INTELLIGENT TRANSPORT SYSTEMS: UPDATE ON THE AUSTRALIAN TAC SAFECAR PROJECT

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ABSTRACT

In Melbourne, Australia, a research project is currently underway with the aim of evaluating on the road and in an advanced driving simulator behavioural adaptation to, and driver acceptability of, a suite of in-vehicle intelligent transport system technologies that have the potential to significantly reduce road trauma in Australia. This paper describes the design of the research project and progress to date.

INTRODUCTION

The term Intelligent Transport System – or ITS – refers to the application of advanced information processing, communications, sensing and control technologies to the driver-vehicle-road infrastructure system with the primary aims of enhancing safety and mobility. When eventually deployed on a sufficiently large scale some ITS applications are estimated to have significant potential to reduce road trauma, particularly in-vehicle systems (1, 2). It has been estimated, for example, that a particular variant of Intelligent Speed Adaptation (ISA), which automatically limits the speed of a vehicle to the posted speed limit, has the potential to reduce fatal crashes by around 40 percent (3), with less than full market penetration.

A wide range of in-vehicle ITS technologies have been developed which are estimated to have significant potential to reduce road trauma (see 1, 2). These are either commercially available or exist as advanced prototypes. Currently, however, there is little or no consumer demand for these systems anywhere in the world. There are three reasons for this. First, the average consumer is generally unaware that such ITS applications currently exist; if consumers do not know that such systems exist, they will not demand to have them. Secondly, at their present state of commercial maturity and deployment, most of these systems are too expensive for the average consumer. Finally, there will be no demand for in-vehicle ITS applications unless vehicle manufacturers and consumers deem them to be safe, reliable and easy to use. As yet, in-vehicle technologies with high safety potential have not been deployed on a large enough scale over a long enough period of time for issues of safety and reliability to be properly evaluated.

Against this backdrop, the Transport Accident Commission (TAC), the provider of "no-fault" transport injury compensation in the Australian State of Victoria, established in June 1999 a partnership with the Ford Motor Company of Australia (Ford) and the Monash University Accident Research Centre (MUARC) to showcase and scientifically evaluate several in-car safety technologies that in combination are estimated to have the potential to reduce road traffic trauma in Victoria by at least 30 percent (4). MUARC is one of the world's leading transport injury research centres. The ultimate aim of this partnership is to stimulate demand – initially by Victorian corporate car fleet owners and, in the longer term, by car drivers in the general community – for in-vehicle ITS technologies. The mechanism for achieving this aim is a four-phase research and development project known locally as the "TAC SafeCar project". The purpose of this paper is to describe the TAC SafeCar project and to outline the progress that has been made to date in developing the ITS-equipped cars that will be trialed and evaluated later this year in Victoria, Australia.

TAC SAFECAR PROJECT

The TAC SafeCar project is being conducted in four phases. Each phase is described below. The focus of the discussion is on Phase 2 activities that have been completed since an update on the project was last presented at a previous Road Safety Research, Policing and Education conference (see 5).

Phase 1: Selection of Candidate Systems

In Phase 1, which was completed in January 2000, a range of currently available in-vehicle ITS technologies were identified that were estimated to have the potential to significantly reduce road trauma in Victoria. These were: ISA; following distance warning; breath alcohol "sniffer" system; seat belt reminder system; reverse collision warning; emergency notification ('mayday") system; route navigation system; and daytime running lights. The process that was used to identify these systems is described in detail elsewhere (see 6).

Phase 2: Development and Testing of Prototype Vehicles

During Phase 2, which began in February 2000 and was completed in August 2001, two Ford Fairmont Ghia vehicles were equipped with all but one of the ITS technologies identified in Phase 1. At the time this paper was being prepared, the only system not equipped to the demonstration vehicles was the breath alcohol "sniffer" system (see below), which was still under development.

Specification of Systems. The first step in Phase 2 was to develop functional and human machine interface (HMI) specifications for all of the ITS technologies identified in Phase 1. These were prepared by a multi-disciplinary design team that included representatives from MUARC, Ford and the TAC. Some systems were purchased "off-the shelf" and were modified where appropriate to meet these specifications. Other systems were developed locally and these were built to the same specifications. Several organisations, acknowledged later in this paper, were involved in the development and provision of the on-board systems. The central philosophy underpinning the design of the chosen technologies was that, when driving safely, drivers should not be aware that they are driving an ITS-equipped vehicle.

Installation of Systems. The next step involved the installation of the chosen technologies into two Ford Fairmont Ghia cars The two vehicles, which were supplied by Ford, served as demonstration/prototype vehicles. Ford played a major role in sourcing, selecting and installing the following ITS technologies in these vehicles.

- *Intelligent Speed Adaptation (ISA)*. Two separate variants of this system were developed locally, known as "informative" and "actively supporting" systems. Both systems use global positioning system (GPS) derived signals to determine the host vehicle's location relative to an on-board digital map of the Victorian road network containing posted speed limits. In the informative system, a static visual icon of a speed limit sign denoting the currently posted speed limit appears on the main ITS display (which is located above the dashboard roughly in line with the left-most part of the steering wheel) when the posted speed limit is exceeded by 4km/hr or more. If this warning is ignored for 5 seconds or more, the visual icon flashes and a repeating auditory tone is heard. The actively supporting system is much the same as the informative system except that the auditory tone is replaced with strong upward pressure on the accelerator pedal. These systems include a button which, when manually depressed, displays a static icon of the currently posted speed limit on the main ITS display.
- *Following Distance Warning (FDW)*. This microwave radar-based system warns the driver if he or she is following a lead vehicle too closely. A static ladder-like display appears on the right side of the main ITS display when time headway is reduced to the point of becoming unsafe. The ladder is thinner at the top than at the bottom of the display. From top to bottom, the six gaps between each "step" of the ladder illuminate successively in the following colour sequence as time headway decreases: yellow, yellow, yellow, red, red, red. The entire ladder display flashes when the first red gap is illuminated, and a repeating auditory warning sounds when the third red gap is illuminated.
- *Breath Alcohol "Sniffer" System (BASS)*. This system passively detects the presence of breath alcohol in the car cabin and advises the driver to blow into a breathalyser to obtain an accurate reading if alcohol is detected. If the driver is over the corporate or legal alcohol limit, he/she is instructed to stop the car within a certain period of time. As yet, this system has not been installed on the prototype vehicles.
- *Seat Belt Reminder System* (SBR). This system, which contains seat buckle and weight sensors, warns the driver if he/she or any other car occupant is unrestrained. If so, a repeatedly flashing "unrestrained" visual icon (with an accompanying text message) appears on the main display at vehicle speeds of up to nine km/hr. Above that speed, a repeating auditory tone accompanies the flashing icon and warnings continue until all occupants are restrained.

?? *Reverse Collision Warning (RCW).* This off-the-shelf and unmodified ultrasonic-based system, the Bosch ParkPilot, warns the driver if he or she is about to collide with a rear object whilst reversing. The device issues auditory warnings if an object is detected at a distance of one metre or less behind the reversing vehicle. These warnings become more rapid the closer the object is to the reversing vehicle.

?? *Emergency notification ("mayday") system (ENS).* This off-the-shelf GPS-based system provides rapid manual or automatic notification to emergency services of vehicle location in the event of a crash or medical emergency. A small interface unit containing an "SOS" button is used to manually alert emergency services. Automatic notification is achieved via the use of crash and rollover sensors equipped to the vehicle.

?? *Route Navigation System (RNS).* This system is an adaptation of a commercially available system supplied to Ford Australia by VDO. Once the desired destination has been manually programmed into the system, it selects an appropriate route and issues turn-by-turn instructions (visually and by voice) to the driver on how to reach the destination. The dedicated display for this system is located slightly above where the car radio is normally installed in vehicles.

?? *Daytime Running Lights (DRL).* The car headlights turn on automatically on low beam (in DRL mode) when the engine is started and switch off automatically when the engine is turned off. In DRL mode, the headlights will operate at 80% of their normal low beam luminance to conserve power and operate without activation of interior lights or other exterior lights.

In addition to these systems, the demonstration vehicles have a system override ("panic' button") which when depressed temporarily turns off all system warnings, a log in/log out system and a data logging system. Following the installation of the systems, a number of inter-related activities were undertaken to assess the prototype vehicles. These activities are described below.

Acceptance Testing. During "acceptance testing" the functioning of the various systems in the demonstration vehicles was tested against the original design specifications for the systems. To the knowledge of the authors, there do not currently exist publicly available guidelines or draft standards which provide guidance for conducting acceptance testing of in-vehicle ITS technologies. In the absence of these, an acceptance testing protocol was developed that specified the scenarios in which each system must be tested against the original functional specifications developed for that system. This was not an easy task since it required anticipating every possible driving situation in which each system might be expected to perform. In the case of the ISA system, for example, we had to specify a range of scenarios to test the capabilities of the GPS, digital speed limit database and computational elements of the system that included driving on different roads, driving in changing speed zones, driving near tall buildings, driving in a range of weather conditions, and so on. The acceptance testing process revealed a number of mismatches between the functioning of the systems and the original system specifications and also highlighted some functional deficiencies in the systems that had not been anticipated during their conception. Together with the findings of the usability testing process (see below), the outputs of the acceptance testing were used to further refine the specifications for the systems that are to be incorporated into the fleet passenger cars in Phase 3.

Usability Testing. It is vitally important that any ITS technology that requires interaction with the user be assessed for its usability as part of an iterative design process. In this way, any usability problems with a system can be identified and the human-machine interface (HMI) can be rectified prior to deployment. Currently there are no draft or ratified international standards known to the authors which specify the procedures to be followed in order to test the usability of the HMI for in-vehicle ITS technologies such as those in the TAC SafeCars, although the issue of *suitability* - which is the subject of a draft international standard (see 7) – encompasses some aspects of usability (i.e., effectiveness and learnability). Consequently, conventional usability testing methods were employed and adapted for use in assessing the TAC SafeCar user interfaces. The usability goals against which the TAC SafeCar systems were assessed were *effectiveness, learnability, attitude (i.e. driver satisfaction) and usefulness.* Definitions of these attributes and a full description of the usability testing process that was used is contained elsewhere (see 8). Essentially, this process involved the development of a Usability Testing Plan that specified the following: the characteristics of the participant group to be tested; the usability testing goals; the user tasks to be undertaken in order to expose drivers to the full range of user interactions associated with use of each ITS technology; measures for assessing the effectiveness, learnability, usefulness and degree of satisfaction associated with the various systems (e.g. whether participants responded to warnings; whether participants were able to perform certain ITS-related tasks unassisted; how quickly participants responded to warnings; participant responses to various open ended and scaled questions, etc); and data collection methods (direct observation, questionnaire, and user verbal feedback). Data were obtained from a total

of 20 drivers, including some MUARC employees. The findings deriving from the usability testing process were used to refine the HMI in the demonstration vehicles and to specify the HMI to be implemented in the 15 Phase 3 fleet cars (see below). A summary of findings deriving from the usability testing process can be found in Mitsopoulos, et al. (8).

Training Needs Analysis. Training of the fleet car drivers (in Phase 4 of the present study) in the proper use of the various ITS technologies was considered by the project team to be of vital importance in ensuring that participants are not inadvertently exposed to unsafe driving circumstances through misconceptions regarding the operation of the systems and the systems' functional capabilities. In addition it was considered, from an experimental design point of view, that some formal training was necessary to ensure that behavioural adaptation to the systems was not confounded by any unwanted effects arising from misconceptions or confusion regarding operation and interpretation of the various systems. To this end, a formal training needs analysis (TNA) was conducted by MUARC with assistance from an expert in instructional system design (see 9 for a detailed summary of the TNA activities undertaken). The first step in the TNA process was to identify potential risks to safe driving performance in relation to each of the ITS technologies in the TAC SafeCar. In relation to the ISA system, for example, a driver might come to over-rely on speed warnings such that the speed limit is exceeded in cases where some limits are not recorded in the speed zone digital database. The next step involved determination of "competency elements" based on correct use of the systems and identification of the "skill variables" associated with the proposed competency elements. One such competency element identified, for example, was "initialize systems when starting vehicle"; an associated skill variable identified for this competency element was "boot failure of one or more systems". Finally, the proposed competency elements and associated range of variables for skill performance were applied to a skill learning model (Incremental Transfer Learning) based on the principles of transfer of learning (see 10). Likely levels of experience of the fleet car drivers and potential risks to safe driving performance, noted above, were taken into account to derive a set of training tasks consistent with the skill learning model. At the time this paper was being prepared the specifications for the training materials were being finalised.

Message Prioritisation. When multiple in-vehicle ITS technologies are present in a vehicle there is the potential for the various messages and warnings to be activated simultaneously. If these messages are not prioritised in some way they have the potential to confuse and/or overload the driver, which may degrade safety. For this reason, it was important to develop a computerised system for automatically prioritising the visual and auditory messages displayed to the TAC SafeCar drivers. The International Organisation for Standardization Draft Standard ISO/WD 16951 "Road Vehicles – Ergonomic Aspects of Transport Information and Control Systems: Procedure for Determining Priority of on Board Messages Presented to Drivers" was initially consulted for guidance (see 11). This standard describes a method for prioritising messages that requires a number of evaluators to rate on a 4-point scale the "criticality" and "urgency" of each message/warning. These ratings are then converted into a "priority index" for each message that incorporates these two dimensions. For several reasons, the draft ISO standard was deemed to be unsuitable for the purposes of developing a message priority scheme for the TAC SafeCar warnings (see 9). Therefore, a slightly different approach was taken from that described in the ISO draft standard, which resulted in a message priority scheme that adheres to the following general principles:

?? FDW system warnings that reach critical status (i.e. are issued as auditory alerts) suppress all other warnings;
?? ISA warnings at any level of criticality suppress seat belt reminder warnings. However if, after 5 seconds, ISA warnings are still being issued because the driver has not slowed down sufficiently, alternation of the Seat Belt Reminder and ISA warnings occurs in 5 second cycles; and
?? FDW system warnings that do not reach critical status (i.e. which do not reach auditory warning status) are always displayed (visually), but they do not suppress other warnings.

At the time this paper was being written the key Phase 2 activities remaining to be completed were: programming of the advanced driving simulator to simulate the ITS technologies to be equipped to the Phase 3 test vehicles (see below), detailed design of the Phase 4 on-road study (see below), and pilot testing in readiness for Phase 4 activities.

Phase 3: Development of Fleet Vehicles

The third phase of the project commenced in July 2001, and is expected to be completed in September 2001. During this phase, 15 Ford passenger sedans and wagons will be equipped with a sub-set of the technologies fitted to the demonstration vehicles. Under a leasing arrangement, these vehicles will be supplied to, and operated by, four corporate organisations in Victoria who have agreed to participate in the research project. The systems to be fitted to the vehicles are: ISA ("informative" and "actively supporting" systems); following distance warning; seat belt reminder; reverse collision warning; and daytime running lights. The fleet vehicles will also be equipped with the Log In/Log Out system, the System Override ("panic") button, the ISA manual speed limit request button and the data logging system. In the demonstration vehicles all systems were controlled via a PC using the Windows 98 platform in order to permit full flexibility in changing parameters and performance of the systems. This, however, required a boot up time of up to 90 seconds before the systems were operative - an unacceptably long delay for users. The fleet vehicles use dedicated microprocessors for each system function with a separate processor based on the Windows CE platform to provide the data output in a form suitable for the display module (including message prioritisation) and data logging. This provides for a shorter boot up time of around two to three seconds. In both cases, the PC incorporated into the overall system is of the "biscuit type" which contains no moving parts in order to ensure system robustness and reliability.

In Australia, the major vehicle manufacturers sell about 65 percent of their new cars to corporate car fleet owners. This is important information. It suggests that, if we are going to stimulate societal demand in Australia for in-vehicle systems that enhance safety, then an important first step is to stimulate demand for these systems by fleet owners. Fleet owners are more likely than consumers to choose combinations of ITS technologies with demonstrable safety benefits and the vehicles they equip with these technologies will eventually be driven by people in the general community. The TAC SafeCar project is designed to make fleet owners and drivers thoroughly familiar and comfortable with ITS technologies and to demonstrate to them the positive benefits of the technologies in reducing crash, fuel and other costs. At the time this paper was being prepared, selection of the participating fleets was being finalised.

Phase 4: On-Road and Simulator Evaluation

During the final phase of the study data will be collected, both on-the road and in an advanced driving simulator located at MUARC, to assess the technical operation of the chosen ITS technologies, to assess driver attitudes to and acceptance of the technologies, and to evaluate the effects of the technologies on driving performance and safety. Between forty-five and sixty corporate fleet drivers will participate in the on-road study. Where practically possible, drivers will be selected on the basis of their age, gender, driving style, driving experience and other factors to ensure that the sample is as representative as possible of the broader fleet driving community.

As noted previously, four fleets are expected to participate in the on-road study. Within a fleet, each driver selected for the on-road study will be allocated one of the 15 ITS-equipped vehicles and will be required to drive the vehicle, for both business and recreational purposes, over a distance of approximately 20,000 kilometres. Following that, the car will be allocated to the next selected driver in that fleet. The on-road study will take about 12 months to complete. At the time this paper was being prepared, the design of the on-road study and of the simulator experiment was being finalised. In the on-road study, driving performance will be compared before, during and after exposure to the ITS technologies, individually and in certain combinations. The simulator study will run in parallel with the on-road study. This will allow an examination of behavioural adaptation to the same mix of ITS technologies in traffic scenarios known to pose high risk to different driver sub-groups that cannot be safely examined in the real world. It will also allow an examination of the degree to which the various systems, in isolation and in combination, affect driver mental workload and induce distraction.

CONCLUSIONS

Several features of the present study distinguish it from other ITS research projects around the world: the focus of the study is on the drivers of fleet passenger cars, as fleet cars represent about 65 percent of the new car market in Australia and will drive societal demand for in-vehicle ITS systems; the project has the involvement and strong support of a major vehicle manufacturer, the Ford Motor Company of Australia; the vehicles to be trialed and evaluated will contain multiple ITS technologies, allowing examination of the *interactive* effects of these systems on human performance over time; the choice of ITS systems has been guided by the central design philosophy that, when driving safely, drivers should not be aware that they are driving an ITS-equipped vehicle; and the study will involve the concurrent collection, in the simulator and on the road, of human performance data

for the same ITS systems. Moreover, this will yield important data on the validity of simulator studies of ITS applications in general.

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