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Assessing driver acceptance of Intelligent Transport Systems in the context of railway level crossings

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A B S T R A C T

Intelligent Transport Systems (ITS) have the potential to substantially reduce the number of crashes caused by human errors at railway levels crossings. Such systems, however, will only exert an influence on driving behaviour if they are accepted by the driver. This study aimed at assessing driver acceptance of different ITS interventions designed to enhance driver behaviour at railway crossings. Fifty-eight participants, divided into three groups, took part in a driving simulator study in which three ITS devices were tested: an in-vehicle visual ITS, an in-vehicle audio ITS, and an on-road valet system. Driver acceptance of each ITS intervention was assessed in a questionnaire guided by the Technology Acceptance Model and the Theory of Planned Behaviour. Overall, results indicated that the strongest intentions to use the ITS devices belonged to participants exposed to the road-based valet system at passive crossings. The utility of both models in explaining drivers' intention to use the systems is discussed, with results showing greater support for the Theory of Planned Behaviour. Directions for future studies, along with strategies that target attitudes and subjective norms to increase drivers' behavioural intentions, are also discussed.

1. Introduction

Level crossing crashes result in enormous personal, social and financial consequences. According to the Australian Transport Safety Bureau (2008), in less than an 8-year period there were 578 road vehicle collisions at railway level crossings (RLXs) in Australia. The Australasian Railway Association has presented figures showing that, since April 2006, there have been 14 major RLX crashes resulting in the loss of 17 lives and costs exceeding $100 million (Tooth & Balmford, 2010). Research has demonstrated that errors and violations on the road user's part are among the largest contributing factors to RLX crashes (Australian Transport Safety Bureau, 2008; Railway Safety Regulators' Panel, 2008). Drivers are not only complacent but lacking in knowledge when it comes to complying with both active (flashing lights with or without boom gates, see Fig. 1a) and passive (stop sign, see Fig. 1b) warning systems (Yeh & Multer, 2008). The current safety approach to reducing RLX crashes focuses on countermeasures either on the approaching road or at the crossing itself, through the use of signs, warning sounds, pavement markings, flashing lights and boom gates. Whilst these remain important, the data suggest there is an urgent need for innovative interventions to complement existing railway interventions.

Innovative technology, such as in-vehicle systems that warn motorists of approaching trains, are among the emerging vehicle-based methods designed to enhance driving behaviour. Furthermore, roadside interventions that utilise warning lights and signs, and warning lights on the road surface that activate when a train approaches, are among the possible

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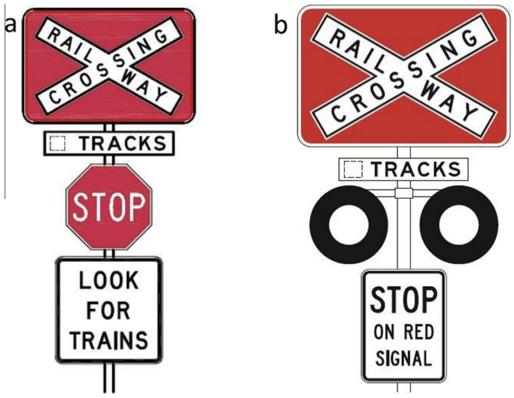

Fig. 1. Signage at (a) passive and (b) active crossings (Standards Australia, 2009).

road-based countermeasures that have the potential to improve motorists' compliance. To date, however, emerging technologies have typically been developed to target only one major objective of RLX safety systems; to improve the detection of crossings and trains. The other objective, to address the need to eliminate the ability of the driver to circumvent the technology, has been largely overlooked. Furthermore, emerging technology approaches can easily be bypassed or ignored by the driver. Thus, such approaches must be seen as complementary to existing traditional approaches and acceptance of the technology by drivers is necessary for such interventions to be successful.

Emerging technologies fall under the umbrella of active protection given that they provide automated warnings to motorists of the presence of crossing locations and train traffic. Warnings can be delivered in the form of visual or audio warnings, or a combination of both. Typically, emerging technologies developed for RLX safety involve vehicle-to-vehicle (e.g., train to road vehicle) or vehicle to infrastructure (e.g., road vehicle/train to existing warning infrastructure at crossings) communication. Two approaches are typically used to communicate information between vehicles. Firstly, a two-point system, involving the direct transmission of information from trains to road vehicles can be employed. On the other hand, a three-point system can be used whereby the communication is mediated by wayside transceivers located at the crossing (Richards & Bartoskewitz, 1995). Current technology trials include: in-vehicle warning systems, with a special reference to collision avoidance systems; dynamic warning signals, including advanced variable message warning signs and second-train warning signals; automated photo and video enforcement; obstacle detection systems; alternative low-cost train detection systems; wayside horns, and; intelligent grade crossings, which combine multiple emerging technologies, typically in conjunction with traditional safety approaches (Tey, Ferreira, & Dia, 2009).

Obviously, vehicles must be equipped with the appropriate technology to receive such advanced warnings. A wide variety of technological elements are employed to deliver these warnings, including: antennas; transmitters and receivers; radar; microwave technology; infrared sensors; pressure sensitive pads; radio frequency detection; GPS technology; short-range communication devices, and closed-circuit television, to name but a few (State of Victoria, 2009). A particularly important application of these emerging technologies is the development of alternative low-cost warning devices for rural and remote crossings with low road and train traffic volumes. Thus, emerging technologies present a particularly effective approach to low-cost countermeasures for low traffic volume RLXs with greater train speeds (Zaworski, Bell, Hunter-Zaworski, & Sacmaci, 1995).

This project aims to assess the effectiveness of various emerging technologies, both road and in-vehicle based, to improve the safety of drivers at RLXs in Australia. Such technologies have previously been assessed in a systematic approach focusing on the safety of the intervention, deployment cost, and effects on the road traffic around the crossings. Findings of this larger investigation can be found in Larue et al. (2014). The current study is dedicated to gaining a better understanding of drivers' acceptance of technologies designed to reduce RLX crashes.

1.1. Trials of ITS interventions for railway crossings

There is interest in Australia for lower cost interventions at passively protected crossings due to their large number (5900 public crossings and 13,000 private and occupational crossings), which make traditional signals too expensive for remote crossings with low traffic (Graham & Hogan, 2008; Roop, Roco, Olson, & Zimmer, 2005). Various simulator studies have been conducted in order to evaluate the effect of lower cost interventions on driver behaviour, such as traffic lights (Lenne, Rudin-Brown, Navarro, Edquist, & Trotter, 2011), rumble strips and in-vehicle audio or visual systems (Larue et al., 2014; Tey, Wallis, Cloete, Ferreira, & Zhu, 2012). Traffic signals at railway level crossings do not appear to offer any safety benefits over and above flashing red lights, and rumble strips seem to be effective in reducing approach speed but not compliance at passive crossings. On the other hand, in-vehicle interventions tend to result in driver behaviour similar to active crossings, which result in higher compliance. Such interventions will only achieve improvements in safety if drivers' tendency to