Using On-board Driver Feedback Systems to Encourage Safe, Ecological and Efficient Driving: The Foot-LITE Project

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Abstract. In response to increasing political and individual awareness of the need to address the social and environmental costs of unsafe, inefficient and highly polluting driving styles, the Foot-LITE research project seeks to deliver innovative driver/vehicle interface systems and services to encourage and hopefully persuade sustained changes to driving styles and wider travel behaviour. Stakeholders' requirements help to define the functionalities of the system being developed in the context of a rapidly evolving market with many products potentially competing for Original Equipment Manufacturer (OEM) application or retrofitting to vehicles.

1 INTRODUCTION

The Foot-LITE project addresses two of the Future Intelligent Transport Systems' (FITS) Innovation Platform priorities in a joint call from the UK Department for Transport (DfT), the Technology Strategy Board (TSB) and the Engineering and Physical Sciences Research Council (EPSRC) in October 2006: namely, improving road safety and better travel and traveller information. The accepted Foot-LITE proposal included a case for an eco-driving and safety advisory system. It intends to deliver innovative driver/vehicle interface systems and back office services to encourage sustained changes to driving styles and behaviours which are safer, reduce congestion, enhance sustainability, help reduce traffic pollution emissions and reduce other social and environmental impacts. These objectives are encompassed by three main characteristics of altered driving behaviour that the Foot-LITE system intends to deliver: eco-friendly (green), safe and efficient driving. The Foot-LITE project began in the summer of 2007 and is currently due to be completed by mid-2010.

There are clear interdependencies between the three driving styles noted above; for example, eco-driving can be a by-product of safe driving as it leads to a better anticipation of events, whilst driving and network efficiencies are derived from safer and greener driving styles. However, the different driving styles may not always be complementary. Finally, analysis of the driving task suggests that the Foot-LITE design must be acceptable, useable, non-distracting and be a valued interface that supports the driver.

2 MARKET ANALYSIS

There has been increasing awareness of the impact of vehicle emissions on the environment combined with a period of rapidly increasing fuel prices in the latter part of 2008. This has encouraged several vehicle manufacturers and independent organisations to produce devices and services with similar motivations to Foot-LITE.

These systems and services do not fulfil all the characteristics of driving that Foot-LITE addresses. An objective of the Foot-LITE system is to provide both online and offline driver feedback for safety and eco-driving, which is not offered by the systems reviewed. Fiat's eco:Drive system [1] requires the user to download vehicle data using a USB drive; this data set is then uploaded to the user's home computer where it is analysed using a Fiat webservice, providing only offline feedback. The eco:Drive product provides information such as journey cost and CO_2 emissions, alongside tips for better driving. Green Road [2] is a system that collects in-vehicle data and analyses it to provide both on- and off-board feedback. The on-board feedback is presented by a simple dashboard display that shows a green, amber or red light depending on the driving style, with red indicating riskier and/or more polluting behaviour. More detailed analysis is presented by text message to the user's mobile phone and on the Green Road website. The drawback to the Green Road method of on-board information presentation is that it does not provide information on the specific behaviour causing the poor driving performance at that instance and therefore the driver does not instantly learn the corrective behaviours.

Other products such as the Driver Fatigue Monitor (DFM) produced by SafeDrive Europe [3] only alert the driver to specific safety issues, in this case the warning signs of a driver falling asleep. A system soon to be available on new Vauxhall Insignia models provides road sign recognition along with lane departure warnings [4]. Specific issues are addressed with specialist products such as Audi's 'Travolution' project [5]. This system interrogates traffic signals as the vehicle approaches and if the traffic signal is red, the system can indicate the ideal speed for the vehicle to travel from that point in order to reach the lights as they turn green. This reduces the need for braking and accelerating, thereby creating smoother journeys and reduced emissions.

There are also services available for training drivers in safe and economical driving. These are mostly aimed at fleet users

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and professional drivers of the largest and most polluting vehicles such as city buses and heavy goods vehicles. Several companies large and small offer these services including the AA, the Institute of Advanced Motorists and the Royal Society for the Prevention of Accidents (RoSPA). Whilst these training courses garner successful results in the short-term by correcting poor driving styles, they do not provide continuous driving behaviour feedback that an in-vehicle device such as Foot-LITE presents. Furthermore, whilst being aimed at fleet users, there is no mechanism to feedback to the fleet manager after the initial course monitoring of continuous driving behaviour, essentially allowing drivers to revert back to old habits should they wish.

3 CONCEPT DEVELOPMENT

Cognitive Work Analysis (CWA) [6] was carried out in order to define a framework for identifying the parameters of the Foot-LITE system [7]. This leads to the identification and definition of variables known as Physical Objects that can be used to describe the Foot-LITE system; they are labelled as Physical Objects to encompass the measurement of physical metrics of the vehicle (such as speed) and describe physical attributes of the device (such as display screen size). The Physical Objects were assigned to one or more situations in a Contextual Activity Template (CAT): pre-driving, low mental workload driving, high mental workload driving, immediate post-driving and an evaluation period after the journey. In addition, Use Case Analysis was conducted as a parallel activity, which identified three further stages: organisational and legal, establishing the system and system decommissioning.

Three main stakeholder groups were identified. The first group, the consortium stakeholders, comprised the sponsors, product manufacturers and consortium partners. Second, interested organisations included policy makers, vehicle manufacturers and motoring organisations. Finally, end user groups were categorised according to private organisations or local/statutory authorities with a bulk fleet management function, driving schools and individuals.

Stakeholder requirements, conducted by Newcastle University, identified the attitudes of the stakeholder groups using a mixed methods approach. Research project members provided knowledge input through the CWA and a series of structured sessions, whilst interested organisations contributed through the CWA and focus groups. Potential end users were consulted via focus groups and questionnaires. The aims of the focus groups were twofold: to confirm or reject the knowledge characteristics generated by the CWA and to identify additional knowledge characteristics that had been rejected or not identified by the CWA. Information from potential end users was required about the knowledge requirements, rather than the device requirements, which enable the technical realisation of the knowledge. Focus groups sampled across the potential market. The first step was to identify the key characteristics of individuals with a pre focus group questionnaire.

At the focus groups background statements were used to provide context by describing the objectives of the system, examples of safe, green and efficient driving based on an advanced driving guide and potential characteristics of the system. The format of the focus groups was structured using the CAT. For each stage, a general open question was asked about the types of information attendees would like to help them with their driving, followed by closed questions related to the Physical Objects. This procedure was followed for safe, green and then efficient driving before considering the next stage. Low and high mental workload states were dealt with together, as attendees were able to understand better the different implications of these two stages. Finally, participants completed a short questionnaire in order to assess the system's market potential, when they would use it and the physical appearance of the in-vehicle device.

The outcomes of the literature review, CWA and focus groups were intended to inform the subsequent stages of the project. First, the need for Foot-LITE and potential applications of the system were identified. This began with a market review of competing systems (as detailed in Section 2) that identified how Foot-LITE could gain a commercial advantage. The potential short/medium term applications of the system were identified, starting with a review of key reports such as the Stern Review, the Eddington Report and the King Reports to identify policy areas that Foot-LITE could address [8], [9], [10], [11]. The environmental context of Foot-LITE was then assessed in relation to climate change, vehicle emissions, local pollutants and noise. The individual context considered how to appeal to end-users by demonstrating economic, ethical and other personal benefits. The organisational context built upon the individual context and demonstrated why targeting Foot-LITE at fleet users may encourage a more rapid take-up of the system, since organisations must address political, legal and financial challenges by delivering improved fleet management through back office functions. Societal benefits considered broader environmental issues relating to driver behaviour and training.

End User Benchmarks were defined with the premise that the Foot-LITE driving style will benefit network performance. Engine speed, gear choice and throttle position were the most important parameters to be addressed. The Institute of Advanced Motorists (IAM) have produced a driving guide [12] which is proposed as the benchmark for Foot-LITE, and hence the Foot-LITE drivers, to achieve.

4 Foot-LITE FEEDBACK

The Foot-LITE system will deliver feedback to drivers and potentially vehicle owners (if not the driver) in order to promote the take-up and retention of appropriate eco-friendly (green), safe and efficient driver behaviour [7].

Various driver behaviours and attitudes, including attitudes towards car maintenance, are encompassed in each area. Eco-friendly driving can be seen as a method of reducing fuel consumption and therefore (potentially) emissions. Several studies have investigated the fuel consumption of drivers before and after training. Depending on the type of vehicle used and the initial skill of the driver, figures from a review of studies show a reduction in fuel consumption typically in the order of 6 to 15% [14], [15], [16]. Eco-driving encompasses several characteristics, some of which can be altered by the use of a system like Foot-LITE and are listed below:

- driving style (the primary focus of Foot-LITE);
- vehicle maintenance;
- vehicle loading;
- vehicle drag; and
- the use of vehicle accessories.

Safe driving encompasses the ability of the driver to control the vehicle in all conditions, adherence to the laws of the road and knowledge of the adaptation of the normal driving style in adverse environmental conditions. Several studies have shown that driving speed is the main factor in the risk and severity of a crash [17], [18], [19]. Safe driving and eco-driving can, in some circumstances, be complementary. For example, by anticipating traffic signals and slowing accordingly in order to avoid stopping the vehicle, the driver is also approaching queuing traffic more cautiously and, should the need for rapid braking occur, is already travelling at a slower speed. However, in some circumstances eco- and safe driving may not be in harmony; for example, trying to maintain a constant speed by avoiding braking may compromise vehicle headway; also, travelling in the highest possible gear may adversely affect vehicle control. Thus, in some situations, priority may have to be given to safe rather than eco-friendly driving behaviours [13].

Within the context of Foot-LITE, the aspect of efficiency refers to efficient road transport, this being the generalised cost for both the Foot-LITE user (individual) and other road users (network impacts). This is achieved in the Foot-LITE system by informing the driver before and during a trip about the state of the road network. This includes suggestions to undertake the journey at another time or using a different mode (by providing appropriate pre-trip information) or by providing alternative routing that avoids traffic congestion or even cancelling the journey altogether. If a driver is already committed to a journey by car, during-trip information would use dynamic traffic information to present alternative choices such as a revised route and its associated journey time.

5 HUMAN MACHINE INTERFACE

Modern vehicles contain an increasing amount of instrumentation as a combined consequence of factors including the motivations of vehicle manufacturers, advances in technology, government legislation and consumer demand. Whilst in-vehicle Human Machine Interfaces (HMI) have existed for almost as long as motorised vehicles themselves, in the last 15 years these interfaces have evolved beyond simple dashboard instrumentation and in-car audio equipment. The rapid development of Advanced Driver Assistance Systems (ADAS) has resulted in an increased need for these systems to interact with and inform the driver. However, the added information available to the driver raises significant ergonomic concerns for driver mental workload and driving task performance.

Driver mental workload can be affected by a number of factors, which are a combination of being external (e.g. traffic, road conditions) and internal (e.g. the driver's age and experience) to the individual [20], [21]. In addition, different elements of the driving task (such as navigation and vehicle control) can impose varying levels of mental workload. For instance, steering appears to be a significant source of workload in vehicle control [22], whilst tuning a car radio is one of the most demanding in-car tasks [23].

6 THE Foot-LITE SYSTEM

In order to define achievable final user requirements for the Foot-LITE system, the outputs from the end user requirements were considered together with the other stakeholder opinions. These were classified as general functionality, advice functionality and metrics (driver and specific).

General functionality ensures that the system meets non-advice criteria, e.g. the requirement for security means the system needs to identify drivers and ensure that data uploaded to a back-office system for analysis is kept confidential and secure. Configurability is very important, for example, the selection of driver preferences and focusing on weak points of driving style. Some general functions were not derived directly from the end user requirements. For example, the system has to operate during all times of the day and adjust advice according to the external environment. Furthermore, all data has to be stored in a driver specific manner and advice to the driver must be timely, enabling the driver to take action that will improve driving performance.

Advice functionality describes what advice is presented to the driver and how this advice is disseminated. Thus, the system can utilise visual, audible and tactile means of providing advice and training to the driver, whilst not knowingly giving advice which is unsafe or presents problems for other road users. Advice may include the appropriate lane position with respect to other road users and road features and identification of inappropriate lateral movement.

On- and off-line driver metrics are predefined levels against which the driver's behaviour is measured. They are required in order to fulfil the general and specific functionalities. The system must be able to aggregate data over time in order to monitor driver performance and store data locally or transmit data to an off-vehicle system for further analysis and storage. It also needs to feed selected metrics back to the driver in real time (on-line) as an immediate measure of performance and off-line in order to enable the user to examine trends in their behaviour over time.

7 SUMMARY

Foot-LITE, as an encouraging and possibly persuasive digital technology, will monitor drivers' behaviour, vehicle metrics and road network conditions. These data sources will be analysed via an on-board device, providing information for appropriate advice, tips and useful reminders to be presented to the driver with consideration to the journey stage and the driver's mental workload state.

The Foot-LITE project has reached the stage of human machine interface (HMI) design with two system designs being simulated in software, which will be tested using volunteers on a full scale vehicle simulator at Brunel University. The approved design, after revisions based on user feedback, will be constructed in hardware integrated into a user device with vehicle data inputs, touch sensitive liquid crystal display (LCD) and audible alert capability ready to be manufactured for further trials.

Following the trials of the on-board Foot-LITE device on the Brunel simulator, it will be applied to a highly instrumented vehicle at Southampton University before moving to a small fleet of three vehicles and finally onto a fleet of up to 30 vehicles.

Evaluation of the results of the trials will assess the suitability of the input data gathering, data analysis and comparative driver behaviour models and advice/commands output methods. As well as evaluating the physical and analytical characteristics of the device, the trials will also assess the feasibility of such a system to change driver behaviour not only in terms of their technical competence for achieving and maintaining safe, ecological and efficient driving, but also personal acceptance and wider benefits of the technology.

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