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Assessing Driver Acceptance of Intelligent Transport Systems in the Context of Railway Level Crossings

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Abstract

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.

Keywords

Intelligent Transport Systems (ITS); Drivers; Railway level crossings (RLX); User acceptance; Intentions

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 Figure 1a) and passive (stop sign, see Figure 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.

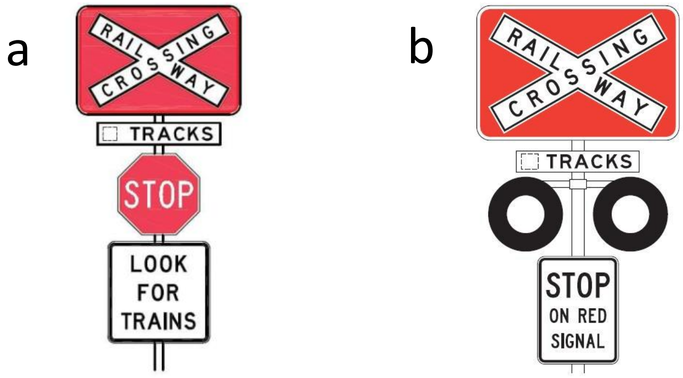

Figure 1: Signage at (a) passive and (b) active crossings (Standards Australia, 2009)

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 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 (5,900 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 over-rely on such systems is tackled appropriately or if such in-vehicle devices reach a high level of reliability and integrity (Larue & Rakotonirainy, 2014).

1.2. Driver Acceptance of ITS

Intelligent Transport Systems are only effective at enhancing driver safety if and when they are accepted by their user. User acceptance can be defined as a prospective user's predisposition towards using a certain system (Swanson (1988). In the context of RLX warning devices, driver acceptance is contingent upon motorists' understanding of the device and their perception that the system is reliable and easy to use (Abraham, Datta, & Datta, 1998). If systems do not appear credible or fail to respond to drivers' needs and expectations, they are unlikely to be purchased or switched on, precluding the device from having any significant impact on driver behaviour (Van Der Laan, Heino, & De Waard, 1997). Attempts to enhance driver acceptability must, therefore, ensure that the design of ITS interventions is centred on the user rather than on the technology itself.

Another important factor determining ITS usage concerns an individual's intention or motivation to use the device. According to Ajzen (1991), intentions are the most proximal determinant of behaviour. Research supports a strong causal relationship between an individual’s behavioural intention to use a new technology and their actual use of it (Chau & Hu, 2001). Intention is considered a critical antecedent of behaviour in a number of important explanatory models of human behaviour, two of which are discussed in detail below.

1.3. Measuring driver adoption of technology

The Technology Acceptance Model (TAM) and the Theory of Planned Behaviour (TPB) provide sound theoretical frameworks for investigating users' adoption of new technologies (Chen, Fan, & Farn, 2007). Both the TAM and TPB have been applied widely and effectively to predict various intentions and behaviours relating to technology use (King & He, 2006; Lederer, Maupin, Sena, & Zhuang, 2000; Siragusa & Dixon, 2009), including those specific to railway level crossings (Rail Safety and Standards Board, 2011). The TAM has been particularly prominent in studies aimed at predicting the likelihood of users’ adopting new technologies (Turner, Kitchenham, Brereton, Charters, & Budgen, 2010). It has to be noted, however, that positive intentions toward a new technology does not always result in the use of the technology, illustrating the well-recognised gap between intention and behaviour (Sheeran, Trafimow, & Armitage, 2003).

1.3.1. Technology Acceptance Model

The Technology Acceptance Model (TAM) was developed by Davis et al. (1989) to offer explanation for why users accept or reject particular ITS (see Figure 2). The model is an adaptation of Fishbein and Ajzen's (1975) Theory of Reasoned Action (TRA), which posits that attitudes and normative pressures influence both an individual’s intention to perform, and subsequent performance of, a given behaviour. In the TRA, attitude is considered to be an important mediator between perception and behavioural intention (Fishbein & Ajzen, 1975). This mediator was also included in the original TAM, although its inclusion was questioned as a result of research that failed to find a significant link between attitude and intention (e.g., Davis et al., 1989). For instance, it is possible that a technology might be used because it enhances an individual’s performance, not because the individual holds a positive attitude towards it. A more parsimonious version of TAM (TAM2) was thus proposed in which the attitude construct was removed (Wu, Cheng, Yen, & Huang, 2011) and additional constructs could be incorporated (Turner et al., 2010). This model supports the premise that people intend to use a technology for reasons other than having favourable attitudes towards it.

The TAM is based on the assumption that behaviour is volitional, that is, that the technology can be used voluntarily and at the discretion of the user (Dishaw & Strong, 1999). The model posits that two types of user beliefs, perceived ease of use and perceived usefulness of the technology, are the most important factors determining a system’s usage (Legris, Ingham, & Collerette, 2003). According to the model, perceived ease of use and perceived usefulness influence an individual’s intention to adopt the technology (Turner et al., 2010; Wu et al., 2011), with intention, in turn, influencing actual use (Dybå, Moe, & Arisholm, 2005). A technology is perceived to be *useful* if the user believes the system can improve or facilitate their performance during a task, while its *perceived ease of use* depends on the user believing that minimal effort is required to use the system (Wu et al., 2011). Both factors are equally important in shaping intentions, since an individual might perceive a technology to be useful yet still find it difficult to use (Davis, 1989). An appropriate balance between the perceived utility of the device and the effort of using it is therefore critical in shaping intentions.

The TAM has consistently been found to predict approximately 40% of a system’s use (Adams, Nelson, & Todd, 1992; Ajzen & Fishbein, 1980; Davis et al., 1989; Hu, Chau, Liu Sheng, & Kar Yan, 1999; Mathieson, 1991; Straub & Keil, 1997). In an investigation concerning usage of a company’s computer expert support system, Keil, Beranek and Konsynski (1995) indicated that perceived usefulness was a stronger predictor of usage than perceived ease of use, with the latter also influencing intention to use the technology indirectly via perceived usefulness. Similarly, Davis (1989) found perceived ease of use to be a causal antecedent to perceived usefulness for four trialled information technology programs instead of a parallel, direct determinant of system usage (Davis, 1989). Therefore, the most commonly used version of the TAM is the parsimonious model in which the indirect link between perceived ease of use and intention is included (e.g., Adams et al., 1992; Hu et al., 1999; Szajna, 1996; Venkatesh, 2000; Venkatesh & Davis, 2000). Historically the TAM has not been used in the road safety domain for evaluating the acceptance of in-vehicle safety interventions. However, it is often used to evaluate the acceptance of in-vehicle devices such as GPS navigation (Chen & Chen, 2011), multimedia entertainment and wireless communication systems (Chen & Chen, 2009). Such studies have highlighted the effect of perceived ease of use, attitude and perceived behavioural control on driver intention to use the technology, while usefulness failed to explain intention (Chen & Chen, 2009). In contrast, a study concerning an in-vehicle distraction mitigation system found that both perceived usefulness and perceived ease of use predicted intention to use, with perceived ease of use being the strongest predictor (Roberts, Ghazizadeh, & Lee, 2012).

Although the TAM has been well-substantiated, most studies have provided evidence for its utility in predicting intention to use, rather than actual use of, technology (Straub & Limayen, 1995; Turner et al., 2010). Moreover, research has indicated that measures based solely on the constructs of perceived usefulness and perceived ease of use may not represent the most precise indicators of technology usage, given that other influential factors also exist (Legris et al., 2003; Subramanian, 1994). For example, Wu et al. (2011) demonstrated that the link between intention and actual use of wireless technology in the workplace was stronger among users experienced in using the technology, whereas the intentions among users who had no hands-on experience with technology were unrelated to actual usage. Similarly, in a study examining the TAM in pre-implementation and post-implementation contexts, Szajna (1996) revealed that perceived ease of use was a stronger predictor of intention among participants who had no prior experience with a trialled electronic mail system, compared to their experienced counterparts. In addition, the research indicated that intentions did not predict actual system usage in the pre-implementation version, but were predictive of use in the post-implementation version. These findings highlight the importance of experimental designs in which participants are introduced and trained to use a new technology before they provide responses in accordance with the TAM constructs (Wu et al., 2011).

1.3.2 **Theory of Planned Behaviour**

The TPB is also an extension of the TRA (see Figure 2). In contrast to the TRA, which emphasised rationality and conscious control over behaviour, the TPB was designed to account for behaviours over which people do not have complete volitional control. Unlike the TRA, the TPB includes an additional factor called perceived behavioural control, which refers to people's perception of the ease or difficulty of performing the behaviour of interest. Behaviours associated with greater perceptions of control or confidence can be predicted from intentions with considerable accuracy (Ajzen, 2005; Sheppard, Hartwick, & Warshaw, 1988). Most behaviours, however, depend at least to some extent on non-motivational factors such as time, money, skills and cooperation. Collectively, these factors determine an individual's actual level of control over performing a behaviour (Ajzen, 1991), which varies substantially across situations and actions.

The TPB identifies three antecedents of behavioural intentions: attitude, subjective norm, and perceived behavioural control. Attitude and subjective norm reflect an individual's perceived desirability of performing the behaviour. Attitudes toward the behaviour comprise an individual’s positive or negative feelings towards performing a particular behaviour, while subjective norm reflects an individual’s perceptions of social pressures to perform in a particular way. The third construct, perceived behavioural control, measures the extent to which users perceive they have control over a given behaviour along with the power of internal and external constraints on their ability to perform the behaviour (Ajzen, 1991; Dishaw & Strong, 1999; Elie-Dit-Cosaque, Pallud, & Kalika, 2011). In the TPB, perceived behavioural control directly affects intention, and may indirectly affect behaviour in situations where the user intends to perform the behaviour but is prevented from doing so. Prediction of such behaviour improves as the individual’s perception of behavioural control more realistically reflects actual control (Ajzen, 1991).

To our knowledge, the TPB has neither been used for evaluating railway crossing interventions nor for in-vehicle warning interventions, but has been applied to other areas of injury prevention research such as studies concerning intentions to cross roads in risky situations (Holland & Hill, 2007), violate traffic regulations (Diaz, 2002) drink and drive (Moan & Rise, 2011) and ride motorcycles at inappropriate speeds (Chorlton, Conner, & Jamson, 2012).The model has also been used in conjunction with the TAM for in-vehicle devices such as navigation systems. Research has demonstrated the impact of attitudes and perceived behavioural control on drivers’ intention to use such systems, but the predictive ability of subjective norms has been less promising (Chen & Chen, 2011; Chen & Chen, 2009). Comparisons between TAM and TPB have concluded that the TAM's ability to account for the variance in intention to use, or actual use, is approximately equivalent to the TPB (Mathieson, 1991; Taylor & Todd, 1995). The TAM, however, has been criticised for overlooking important variables related to both human and social factors (Legris et al., 2003), which the TPB takes into account. A number of studies have thus chosen to integrate these two critical models (Fu, Farn, & Chao, 2006; Venkatesh, 2000; Venkatesh & Davis, 2000).

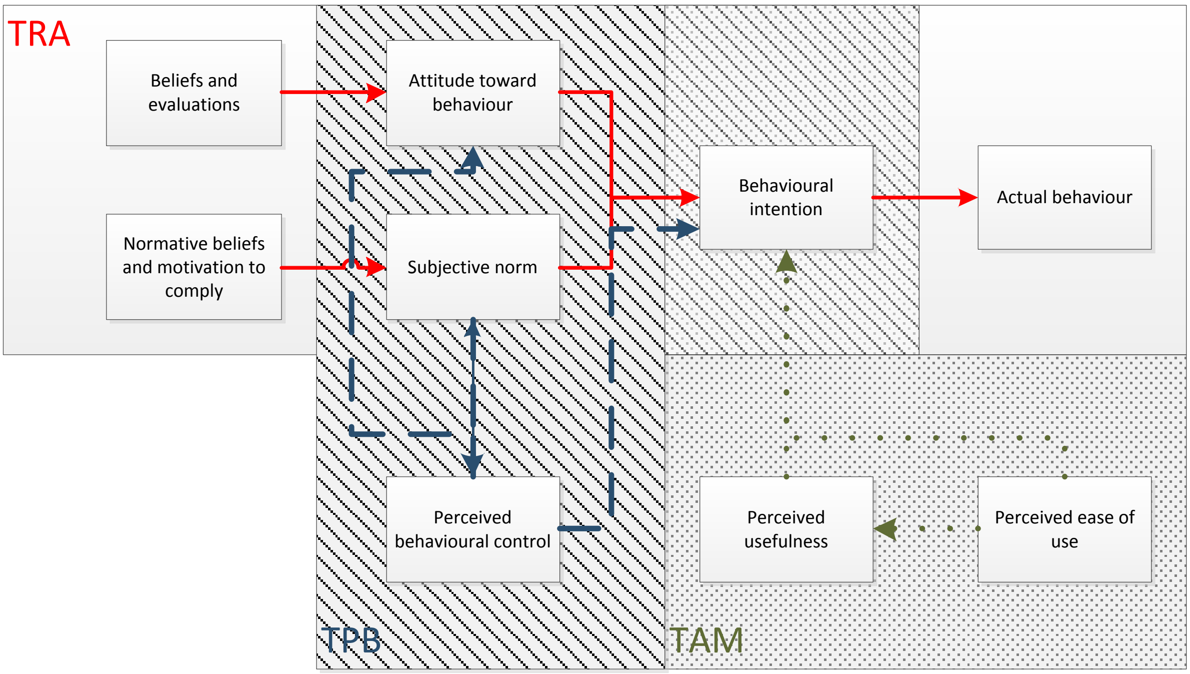

Figure 2: The TRA, TPB and TAM (parsimonious version)

1.4. The Current Study

This study represents part of a larger investigation aimed at identifying, understanding from the user's perspective, and trialling the impact of, different ITS safety devices designed to enhance driver behaviour at both active and passive RLXs. The first phase of the study comprised a comprehensive literature review in which we aimed to identify the most promising in-vehicle and on-road ITS devices for facilitating RLX safety. Using this information, we then conducted a series of focus groups with Queensland drivers to determine the ITS interventions most likely to be accepted by drivers, and thus most suitable for implementation in the current study. Findings from the literature review and focus groups can be found in Larue et al. (2014). The aim of the current study was to evaluate, using an advanced driving simulator, drivers' responses to the introduction of new ITS interventions in the context of RLXs. Specifically, the study was interested in user acceptance of three ITS interventions selected on the basis of our previous research: *in-vehicle visual warnings*, *in-*

vehicle audio warnings, and a *road-based valet system*. These systems will be detailed in the following subsections.

2 Method

2.1 Participants

A total of 76 participants, divided into three groups, were recruited to take part in the study. A sample size of $N = 60$ was expected to yield adequate statistical power (of between 80%-90%) for detecting between-group differences (Kirkwood & Sterne, 2003). Sample size estimations also took into account the attrition rates commonly reported in driving simulator research (Dawson, 2011), including the 10% non-completion rate observed in studies using the current study's simulator (The Centre for Accident Research and Road Safety – Queensland [CARRS-Q] Advanced Driving Simulator, see Figure 3) (Larue, Schramm, Smith, Lewis, & Rakotonirainy, 2013; Rouzikhah, King, & Rakotonirainy, 2013). Eighteen participants were unable to complete the study due to motion sickness and technical errors, and were thus excluded from final analyses. The final sample consisted of 58 drivers, 39 (67%) males and 19 (33%) females, aged 19 to 59 years ($M = 28.2$, $SD = 7.63$). The three groups of participants were balanced in terms of gender, exposure to railway crossings, (with 'regular experience' of driving at crossings being defined as driving across RLXs at least once a week), age and driving experience. A total of 20 participants were allocated to trial the visual in-vehicle ITS; 19 were allocated to the audio in-vehicle ITS condition and; 19 trialled the on-road valet system.

Participants were recruited via advertisements placed in Brisbane local newspapers, Queensland University of Technology's (QUT) psychology undergraduate research participant pool, and snowballing methods. To be eligible for participation, participants were required to have held a drivers licence for at least two years and drive more than 10,000km per year (classing them as regular drivers). Interested participants who contacted the research team were screened to ensure that they did not suffer from epilepsy, motion sickness, or pre-existing medical conditions or injuries involving the back and neck that would compromise their ability to use a driving simulator. Participants' written consent was obtained by the research team at the appointed time of data collection at QUT. Participants received a $50 incentive for partaking in the study.

2.2 Equipment

2.2.1 Advanced Driving Simulator

The ITS devices tested in the current study were implemented using the CARRS-Q Advanced Driving Simulator (see Figure 3). The simulator included a complete automatic Holden Commodore vehicle with working controls and instruments, and used SCANeR™ studio software with eight computers, projectors and a six degree of freedom motion platform. When seated in the simulator vehicle, the driver was immersed in a virtual environment which included a 180 degree front field view composed of three screens, simulated rear view mirror images on LCD screens, surround sound for engine and environment noise, real car cabin and simulated vehicle motion. The road and surrounding environment were designed to represent, as closely as possible, realistic traffic conditions developed in accordance with Australian Standards at railway crossings.

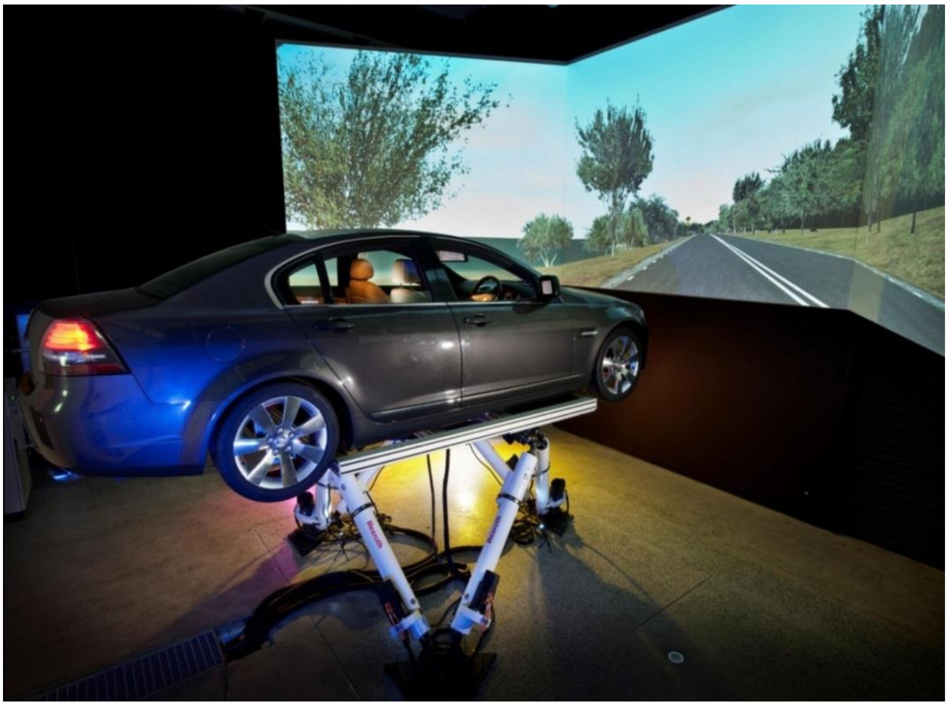

Figure 3: CARRS-Q Advanced Driving Simulator

2.2.2 The three ITS devices

All three devices trialled in the current study provided similar information through different human machine interfaces. Each device served to provide the driver with two primary safety messages: 1) the reason for the warning to be displayed (either because a train was approaching the crossing or because there was congestion at the crossing), and; 2) the action the driver was expected to perform (i.e., to stop rather than proceed at the crossing). The road-based valet system differed from the two in-vehicle interventions as it did not target the issue of congestion.

2.2.2.1 Visual ITS

The visual in-vehicle ITS device was implemented using a personal digital assistant in the form of a Nokia smartphone. Real Time, Multisensor, Advanced Prototyping Software was used to collect information directly from the driving simulator and generate real-time messages on the in-vehicle device. The device was positioned within the driving cabin at the usual, centre-dashboard location of a GPS.

In the “train approaching” scenario, and at active crossings, the device displayed two alternative pictures (see Figure 4) which mimicked the flashing light effect seen at active crossings. For passive crossings, the warning was displayed at the time the crossing would have been activated if the crossing was actively protected. The warning provided both explanation and action messages to the driver in one symbolic representation, indicating that a train was approaching the crossing and that the driver was expected to stop.

Figure 4: Symbolic representation of the visual human machine interface – Train approaching case.

(The lights are located in the circles and are flashing alternatively in red)

In the “congestion” scenario, the in-vehicle device retained its purpose of providing both an explanation and action message simultaneously, but displayed a different visual warning. As seen in Figure 5, the warning displayed a railway crossing sign, three vehicles queuing and a stop sign. The symbolically-represented vehicles alternated between black and red, producing a flashing effect to attract the driver’s attention.

Figure 5: Symbolic representation of the visual human machine interface – Congestion case

(The vehicles are flashing in red)

2.2.2.2 Audio ITS

The audio in-vehicle ITS device was implemented using the speakers mounted inside the car (under the seat) to provide verbal warning messages to the driver. Through simulator scripting the messages were played as the status of the crossing changed and required a particular warning. In the "train approaching" scenario, a verbal warning was provided whilst the flashing lights of simulated active crossings were activated. For passive crossings, the warning was provided at the time the signal would have been activated if the crossing was actively protected. Similar to the two messages provided in the visual ITS, the verbal warnings were "*Train approaching the crossing ahead*" and "*Stop at the crossing*".

In the "congestion" scenario, the messages were provided at similar times to the "train approaching" warning. These messages were "*Congestion at the crossing ahead*" and "*Stop at the crossing*".

2.2.2.3 On-road flashing markers

The road-based ITS system used flashing warning beacons on the road which were activated when a train was approaching the crossing. These beacons highlighted, in a similar way as illuminated airplane runways, the location where the driver was expected to stop their vehicle. Such an intervention is similar to the SafeZone system (valet) from Inventis Technology. In the current study, flashing markers on the road were activated at the same time as the flashing lights of an active crossing, and were positioned up to 150 metres from the crossing. In the case of passive crossings, the lights were activated 20 seconds prior to the arrival of the train, providing a comparable time for the driver to react to the warning. Three in-road red lights were used to emphasise the stop line at the crossing. Five in-road yellow lights were positioned in the middle of the road every 6 metres, and a further 10 yellow lights were positioned every 12 metres. Each individual flashing beacon was designed in accordance with Australian Standards reflective road markers.

In the "train approaching" scenario, the ITS was activated via scripting similar to that used to generate messages regarding the flashing lights of an active crossing. Because of the nature of the valet system, the reason for road markings to flash (primary message 1) was not communicated via the ITS itself but was instead conveyed to the participant during training to ensure that they understood the ITS message. Figure 6 provides a screen capture of the simulated road markings from the driver's view.

Figure 6: Simulator rendering of the on-road ITS

2.2.3 Acceptance Measure

A 17-item acceptance questionnaire was developed in accordance with the TAM2 and TPB. Most items were positively worded and all were scored on 7-point Likert scales ranging from *strongly agree* to *strongly disagree*. Each question was asked with reference to both passive and active crossings. Behavioural intention, relevant to both the TAM and TPB, was measured using three items (e.g., "*Overall, I intend to use this technology regularly when I am driving*"). Items were averaged to yield an overall measure of intention, which was reliable (α = .89).

From a TAM perspective, three items assessed participants' perceived usefulness of the technology (e.g., "*I believe the use of this technology would improve my awareness at the crossing*") and three assessed their perceived ease of use of the technology (e.g., "*Overall I find this technology easy to use").* Items were averaged to obtain an overall measure of perceived usefulness and perceived ease of use, with both exhibiting high scale reliability (α = .90 and α = .80, respectively).

From a TPB perspective, four items comprised the measure of attitude (e.g., "*I feel implementing this technology at crossings is a waste of time*"), two items comprised the measure of subjective norm (e.g., "*Most of my family and friends would use this technology*") and three items comprised the measure of perceived behavioural control (e.g., "*I have the knowledge necessary to drive over crossings safely with this technology*"). Items were averaged to obtain overall direct measures of the TPB constructs, with most scales possessing high internal reliability (attitude, α = .83; subjective norm, α = .88; perceived behavioural control, α = .59). The reliability of the perceived behavioural control scale was low, but a correlation matrix analysis did not allow the identification of which item contributed to this low reliability. Therefore, we retained all items for perceived behavioural control, but acknowledge the scale's low reliability.

2.3 Procedure

Each participant took part in a simulated driving task consisting of three scenarios and lasting approximately 2 hours in total. Upon arrival, participants completed a questionnaire assessing their demographics, general driving experience and exposure to passive and active crossings in Australia. Participants were then provided with a short familiarisation drive in the simulator allowing them to become accustomed to accelerating, stopping, and driving though intersections, active and passive railway crossings and curves.

Prior to their experimental drive, participants were briefly exposed to the ITS system to which they were allocated. For both the visual in-vehicle ITS and road-based valet conditions, participants were presented with paper-based screen captures from the simulator and photos of the device from inside the vehicle. In the case of the audio ITS, verbal messages were played to the participant. Participants were then given a familiarisation drive with the ITS switched on to enable them to feel confident whilst driving with the system activated. Participants subsequently drove three driving scenarios, each containing the same number of traffic lights, intersections and active and passive crossings, but differing in terms of the order in which they were presented. These three separate scenarios were necessary to account for the combination of possible road and environmental characteristics that were included in our larger investigation (e.g., low visibility, type of road approaching the crossing). Each scenario was driven twice; once with the system turned off and once with the system activated, lasting approximately 30 minutes in total. Ten minute breaks were provided between each scenario, during which time participants completed a questionnaire assessing their experience of the ITS in accordance with the TAM and TPB frameworks.

3 Results

The following section provides only results concerning the three trialled ITS interventions from an acceptance perspective, using the two aforementioned models for explaining and predicting behaviour. Findings regarding the safety effects of the ITS interventions and their impact on driving variables can be found in Larue et al. (2014).

3.1 Behavioural intention

This study was particularly interested in determining whether, and to what extent, behavioural intention differed for the three trialled ITS interventions in the context of both active and passive crossings. Means and standard deviations of participants' self-reported intention to use the ITS systems are reported in Table 1, according to the type of RLX protection. The table indicates that, at both active and passive RLXs, participants using the on-road valet system formed stronger intentions to use the system when compared to participants using other ITS interventions.

Table 1. *Means and Standard Deviations of Participants' Ratings on the TPB constructs*

ITS	RLX type	Intention		Attitude		Perceived behavioural control		Subjective norm	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Visual	Active	4.8	1.69	5.1	1.26	5.5	0.75	4.5	0.96
	Passive	5.4	1.56	5.4	1.35	5.7	0.59	4.9	1.04
Audio	Active	5.5	1.17	5.7	0.82	6.0	0.68	5.4	0.94
	Passive	5.7	1.18	5.7	1.17	5.9	0.86	5.5	1.06
Valet	Active	5.9	1.14	5.8	1.19	6.3	0.71	5.9	1.09
	Passive	6.0	1.07	6.0	1.04	6.3	0.75	5.8	1.19

A generalised linear mixed model analysis (GLMM) was used to evaluate whether differences existed between the ITS interventions at active and passive RLXs. No significant differences were found between the in-vehicle visual system and the in-vehicle audio system. Compared to these two ITS interventions, participants exposed to the valet system held significantly stronger intentions to use the technology at passive, but not active, crossings (t = 2.38, df = 56, p = .02).

3.2 TPB constructs

3.2.1 Attitudes towards the technology

Mean values and standard deviations of participants’ self-reported attitudes toward the ITS systems are reported in Table 1 for both types of RLXs. These results suggest that attitudes towards the technology were most favourable among participants using the on-road valet system, and that attitudes were stronger in the presence of passive crossings compared to active crossings.

A GLMM analysis indicated that attitude differed according to the type of RLX, but not the ITS intervention. Participants held stronger attitudes towards the technologies at passive RLXs than they did at active RLXs ($t = 2.10$, $df = 56$, $p = .04$).

3.2.2 Perceived behavioural control

Mean values and standard deviations of participants’ self-reported perceived behavioural control are reported in Table 1 for each ITS intervention, according to RLX type. The results show that the valet system was associated with greater perceptions of behavioural control at both active and passive crossings, meaning that participants felt they were more capable of using the system and could do so with ease.

A GLMM analysis indicated that participants’ perceived behavioural control differed significantly according to the type of ITS intervention but not the type of crossing. No statistically significant differences were found between the in-vehicle visual system and the in-vehicle audio system. In contrast, participants exposed to the valet ITS possessed significantly higher levels of perceived behavioural control ($t = 2.40$, $df = 55$, $p = .020$).

3.2.3 Subjective norm

The means and standard deviations of participants’ self-reported subjective norm for each ITS intervention, across RLX type, are reported in Table 1. The results indicate that stronger subjective norms were exhibited among participants using the road-based valet system; that is, participants believed that significant others would approve of them using, and would also use, the valet system at both active and passive RLXs.

A GLMM analysis revealed that subjective norms differed significantly as a function of the ITS intervention but not the type of RLX. Participants using the in-vehicle audio intervention had significantly stronger subjective norms than those using the in-vehicle visual device (t = 2.44, df = 54, p = .02), while the strongest subjective norms were found among participants exposed to the valet condition (t = 3.57, df = 54, p <.001).

3.3 TAM constructs

3.3.1 Perceived usefulness

Table 2 provides the means and standard deviations of participants' self-reported perceived usefulness of the different ITS interventions according to the type of RLX. Results suggest that, at both types of crossings, the valet system was associated with a higher level of perceived usefulness compared to the visual and audio ITS interventions.

Table 2. *Means and Standard Deviations of Participants' Ratings on the TAM constructs*

ITS	**Crossing type**	**Perceived usefulness**		**Perceived ease of use**	
		Mean	**SD**	**Mean**	**SD**
Visual	Active	5.1	1.52	5.9	0.61
	Passive	5.7	1.57	6.1	0.62
Audio	Active	5.6	0.93	6.2	0.62
	Passive	5.8	0.81	6.2	0.81
Valet	Active	6.3	0.89	6.7	0.55
	Passive	6.4	0.74	6.6	0.56

A GLMM analysis indicated that there were no significant differences in perceived usefulness between the in-vehicle audio and in-vehicle visual interventions. Compared to these in-vehicle systems, the valet system yielded a significantly higher level of perceived usefulness (t = 3.02, df = 55, p = .004), particularly in the presence of passive crossings (t = 2.24, df = 56, p = .03).

3.3.2 Perceived ease of use

Table 2 provides the means and standard deviations of participants' self-reported perceived ease of use of the different ITS interventions according to the type of RLX. Results indicate that, although all systems were perceived to be easy to use, participants exposed to the valet system reported the highest perceived ease of use compared to other ITS interventions.

A GLMM analysis indicated that perceived ease of use differed depending on the type of ITS but not on the type of crossing. No significant differences were found between the visual and audio ITS interventions. In comparison to these in-vehicle systems, the valet system yielded a significantly higher level of perceived ease of use (t = 3.26, df = 55, p = < .01).

3.4 Comparison of the TAM and TPB in explaining behavioural intentions

The following section provides information about the TPB and TAM constructs that best explain participants' intentions to use the trialled ITS systems. Although the two models were analysed separately, it was not possible to perform analyses according to ITS and RLX type given the small number of participants in each experimental condition (n = 20). Since both the TPB and TAM were developed for large samples, the following analyses combined all data from the different ITS interventions and RLX types. This enabled a higher pool of participants for investigating how the different constructs of the models influenced intention to use the technologies.

3.4.1 The TPB

A GLMM analysis was conducted to examine the effect of attitude, subjective norm and perceived behavioural control on behavioural intention. The model's equation indicated that both attitude (t = 6.72, df = 56, p <.001) and subjective norm (t = 5.82, df = 56, p <.001) had large effects on intention to use the technology, with their effects being of similar magnitude. In contrast, the effect of perceived behavioural control on intention was not statistically significant. Overall, the model explained 66% of the variance in intention, as measured by marginal R^2.

3.4.2 The TAM

A GLMM analysis was conducted to examine the effects of perceived usefulness and perceived ease of use on behavioural intention. The model's equation indicated that perceived usefulness had a significant positive effect on intention ($t = 11.84$, $df = 56$, $p < .001$). Perceived ease of use had no effect on intention. Overall, the model explained 54% of the variance in intention, as measured by marginal R^2.

4 Discussion

The purpose of this study was to investigate drivers' acceptance of three different types of ITS designed to enhance RLX safety. The results of the study indicated that drivers intended to use all three interventions, with the highest acceptance being found for the valet system at passive crossings. In general, this system was associated with the highest levels of perceived behavioural control, subjective norms, perceived usefulness and perceived ease of use. Thus, participants using the system felt they were capable of doing so, that important others would approve of them using it, that it was worthwhile and easy to use, and that they would make use of it particularly at passive crossings. These findings have important implications for the selection of future RLX safety interventions. Aside from receiving the greatest level of acceptance, the valet system may prove particularly beneficial since it would not be possible for a driver to override or disable the device. With research indicating that the impact of in-vehicle devices may only be short-lived (Musicant, Lotan, & Toledo, 2007) and that user's tendency to disengage or override such systems only increases with exposure (Lai, Hjalmdahl, Chorlton, & Wiklund, 2010), the safety impact of on-road ITS interventions such as the valet system used in this study warrants further investigation.

Whilst attitudes did not differ significantly according to ITS type, participants indicated they would prefer, find more value in, and feel more comfortable when using any of the trialled systems at passive rather than active crossings. Such preferences are not surprising given the nature of these two RLXs. For passive crossings, the system provides information about the presence of trains and traffic that the driver is unable to obtain in the absence of ITS. At active crossings, only the information about congestion is new to the driver, while information about the presence of a train can be gained by scanning the environment. Moreover, passive crossings pose a greater risk of collisions than active crossings, and drivers may therefore welcome additional support when approaching these more dangerous RLXs. These findings concur with previous studies indicating that drivers are more accepting of ITS interventions in critical situations, such as when driving on a slippery road or in the presence of blind spots, when the system clearly adds benefit to the situation (Joshi, Bellet, Bodard, & Amditis, 2009; Van Driel & can Arem, 2005; Varhelyi & Makinen, 2001).

Although, in general, there were few statistically significant differences between the visual in-vehicle device and the audio in-vehicle system, participants tended to view the visual ITS as least favourable. This was supported by the finding that participants in the visual ITS condition responded less positively to questionnaire items than participants in other conditions across all constructs measured by the TPB and TAM. These findings should be noted among those intending on designing and implementing ITS devices that utilise in-vehicle visual display warnings. Such devices may be perceived as distracting, irritating or unnecessary, and some such concerns were raised in the focus groups that preceded this phase of our investigation (Buckley, Larue, Haworth, & Rakotonirainy, 2013). Prior research has similarly noted that such devices are associated with low levels of acceptance and that they may in fact be more detrimental than beneficial (Roberts et al., 2012).

In terms of model utility, drivers' intention to use the ITS systems was best explained by the TPB when compared with the TAM. Overall, the TPB explained 66% of the variance in intention to use the three ITS interventions. Compared to the average amount of variance explained by the TPB (39%; Armitage & Conner, 2001), the current model accounted for a much greater proportion of variance in intentions, thus highlighting its suitability in the context of ITS interventions designed to enhance RLX safety. The model indicated that both attitude and subjective norm had a significant effect on behavioural intention, while perceived behavioural control did not. The finding that perceived behavioural control did not influence intention echoes previous research indicating that approximately one third of TPB studies fail to find a significant effect of PBC on intentions (Sutton, McVey, & Glanz, 1999). This may be because the impact of PBC declines as an individual's control over a given behaviour increases (Ajzen, 1991). Rather than suggesting a lack of support for this construct in the model, the current findings may reflect the volitional nature of the driver's decision to either disregard or pay full attention to the device. Alternatively, a different pattern of results may have been found with a more reliable perceived behavioural control scale.

In the current study, intentions to use the trialled technologies were determined by positive attitudes and the perception that important others would use and approve of the ITS systems. These results suggest that addressing the attitude and subjective norm constructs of the TPB model to strengthen behavioural intentions would be worthwhile when considering implementing ITS technologies at RLXs. For instance, interventions that promote the perceived benefits of using ITS devices in the context of RLXs may serve to induce favourable attitudes towards the system. In addition, highlighting the perception that friends, colleagues and family members would also make use of ITS devices may assist in strengthening one's intention to adopt such technologies.

Perceived usefulness was the only predictive variable in the TAM, which may be attributable to the fact that participants generally perceived all trialled technologies to be very easy to use, making the construct of perceived ease of use less variable. These findings are inconsistent with prior research investigating other forms of in-vehicle devices (e.g., navigation and multimedia entertainment systems) in which only perceived ease of use predicted intentions to use the technology (Chen & Chen, 2009; 2011). In contrast, in a recent study concerning an in-vehicle distraction mitigation system, both constructs were found to predict intentions (Roberts et al., 2012). Arguably, the power of these constructs will differ considerably depending on the context and type of device under investigation. For example, research based on participants who are obliged or mandated to use a particular system has indicated that perceived ease of use is a more important determinant of intentions than perceived usefulness (Brown, Massey, Montoya-Weiss, & Burkman, 2002). In safety critical situations, however, it is reasonable to assume that perceived usefulness may overshadow perceived ease of use, particularly when the implications of not using the device may be fatal. Further research is warranted to ascertain whether one TAM construct is in fact a stronger predictor than the other in the area of ITS devices designed to improve RLX safety.

The primary limitation of this study concerns the small number of participants involved in trialling the three technologies. As such, it was not possible to determine the ability of each of the TPB and TAM constructs in predicting intention to use each of the different ITS devices. Although attitude, subjective norm and perceived usefulness were found to significantly predict intention to use the technologies, it was not possible to ascertain for which trialled technologies the models' constructs were most influential. Future research should aim to recruit larger samples in order to delineate the impact of the TPB and TAM variables on intention to use different ITS interventions. With a larger sample, future research could also investigate mediation and moderation effects of perceived usefulness and perceived ease of use, as both factors have been found to play a mediating role between perceived obtrusiveness of technology and intentions (Roberts et al., 2012). In addition, although participants were balanced within each group according to their familiarity with crossings (whether they used them "occasionally" or "regularly"), our small sample precluded the identification of whether previous exposure to RLXs impacted on the TPB and TAM constructs. Future research might therefore investigate whether and to what extent familiarity with crossings impacts on drivers' acceptance of technologies used in RLX contexts.

This study has provided insight into drivers' acceptance of ITS interventions designed to reduce the number of crashes at RLXs, both passive and active, in Australia. Overall, results indicated that participants exposed to the road-based valet system held the strongest intentions to use the technology, particularly in the context of passive crossings. Findings also supported the utility of the TPB over the TAM in explaining the variance in intentions to use the ITS. The systems trialled in the current study were generally perceived to be useful, easy to use, and socially acceptable, with the on-road system being particularly well-regarded by drivers. It is hoped that future research continues to investigate the utility of these innovative interventions to complement existing railway interventions.

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