Control were reported to be quite positive (see Brackstone & McDonald, 2000). For example, in a simulator study on the effects on driver behaviour of Adaptive Cruise Control, Hogema, Janssen, Coemet and Soeteman (1996) reported that participants found the system to be useful. The discrepancy between studies may be in part because of cultural differences,

and in part because of the different methods used to assess acceptability. The participants in Cairney's (1995) study had never experienced the technologies, whereas in Hogema et al. (1996), views on Adaptive Cruise Control had been elicited from participants following exposure to the system in a driving simulator. In the information technology domain, it is generally understood that the acceptability of a computer system is likely to change as a result of interaction over time with the system (e.g. Chau, 1996). This is also likely in the case of in-vehicle ITS. For example, there is evidence to suggest that, with experience, drivers become less positive towards the alerting variants of Intelligent Speed Adaptation and less negative towards limiting variants (Várhelyi, 2001). It is important, therefore, that studies into the acceptability to car drivers of ITS are interpreted in the context of the degree and type of exposure participants have with the systems under study.

Harrison et al. (2000) sought to develop a method that could be used for the assessment of driver acceptability of Seat Belt Reminder systems. An important consideration in the development of the method was that it be able to be applied prior to the technology becoming commercially available in vehicles, and that it involve groups of road users that are the most likely to benefit from use of the technology. Also important was that the assessment method simulate the social processes that might occur with introduction of the technology in the community. The chosen method involved the conduct of focus groups with car drivers who were non-wearers of seat belts. While the main focus of Harrison et al's (2000) study was on the development of a method for the assessment of acceptability, the study also yielded some Australian data on the perceived acceptability of Seat Belt Reminder systems. There was agreement among participants that the system would be a positive road safety measure, with a general feeling among participants that the device would help them develop better seat belt wearing habits, even when driving vehicles not equipped with the system. Nevertheless, participants did raise some concerns about the system, such as whether it was 100 percent reliable, and whether the audio warning issued by the system could be heard over background noise or by drivers with hearing impairments.

Gray (2001) reported on the results of a telephone survey designed to elicit individuals' attitudes and opinions towards the following four in-vehicle technologies: Speed Alerting, Speed Limiting, Forward Collision Warning and Route Guidance systems. Survey respondents had never interacted with the technologies, with the exception of two percent of participants who had a Route Guidance system in their vehicle. The majority of respondents predicted that all technologies would be effective, with the Route Guidance system deemed to be the most effective. However, this was tempered by the finding that the Route Guidance and Speed Limiting systems were the ones predicted to distract drivers the most from the driving task. The Speed Alerting system was reported by most participants to be the least distracting and also the system that participants would most likely use if available in vehicles. The Speed Limiter was the system reported by most respondents to be the system that they would be least likely to use. Overall, only four percent of respondents did not support the introduction of in-vehicle ITS. Unfortunately, participants did not have much opportunity to justify their responses to allow the researchers to identify, more precisely, potential barriers to successful deployment of in-vehicle ITS. Nevertheless, Gray's (2001) findings suggest that provided in-vehicle technologies are not distracting and do not take control away from the driver, they are likely to be deemed positively by Australian drivers.

In summary, several studies have already been conducted into the acceptability to car drivers of in-vehicle ITS, but there is still much work to be undertaken. Firstly, more research needs to be conducted in Australia since it is likely that individuals' acceptability of a technology is influenced by the cultural, social, and technical climate in which the technology is to be introduced. Secondly, more research is required to evaluate driver acceptability of ITS technologies during the design and development process. In this way elements of the technology that are deemed unacceptable by users can be rectified prior to system deployment, saving time and money. Thirdly, more research is required to gauge the perceptions of potential users of ITS for whom the technologies are likely to have the greatest safety effect. This is important since it is conceivable that the individuals for whom ITS technologies will confer the greatest benefit might be the ones who are least accepting of the technologies. These issues provided the basis for the study described below.

OVERVIEW OF THE CURRENT STUDY

The main aim of the current study was to assess the acceptability to car drivers of certain ITS technologies with high estimated safety potential. The car drivers involved in the study would belong to road user sub-groups who should derive the greatest safety benefits from the technologies under investigation. There were two key phases to the study. The first phase involved determining which ITS technologies should be assessed for their acceptability and the potential crash problems that are capable of being addressed by these technologies. The first phase also involved analysis of relevant crash data to determine the driver sub-groups (defined by age and sex) that are over-represented and/or involved the most in the crash types that the selected technologies are intended to address. The final step in Phase 1 was to determine the composition of the focus groups to be conducted in the second phase of the study. Hence, Phase 2 of the project involved assessing the acceptability of the selected ITS applications through focus groups involving members of the driver sub-groups identified in Phase 1. Additionally, estimates were made of the annual savings in crash numbers and costs associated with

deployment in Victoria of each of the systems under study. (For further detail and justification behind the method and discussion of the findings refer Regan, Mitsopoulos, Haworth and Young (2002).)

PHASE 1: SELECTION OF ITS TECHNOLOGIES AND DRIVER SUB-GROUPS

Seven technologies were chosen for study, selected, in part, for their high estimated safety potential (see Regan et al., 2001). The technologies were: Forward Collision Warning; Intelligent Speed Adaptation; Emergency Notification ("Mayday"); Electronic Licence; Alcohol Interlock; Fatigue Monitoring; and Lane Departure Warning. *Forward Collision Warning systems* are designed to warn the driver if his/her vehicle is in danger of colliding with a vehicle in front. Such systems would have the potential to affect all rear-end collisions. *Intelligent Speed Adaptation* is designed to warn the driver when he/she has exceeded the speed limit and, as such, it was assumed that this device would affect speed-related crashes. Speed-related crashes were considered to comprise 20 percent of all single-vehicle, head on, same direction, rear-end, intersection and pedestrian crashes. The *Mayday system* manually or automatically notifies emergency and roadside services of GPS-derived vehicle location in the event of a crash. It is relevant to all crashes. The *Electronic Licence* is designed to prevent unlicensed driving and driving outside licence conditions. This device would affect all crashes where the driver was unlicensed or operating outside the conditions of his/her licence. *Alcohol Interlocks* are designed to prevent drivers with a BAC of .05 or above from driving and, therefore, would affect all crashes where driver BAC was greater than .05. *Fatigue Monitoring systems* are designed to detect and warn the driver of impairment due to fatigue. Such systems were assumed to affect 50 percent of single-vehicle crashes. *Lane Departure Warning systems* are designed to warn the driver when his/her vehicle leaves the designated lane. This device was assumed to affect 50 percent of rural single-vehicle off-path crashes and rural multi-vehicle sideswipe crashes.

Analyses of Victorian road crash data were conducted to identify the driver sub-groups that are over-represented and those that are involved most in the crash types for each ITS. Data from 1999 and 2000 were used for all technologies, except Electronic Licence for which appropriate data were only available for 1995. The outcomes of these analyses served as the primary basis for selecting the driver sub-group composition of the eight focus groups to be conducted in Phase 2. Other considerations were that there be no more than two technologies for discussion in any one focus group to ensure that there was sufficient opportunity to discuss each technology, and that the age range be homogenous within each focus group (e.g. 18 to 24 years) to ensure that participants did not feel inhibited from freely expressing their opinions. Where this was not feasible, the range of ages spanned no more than two consecutive age groups (e.g. 18 to 24 and 25 to 39 years). However, it was felt that, provided that the age range is homogenous, a group comprised of males and females was justified. The final focus group composition is shown in Table 1.

Table 1. Focus group composition

Focus Group	ITS	Driver sub-groups	
		Males	Females
1	Intelligent Speed Adaptation	18 to 24 years	18 to 24 years
2	Intelligent Speed Adaptation	25 to 39 years	25 to 39 years
3	Forward Collision Warning	25 to 39 years	25 to 39 years
4	Forward Collision Warning	40 to 64 years	40 to 64 years
5	Alcohol Interlock	18 to 24 years; 25 to 39 years	
6	Lane Departure Warning; Fatigue Monitoring	18 to 24 years	18 to 24 years
7	Mayday; Electronic licence	25 to 39 years; 40 to 64 years	
8	Lane Departure Warning	65 years & over	65 years & over

PHASE 2: ACCEPTABILITY OF ITS TECHNOLOGIES

A major limitation of previous studies into the acceptability of in-vehicle ITS is the lack of a definition of acceptability to guide the measurement and interpretation of the research findings. Hence, an important preliminary step in the current research was to develop an operational definition of acceptability. Review of the literature on acceptability in information technology (e.g. Davis, 1989; Morris & Turner, 2001) demonstrated that acceptability is a multi-dimensional construct and a term that is not easily defined. Indeed, this is reflected in the number of models that have been proposed to explain user acceptance in the information technology domain (e.g. Davis, 1989; Nielsen, 1993). Underlying these models, however, are several key constructs: *usefulness*, *effectiveness*, *usability*, *affordability* and *social acceptability*. These five constructs comprised the definition of acceptability used in the current study. To be *useful*, the user must perceive the system to serve some goal or purpose. To be *effective*, the user must believe that the system does what it is designed to do. To be *usable*, the user must perceive the system to be easy to use. *Affordability* concerns such issues as whether users can afford to purchase and maintain the system, while s*ocial acceptability* is concerned with the broader social issues that may be taken into account by users in judging whether an ITS is acceptable.

Method

Participants. A total of 52 drivers, 29 males and 23 females, participated in the eight focus groups. Participants varied in age from 18 to 83 years (M=39.5; SD=18.7). Focus groups comprised six or seven participants each, with the exception of one focus group where there were four participants and one focus group with nine participants. For the 18 to 24 year old sub-groups, the mean age across focus groups was 21.3 years (SD=1.2). For the 25 to 39 year old sub-groups, the mean age across focus groups was 32.2 years (SD=6.9). The mean age across focus groups involving the 40 to 64 year old sub-groups was 50.7 years (SD=6.6), while the mean age of the 65 years and over participants was 72.2 years (SD=7.3). Participants were recruited primarily through a random number telephone survey, which was administered to homes in the South-Eastern suburbs of Melbourne. All participants held either a current full or current probationary car driver's licence, and were naïve users of the technologies under study.

Materials and Procedure. A list of open-ended questions was developed to guide the focus group discussions. The key issues covered in the guide included: do drivers feel that the technology would make them safer drivers; do drivers feel that the technology serves a purpose; what, if any, potential problems or concerns do drivers have with the technology; what factors would encourage or discourage drivers from purchasing the technology; how would drivers react if it were compulsory to equip vehicles with the technology; and how would drivers feel if the system were to take away their control as the driver. Brief video clips demonstrating each of the ITS technologies were also developed to provide participants with information prior to the discussion regarding the look and functionality of the technologies and of the type of warnings that the technologies issue.

Results and Discussion

Forward Collision Warning. The Forward Collision Warning system was deemed effective and useful by participants – it would alert distracted drivers and help to minimise the incidence of intentional tail gating. The system was felt to be more useful on freeways and on long drives, but not in areas where there is dense traffic, because repetitive warnings would not be looked on favourably. Some participants raised concerns regarding the level of reliability that can be achieved by the system, the negative safety impact of potential over-reliance by some on the technology, and of false alarms. In terms of usability, participants debated the relative value of the visual versus the audio warning, whether the audio warning could be heard over the radio, and whether there would be any difficulty in distinguishing between warnings if there were multiple systems in the car. Cost and proven effectiveness in reducing the incidence and severity of rear-end collisions were the key determinants of participants' willingness to buy the system; however, cost was the overriding factor. Participants expressed mixed views as to whether the system should be compulsory. It was suggested that the system should only be compulsory for particular driver sub-groups, such as young drivers, who might be over-involved in rear-end collisions. There was an apparent age difference as to whether the technology was best as a passive system (favoured by the 25 to 39 year old group), which warns the driver of an imminent collision, or as an active system (favoured by the 40 to 64 year old group), which automatically applies the brakes in the vehicle.

Intelligent Speed Adaptation. The majority of participants felt that the system would make them safer drivers. It was thought that the technology would be of most benefit to people who speed inadvertently. For many participants, reliability of the system was a major issue influencing the perceived effectiveness of the system. In order for the system to issue warnings when appropriate, the on-board digital map of the road network and speed limits needs to be 100 percent consistent with speed limits on the actual road network. The majority of participants were divided as to whether the main use of the technology was to reduce speed related crashes and therefore save lives, or to reduce speed fines. In general, participants felt that the technology would help in all types of road environments, especially on long monotonous drives. Indeed, perceived usefulness was the overriding factor influencing participants' willingness to buy. It was argued that a person who sees no use for the technology, such as a driver who chooses to speed deliberately, will have no desire to buy the technology. Provided there was a use for the technology, purchase and maintenance cost was the key determinant influencing participants' willingness to buy the technology. Proven effectiveness of the system in reducing the incidence and severity of speed related crashes was an important determinant for those participants who perceived the main use of the technology to be in saving lives, while high reliability of the system was critical for those participants who would use the technology to minimise their chances of receiving a speeding fine. Participants were unanimous in their preference for a speed alerting system over a speed limiting system, since the latter was perceived to take too much control away from the driver. Participants could see no point in compulsorily fitting Intelligent Speed Adaptation to vehicles given that drivers who speed deliberately would ignore or attempt to circumvent it.

Emergency Notification (Mayday) System. Participants generally liked the concept of the Mayday system. However, there was some concern over whether the system would function reliably in remote areas, and whether it could withstand the impact of a crash. The system must also be able to confirm to the driver (if conscious) that a distress signal has been received, and maintain constant contact between occupants of the vehicle involved in

the crash and emergency services until help arrives. The cost of the system, maintenance and calls to emergency services was the main determinant influencing participants' willingness to buy the system. Participants felt that the system should not be compulsory in all vehicles, but if it were it would need to be subsidised. Moreover, participants expressed that drivers would be reluctant to embrace the technology if the drivers believed that the system could be used by authorities to monitor drivers' speed and location on the road network.

Electronic Licence. Participants voiced many concerns over the effectiveness of the Electronic Licence. The main concern was the potential for the system to be cheated and misused by some drivers. While participants generally felt that the system could be useful in preventing drink driving, theft and unlicensed driving, there was consensus among participants that they would only buy the system if it were compulsory or if they owned an expensive vehicle that they did not want to risk being stolen. Drivers would not be willing to purchase the system if they felt that use of the system would compromise their privacy.

Alcohol Interlock. There was agreement among participants that the Alcohol Interlock has the potential to minimise drink driving, and that the greatest benefit of the system would be in keeping repeat drink drivers off the road. However, this was tempered by concerns that drivers could easily circumvent the technology, that the system could issue false positives or that the system might fail. Several participants felt that the breathalyser unit was too large and obtrusive. Participants expressed a general reluctance to having the system in their car because blowing into the breathalyser unit on every occasion that they start the car would become a nuisance. Participants agreed that the system should not be compulsory for every driver, just for repeat drink driving offenders. Essentially, participants felt that, as currently designed, the interlock system takes control away from the driver and that this is not desirable; although, for repeat drink driving offenders taking away driver control may be justified. Participants stated that a voluntary system, which can be turned on and off as desired, or a system that simply warned the drivers that they were over the limit but did not actually immobilise the car, would be a lot less controlling and, hence, more acceptable.

Fatigue Monitoring System. In general, participants believed that the system would be effective in reducing fatigue related crashes, particularly for long drives. Concerns were raised, however, over the ability of the system to reliably detect signs of fatigue. Participants stated that they would be willing to buy the system if a large proportion of their drives were long and monotonous, and provided the system was reliable, did not issue false warnings, and was reasonably priced. Participants were unanimous in their dislike of a more controlling Fatigue Monitoring System that not only warns the driver that he/she is fatigued, but also stops and parks the vehicle for the driver. Regarding deployment options, participants were not against compulsory installation of the technology in all cars provided it was government subsidised.

Lane Departure Warning. Participants stated that this system would be useful, particularly for country driving and when driving for long periods of time. Participants raised some concerns over the ability of the system to function effectively and reliably on different road types and under different weather conditions. Regarding usability, participants felt that a visual warning would be distracting to the driver. Nevertheless, the majority of participants indicated that they would be prepared to purchase the system. Cost and perceived usefulness were the overriding factors influencing willingness to buy. Participants expressed mixed feelings regarding whether the system should be compulsory in all cars. Moreover, participants did not like the idea of a more aggressive system that automatically initiates corrective steering actions.

Estimated Crash Number and Cost Savings

Savings estimates for each ITS under study were made using the methods proposed by Harrison & Fitzgerald (1999), and used the Bureau of Transport Economics (2000) values for cost per crash at each level of crash severity. Of all technologies discussed in the focus groups, the Alcohol Interlock was predicted to lead to the greatest reduction in crash numbers and costs, preventing 906 crashes and saving $AUD263 million per year in Victoria. The other technologies with large predicted savings are the Electronic Licence, preventing 603 crashes and saving $AUD134 million per year, and Intelligent Speed Adaptation, preventing 331 crashes and saving $AUD155 million per year. The Lane Departure Warning was predicted to lead to the least reduction in crash numbers and costs of the technologies discussed, preventing 92 crashes and saving $17 million per year.

IMPLICATIONS & CONCLUSIONS

The safety potential of many in-vehicle ITS technologies will not be realised unless the systems are deemed acceptable to the eventual users – the systems must be useful, effective, usable, affordable and socially acceptable. Several themes arose from the focus groups that can be classed as general barriers to use of the technologies in the manner intended by system developers. It was found that: drivers generally are not in favour of systems that take away driver control; drivers will only embrace a technology that is useful to them; drivers are sensitive to poor human-machine interface design; drivers are reluctant to embrace a technology with low

reliability, a high false alarm rate, and which they believe can be circumvented; drivers generally need firm scientific evidence that a system is effective in order to use that system; drivers are unlikely to accept ITS technologies that take away their privacy; drivers are willing to accept compulsory fitting of some technologies to vehicles; and the cost of a system is a critical factor influencing drivers' willingness to use a technology. Even if drivers perceive the technology to be useful, effective, usable and socially acceptable, the overall acceptability of the technology will be compromised if the system is not affordable for a wide range of drivers.

The Alcohol Interlock and Electronic Licence were the least acceptable of the ITS technologies discussed. However, they are also, along with Intelligent Speed Adaptation, the systems that are likely to confer the greatest benefit in terms of crash number and cost savings. This finding suggests that, unless appropriate mechanisms are put in place to increase the perceived acceptability to drivers of these systems, the high potential crash and cost savings that could be derived from use of these systems will never be realised.

In summary, the main purpose of this study was to assess the acceptability to car drivers of certain ITS technologies with high estimated safety potential. Participants in the study belonged to car driver sub-groups who, based on analysis of crash data, should derive the greatest safety benefits from use of the systems studied. A definition of acceptability was derived to guide interpretation of the findings. This facilitated the identification of barriers that are likely to influence the successful deployment of many in-vehicle ITS. The study also involved calculation of the estimated savings from deployment of the technologies under study. This made it possible to link perceived acceptability of a technology with its perceived safety benefit. It is important that these results are brought to the attention of authorities who influence the design and uptake of ITS technologies.

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