Safety at railway level crossings: Driver acceptance of potential ITS interventions

Buckley[a], L., Larue[a], G., Haworth[a], N. & Rakotonirainy[a], A.

[a] Centre for Accident Research & Road Safety-Queensland, Queensland University of Technology

Abstract

There is a continuing need to improve safety at Railway Level Crossings (RLX) particularly those that do not have gates and lights regulating traffic flow. A number of Intelligent Transport System (ITS) interventions have been proposed to improve drivers' awareness and reduce errors in detecting and responding appropriately at level crossings. However, as with other technologies, successful implementation and ultimately effectiveness rests with the acceptance of the technology by the end user. In the current research, four focus groups were held (n=38) with drivers in metropolitan and regional locations in Queensland to examine their perceptions of potential in-vehicle and road-based ITS interventions to improve safety at RLX. The findings imply that further development of the ITS interventions, in particular the design and related promotion of the final product, must consider ease of use, usefulness and relative cost.

Introduction

Collisions at railway level crossings (RLX) continue to represent a public concern and a serious road safety issue. In the United States, despite a decrease in highway rail incident fatalities over the past decade, there were still 3,348 deaths and 10,038 serious injuries over the period 2001-2010 (Federal Railroad Administration, 2011a). Collisions occurring at level crossings represent more than 40% of all rail-related fatalities in Australia each year (Cairney, 2011). While such collisions represent 2% of road fatalities in Australia (Victorian Government, 2009), they undoubtedly have the potential to have catastrophic consequences and be associated with substantial human and social costs. In the US, RLX collisions are sixteen times more likely to involve a fatality than other highway crashes (Raub, 2009).

A sizeable proportion of all railway crossing collisions are the result of motorist error and thus there are continued efforts to decrease the overall number of fatalities through improving safety devices for motorists (Raub, 2009). Intelligent Transport Systems (ITS) are increasingly considered when proposing such devices, particularly where the costs of installing and maintaining lights or gates at crossings are considered prohibitive. However, as with other technologies, user acceptability is likely to represent a significant factor in the ultimate effectiveness of the solution being able to improve safety (Abraham, Datta & Datta, 1998). Thus an indepth understanding of user responses may provide insight into technology acceptance.

The Role of the Motorist in Collisions

Figures from the US Federal Railroad Administration (FRA, 2011a) database show that motorist error contributes significantly to the number of collisions at RLX. An Australian study revealed that unintended errors contributed to 46% of all fatal collisions at RLX, while intentional errors contributed to fewer collisions; including substance impairment (9%), excessive speed (7%), fatigue (3%) and risk-taking (3%) (Australian Transport Safety Bureau, 2009). The addition of flashing lights and sound signals at level crossings that previously had warning signs is estimated to reduce incidents by 51% (Elvik, Hoye, Vaa & Sorensen, 2009). Thus there is potential to improve to safety by increasing driver awareness at RLX.

Engineering Approaches to Improving Safety

Separation undoubtedly represents the most effective approach, given that the potential for conflict between road vehicles and trains is eliminated. However, this approach is expensive and not feasible in many instances of railway crossings, such as in regional areas with lower traffic. Instead, warning systems at railway crossings are typically applied either passively or actively (Tey, 2008; Wigglesworth, 2001). Active warning systems involve the use of automated devices; such as flashing lights, warning bells or alarms and boom-gates. Conversely, passive warning systems involve the use of static warning signs; such as crossbucks, give way signs or stop signs. With the substantial costs of active crossings, around 57% of crossings are passive in the US (Federal Railroad Administration, 2011b) and 67% in Australia (Railway Industry Safety Standards Board, 2009).

More recently, the potential for the development of ITS for railway safety has been considered to provide information to motorists that might facilitate safe decision-making. Such approaches typically involve vehicle-to-vehicle or vehicle-to-infrastructure communication devices; such as transmitters, receivers, antennas or radio frequencies; in conjunction with technology such as Global Positioning Satellites (GPS) or traditional track detection systems. The information thus is designed to address driver lapses and errors. The use of emerging technologies for RLX safety is particularly pertinent for crossings in rural and remote areas given that many currently only have passive warning systems (Carroll, 1999). There are also low-cost rail level crossing warning devices that might be suitable for regional areas (Wullems, 2011).

Acceptability

The costs of developing and implementing new systems are high, and it is necessary for there to be high levels of driver acceptability of RLX warning devices to ensure use and compliance (Abraham, Datta & Datta, 1998). A system is acceptable and considered effective if it satisfies the needs and requirements of the users and stakeholders (Regan, Mitsopoulus, Haworth & Young, 2002). One of the more widely used approaches that explain user behaviour is the technology acceptance model (TAM) (see Davis, 1989). This framework asserts that there are two key components that predict acceptability or favourable attitudes to a new technology: ease of use and usefulness. Ease of use is the concept that a system is clear and understandable, easy to become skilled at operating and easy to learn. Usefulness encapsulates performance enhancement. It takes into consideration the system being appropriate to improve performance and in the case of road safety, reduce the likelihood of crashes. On the other hand, acceptability is defined with the constructs of effectiveness, that it functions according to design specifications; usability, to operate with minimal effort; usefulness, to enhance performance; and equity, that it targets the appropriate end user in the appropriate context (Regan, Mitsopoulus, Haworth & Young, 2002). The current research seeks to identify how such components of acceptability relate to driver acceptance of potential ITS interventions to improve safety at RLX.

To be effective in reducing crashes at RLX, ITS interventions need to be accepted. Indeed if such technologies do not respond to drivers’ needs and expectations, they are unlikely to be purchased or switched on, change driver behaviour and hence have positive effects on safety (Can Der Laan, Heino & DeWaard, 1997). Knowledge of acceptability and likely use is of importance to the rail industry in order to select between alternative technologies as well as help manufacturers design ITS devices that would have greatest consumer acceptance. Thus the research presented in this paper sought to examine how various potential technologies that increase driver awareness at railway crossings are likely to be accepted by drivers, including visual and audio cues presented either in vehicle, or in the case of visual cues, potentially external to the vehicle. Further, the paper identifies components and themes of acceptance of road safety technologies.

Method

Participants

Participants were 38 drivers recruited from two locations in Queensland; a metropolitan city with active crossings in outlying suburbs (n=17) and a regional town with active and passive crossings in and around the town (n=21). There were more females than males (68% female) and participants were aged between 21 and 58 years (mean age of city participants=37.1 years, mean age of regional town residents=43.6 years). The participants' driving experience ranged from 6 months to 40 years (mean = 21.2 years). They were employed in a range of administrative and professional positions and not professional drivers. A large proportion of participants (79%) reported driving across RLX more than once a week. Many had regular experience with passive RLX (32% weekly). Participants from the regional town reported more frequent experience with passive crossings (50% compared with 9% weekly or more frequently).

Procedure

The research procedures adhered to those approved by the university Human Research Ethics Committee. Drivers were recruited through mailing lists of two universities (one in a metropolitan city, the other in a regional town). Participants were eligible if they held a current driver's licence and had no experience working in the railway industry. Four focused discussion sessions of eight to ten participants were facilitated by a member of the research team, a psychologist trained in group facilitation (mean duration of 47 minutes). The discussions were audio-recorded.

An initial pen-and-paper survey collected information about demographics, driving experience and railway crossing experiences.

Discussions began with a brief introduction on the scope of the fatalities and costs of crashes at railway crossings in Australia. The main focus of the discussions related to acceptability of key ITS interventions in the context of (i) active RLX and (ii) passive RLX (order reversed in the second group at each location). Participants were shown colour photographs of a typical rural passive crossing and a typical urban active crossing and computer-generated images of the ITS interventions. There were six visual ITS representations shown of in-vehicle and road-way interventions. The in-vehicle cues were shown as a display of about two inches square to the centre of the car where typically a sound system may be displayed of (i) a single light beside a picture of a railway crossing crossbuck (picture similar to those currently shown on road signs), (ii) an image of two trains facing each other with the same picture of a railway crossing in the middle, between the train images. The display depicted how the in-vehicle message could light under different circumstances – if a train approached from the left, the left train illuminated red, if no trains were approaching the crossing, the image remained black and if two trains approached both trains were illuminated, (iii) the same railway crossing image and an image beside of three overlapping cars that would illuminate to depict an obstruction and (iv) an image of a train to the bottom left of a car (top right in the image) with a flashing star behind both to indicate a likely collision. External cues were depicted as (i) a stationary variable message sign or (ii) a series of lights inserted into the road surface that were increasingly close on approach to the junction and were illuminated in the instance of a train approaching. Audio cues (such as a "*beep*") were described verbally by the facilitator.

The discussion protocol focused on acceptability, usefulness (e.g. "*how might this work in practice?*"), comprehension (e.g. "*how easy is this to understand?*"), annoyance and potential to improve safety (e.g. "*please comment on how this might/ might not improve safety*") of the different systems. Further, participants were asked to comment on the message that the ITS solution would convey including; (i) awareness of RLX, (ii) awareness of a train approaching and (iii) awareness of the potential for a crash.

Data Analysis

Qualitative analysis was conducted to explore the relationships between identified themes in the data. The analytic process involved managing, summarizing and finding meaning in large semi-structured quantities of data. Participants' reports were checked across focus groups to assess whether consensus existed, in order to assess the strength of acceptance of various ITS interventions and the key issues common to accepting any ITS solution. Coding of themes was initially conducted by the first author and the team reviewed responses and the proposed themes. This provided clarification and identification of the main themes generated by participants. The combined efforts provide a thorough and well-justified analysis which in turn, provides a comprehensive and accurate reflection of the data received.

Results

Message Content

Participants were asked to consider potential messages that the ITS interventions could attempt to convey. There was consensus that a train approaching was the most appropriate message for any ITS intervention, particularly with regard to benefits for safety. There was further consensus that notification of an imminent crash would not be of assistance.

The participants who had more frequent experience with passive crossings indicated that notification that they were approaching a crossing could be useful. This may be particularly so in poor visibility, "*in the city areas, they are mostly pretty visible, so I would see as more relevant in the country areas*." In addition, there were participants who acknowledged that there could be benefit to alerting drivers to the direction of travel but these individuals did not think it was a safety benefit instead informative, a city-based participant suggested, "*messages that maybe gave you time to find an alternative route*." With regard to safety, one participant noted, "*if a train's going to hit me or kill me the direction won't matter*." Other participants noted that providing the direction of travel may lead some drivers to rely on technology and not their judgment, "*I would probably ignore the inbuilt system and look left and right, checking, because there could be an issue*."

Effectiveness

Issues of effectiveness related to having confidence in the capability of ITS and trust in its reliability. One of the most common reports by participants related to having trust in the system and the capabilities of the technology for example, "*and you just wonder how you would believe* (it was going to work)," and another participant noted, "*how could it possibly tell*." Trust also extended to reliability and belief that the solution would continue to work, "*what about* (in case of) *a malfunction*." Concerns for trust thus included technical capabilities and limitations, for example, "*what if one day it failed and I didn't know it failed, I would get really, I might forget to look.*" With regard to active RLXs this highlighted particular problems with an in-car solution, for example, "*you're trusting two different systems, if they disagree, which do you trust*." Further, participants suggested methods of integrating ITS interventions into current approaches, potentially representing a method in which they could better reconcile their trust for a new system, "*a GPS* (system to alert for a) *train, then I would prefer that, I think we're pretty much used to that*."

A common response related to trust included placing value in a person's own awareness, for example, "*the most important systems are our eyes and our ears*". Reliability of other technology was compared, "*the amount of times a GPS has told you to turn left and you're like, I don't think* *so*." Along such lines, some participants suggested that for other drivers there may be complete reliance on the ITS solution that would encourage complacency with individuals' observations. For example, one participant noted that, "*whatever applies shouldn't detract from the driving*," and another noted, "*people rely on them too much, and then the system fails and they don't know what to do*."

Ease of Use

Attention.

Attention can be considered as containing key components of; an ability to recognise or identify a message, understand or comprehend the message and respond appropriately to such message. Some participants identified issues around these components while others indicated attention was critical to effectiveness, suggesting that the message would be particularly valuable if attention was improved, "(you would get the) *most value if that says be aware,* (to help) *pay attention*."

Visual message recognition.

Issues around recognition of the message were noted particularly around in-car systems, and identifying audio and visual cues. To aid with recognition, participants noted visual displays should be at eye level or close to other dash signals that are regularly observed (for example, the speedometer). As an example, one participant noted, "*I would see that as being too much out of the eye-line* (if it was below the air-vent), *if it was going to be visual it would need to be right in front of you, on the screen. To actually see it without having to look*." With regards to integrating the signal into the GPS one participant commented, "*if you've got your GPS on, it can be an easy LED thing that can be put into your GPS. It's not dragging your attention away from what's going on.*" Visibility of the light was noted in both of the regional groups, for example, in some conditions the lights might be difficult to see, "*I don't know how effective they're going to be in full sunlight.*"

Audio recognition.

Issues of recognition in audio systems were also noted, for example, one participant asked, "*would you know what it* (a beep) *meant*?" Another participant noted that, "*different messages take some time to learn*." Several participants also noted concerns for those who may have difficulties, "*it would be needed for hearing impaired people* (the addition of other warnings)." Other issues of identifying sound related to perception above other noises, for example, on participant asked, "*would you hear it if you had music playing?*" Further, some participants noted that recognition may be important depending upon the message being conveyed, in particular the timing of message, "*if there's a delay, by the time you pay attention to that, so the timing is important.*"

Participants were asked to consider the use of sounds such as beeps or voice instructions as notification of particular messages. While beeping was slightly less supported than vocal instructions it was nonetheless supported particularly if the beeping message could be comprehended. Participants did note that there could be different messages communicated with the beeping for example, escalation in volume or frequency could indicate increasing urgency of action, "*it could escalate*."

Message displayed.

With regard to the message displayed, one participant suggested a unique prompt of "*pay attention*" would better convey a safety message rather than multiple messages that might require scrolling in the display. There was no support for the display of registration number of the car on the VMS to provide a personalised message; many drivers reported that they did not know their registration number and that others might be unfamiliar (for instance in rental cars). Thus aside from the comprehension of an individual message, the participants acknowledged a variable message display, external to the car, would be easy to understand and easily recognised. The over-riding limitation however was considered to be cost.

Distraction and annoyance.

While comprehension was a key issue in auditory message delivery, recognition and annoyance were also considered. There were a few participants who saw benefits to an annoying system, "*I think it's something that needs to be really annoying, like the noise you get if you don't put your seatbelt* (on)" so that it prompted action, "*the distraction thing would be the key for me, so people don't become lazy*." Most participants identified that the intrusive sounds would prompt them to switch off, for example, "*if you told me that the crossing is coming up, I'd turn it off because I don't want it.*"

Driver control.

Participants expressed a desire to be able to control any in-vehicle system, "*in the car needs a driver override, you can just flick it off but if you're driving in a country area and like you don't know there's a crossing it might be like my car's fitted with a RLX device then it's not something you go, not this.*" However others noted that this would detract from some of the safety benefits, "*you shouldn't choose to turn it off.*"

Usefulness

Many participants identified concerns about the utility of a general system that operated for all drivers in all conditions. With regard to particular situations, participants noted that ITS interventions may be of greater benefit in unfamiliar areas. For example, "(there is) *a very strong benefit for hire cars particularly country areas where there's nothing else to help you*." There were others who noted that usefulness in particular contexts for ITS interventions related to the particular stretch of road, "*some tracks you approach on a bend and they're probably potentially the one*."

Additionally, participants repeatedly queried information about high risk individuals, and didn't see relevance, "*what do statistics tell us? Is it tourists who are unfamiliar or the locals being complacent?*" In another example, a participant noted, "*I also think it's more about who is making the mistakes there's gotta be a way to be more targeted*."

Many believed that ITS interventions would not be useful for those who are likely to take risks and be counter-productive for such groups, for example, "*it would encourage people to go faster*." Another participant indicated, "*I'd see that as dangerous, not look to the right and go speeding past so they just floor it through*."

Cost

There was considerable concern about the cost effectiveness of all ITS interventions described. Participants questioned the value of ITS interventions at active crossings suggesting that unnecessary measures were potentially frustrating, for example, "*so what's the cheapest, most effective and I would imagine that they are all going to have that they're going to have satellite navigation so it would save time changing the design of dashboards*".

For in-vehicle approaches, costs to the individual and government were frequently identified and were acknowledged as especially important. At the individual level, one participant gave an example that conventional warning lights in the car dash that don't work often get ignored due to the costs involved in repair. There were thus comments about costs to particular individual groups and difficulties in paying for new systems, "*what about people that can't afford* (it)?"

Cost effectiveness was identified with regard to installation and maintenance of road-based systems for both individuals and government, this included responding to vandalism as well as general maintenance issues. For example, one participant said it, "*give*(s) *vandals something else to aim at*." Further there were participants who saw costs to be concerning if borne by the individual and others who noted costs to be concerning if they were borne by the government (or taxpayer), for example, "*Not a fan* (of VMS), *I think taxpayer dollars could be better spent*."

Participants suggested a range of possible alternatives, which were mainly passive systems such as audio strips or painted lines ("*rather than lights you could put paint on the road instead*"). Changing the road surface was suggested, for example, "*coming up to some roundabouts they've changed the surface of the road so they're more gravelly you can feel the difference when you're driving for ages you can feel the road change it's probably less expensive*."

Most participants reported greater concerns with the costs of an on-road system particularly in balance with current approaches of lights and boom-gates at active RLX, for example, "*the government are saying that in country areas it's not cost effective to put them in, is this more cost effective, so then you'd just do boom-gates*," and another participant noted, "*I'm not seeing any value beyond flashing red lights*." Thus a particular solution supported by many would be an extension of the current GPS used by drivers.

Discussion

ITS interventions can provide information to the driver, but the acceptance of such technology is a critical link in whether they are effective in improving safety. The current study showed that there were a number of factors associated with a greater acceptability and these are largely consistent with previous research around factors explaining technology acceptance. Several key issues around acceptance were highlighted, including: perceived effectiveness, usefulness, usability, and cost. The Technology Acceptance Model (TAM) similarly includes usefulness (performance enhancing) and ease of use (easy to learn and operate).

One important area that is likely to impact on the implementation of an ITS intervention around railway crossings is the perceived usefulness of the intervention. Participants who saw a clear purpose or goal in the intervention message also were more accepting of the intervention. They identified issues around improving safety, in particular for individuals that they thought would be of higher risk of collisions, and certain situations in which they similarly thought would be of higher risk. The findings have important implications for education around the implementation of such technologies. In particular, if an intervention was to target all drivers then this purpose or value would need to be communicated to the community. Where individuals did see value in the system they were often very supportive.

While many theories, including the TAM, incorporate issues of effectiveness under the construct of perceived usefulness, the findings from this study suggest that effectiveness is a particularly central concern in this context. Participants' concerns about the system functioning as designed are perhaps greater without the availability of prototypes to show how the system might operate. This is further supported by participants' repeated suggestions that incorporating alerts and warnings into existing systems, such as in-car satellite navigation systems (GPS systems) would be optimal. In addition, system reliability was one of the most repeated issues described. This is supported by other research findings, for example, system reliability (reduction of false alarms and missed signals) and user-friendly interface design were key issues identified by Carrol, Passera and Tingos (2001). Future research might thus expand on the current project by examining acceptability in simulated driving scenarios.

Participants identified ease of use as an important component, with a particular focus on recognition, attention and comprehension. The aim of the ITS interventions presented was to improve driver awareness on approach or at RLX by providing information that promotes safer decision making and reduces driver error. The focus on such issues is also reflected in the TAM model construct of ease of use which typically measures constructs related to limited confusion, reducing errors and understanding how the system operates. A system which allows recognition of the warning, draws attention to the situation and can be comprehended by the driver should result in a system where the driver makes fewer errors.

The cost of any system to either the individual directly or to the government was the priority for most participants. This is similar to the acceptance of other ITS road safety initiatives. Conte, Wardman and Whelan (2000), for example, found that cost strongly predicted acceptance of intelligent speed adaptation. While cost is not always considered in models or theories of technology acceptance, this may often be because the company or industry is seen to be responsible for the cost. Importantly, many participants saw the interventions as being of high cost and costs likely to be borne by motorists or government. Further they made suggestions of similar interventions with perceived low technology and low cost that were considered to be favourable. Such findings suggest that the implementation of ITS interventions will need to be undertaken in conjunction with campaigns to highlight to users the value in the solution.

Overall, the findings provide a basic framework for acceptance of railway level crossing technology that largely overlaps with previous models of technology acceptance. The study provides insight through qualitative methodology, that allows participants to elaborate on the way in which they consider the key issues. For example, with regard to cost, participants articulated a trade-off between costs associated with implementation and maintenance of interventions with the costs associated with railway crossing collisions. The study also provides valuable information around potential areas of future testing and potential needs for corresponding campaigns to provide users with information about effectiveness (reliability), cost, ease of use and usefulness.

Despite considerable investment in ITS interventions, they do not always achieve their projected targets. The current study sought to address this issue by understanding driver acceptance of interventions that may improve safety at RLX. However the research design had some limitations, including sample selection. The study involved a limited number of participants from two locations (one metropolitan and one regional). Although detailed information was obtained about acceptability, the generalisability of findings could be expanded with a larger and more diverse sample to include those who are typically over-represented in RLX crashes (for example, young males). In addition, the study promoted participant-generated factors related to acceptability but there may be individual personality and cognitive factors that affect acceptability decisions of which participants may not be cognisant. For example, factors such as self-efficacy and social pressures influence some technology use (Regan, Mitsopoulus, Haworth & Young, 2002). In addition, the focus groups process did not elicit the different types of individuals to which certain technologies might be better suited and a large survey of the community might better elicit such information.

In summary, acceptance appears to be a critical factor in whether drivers report they will use ITS interventions at RLX. An understanding of the way in which interventions are acceptable to drivers can contribute to the development of appropriate policy in implementation as well inform future technology design. As identified by the Technology Acceptance Model (TAM), ease of use and usefulness are critical elements, but additional components of costs and equity may be useful additions to the framework.

References

Abraham, J., Datta, T. K. & Datta, S. (1998). Driver Behavior at Rail-Highway Crossings. *Transportation Research Record,1648,* 28-34.

Australian Transport Safety Bureau (2009). Australian Rail Safety Occurrence Data 1 January 2001 to 30 June 2009. *ATSB Transport Ssafety Report Rail Statistics - RR-2009-007(1) Final*. Australian Transport Safety Bureau.

Cairney, P. (2003). Prospects for Improving the Conspicuity of Trains at Passive Railway Crossings. *Road Safety Research Report RC 217*. ARRB Transport Research.

Carroll, A. (1999). ITS Technology at Highway-Rail Intersections: "Putting It To The Test", 1999 Proceedings From the *ITS Joint Program Office Highway-Rail Intersection Evaluation Workshop.* http://ntl.bts.gov/lib/jpodocs/proceedn/12363.pdf. Accessed Jul. 17, 2011.

Carroll, A., Passera, A. & Tingos, I. (2001). *Vehicle Proximity Alert System for Highway-Railroad Grade Crossings Prototype Research.* Federal Railroad Administration, Washington, D.C.

Conte, S., M. Wardman, M. & G. Whelan G. (2000). Drivers' Acceptance of Automatic Speed Limiters: Implications for Policy and Implementation. *Transport Policy, 7,* 259-267.

Davis, F.D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology, *MIS Quarterly, 13,* 318–340.

Elvik, R., Hoye, A., Vaa, T. & Sorensen, M. (1009). T*he Handbook of Road Safety Measures (2nd Ed.).* Emerald Group Publishing Limited, UK.

Federal Railroad Administration. (2011a). *Ten Year Accident/Incident Overview by Railroad/Region/State/ Country.* http://safetydata.fra.dot.gov/officeofsafety/publicsite/Query/tenyr2a.aspx. Accessed Jul. 17, 2011.

Federal Railroad Administration. (2011b) *Railroad Research and Development Program. Chapter Four. http://www.fra.dot.gov/Pages/1241.shtml*. Accessed Jul. 19 2011

Morris, M.G. & Turner, J. M. (2001). Assessing Users' Subjective Quality of Experience with the World Wide Web: An Exploratory Examination of Temporal Changes in Technology Acceptance. *International Journal of Human-Computer Studies, 54,* 877-901.

Railway Industry Safety Standards Board (2009). *Level Crossing Stocktake, 2009.* http://www.rissb.com.au/linkdev//site/NationalStocktake.php Accessed Oct. 22 2010.

Raub, R.A. (2009). Examination of Highway-Rail Grade Crossing Collisions Nationally from 1998 to 2007. *Transportation Research Record, 2122,* 63-71.

Regan, M.A., Mitsopoulos, E., Haworth, N. & Young, K. (2002). *Acceptability of In-vehicle Intelligent Transport Systems to Victorian Car Drivers. Report No. 02/02*. Monash University Accident Research Centre, Victoria, Australia.

Tey, L.S. (2008). *A Traffic Simulation Approach to Evaluating Cost-effective Rail-Road Level Crossing (RLC) Protection Systems*. Unpublished PhD.

Towards Zero: A Strategy for Improved Level Crossing Safety in Victoria. Victorian Government, 2009.

Van Der Laan, J., Heino, A. & DeWaard, D. (1997). A Simple Procedure for the Assessment of Acceptance of Advanced Transport Telematics. *Transportation Research Part C,5*, 1-10.

Wigglesworth, E.C. (2001). A Human Factors Commentary on Innovations at Railroad-Highway Grade Crossings in Australia. *Journal of Safety Research, 32,* 309-321.

Wullems, C. (2011). Towards the Adoption of Low-cost Rail Level Crossing Warning Devices in Regional Areas of Australia: A review of Current Technologies and Reliability Issues. *Safety Science, 49,* 1059-1073l.