Driver compliance at railway level crossings

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Abstract

Railway level crossings create serious potential conflict points for collisions between road vehicles and trains producing one of the most severe in all traffic crash types. There are approximately 9,400 public railway level crossings in Australia. They are protected either passively (64%) or by active/automated systems (28%). Passive protection systems provide only a stationary sign warning of the possibility of trains crossing. Their message remains constant with time. Active protection systems activate automatic warning devices (i.e., flashing lights, bells, barrier, etc.) as they detect an approaching train. This paper evaluates driver compliance towards different protection systems at railway level crossings. Field data collection using video recording was conducted to measure driver responses at crossings with different protection systems, namely: stop sign, flashing lights/bell and half boom-barrier with flashing lights. This paper describes the field data collection and analysis and subsequently draws conclusions on driver compliance with respect to different types of protection systems. The results indicate that drivers behave differently and are more compliant at actively protected crossings than at passively protected crossings.

Keywords:

Railway level crossing, protection systems, driver compliance, field survey, video recording.

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1. Introduction

Railway level crossings (RLX) create serious potential conflict points for collision between road vehicles and a train or trains producing one of the most severe in all traffic crash types. It continues to be the largest single cause of fatalities from rail activity in Australia (Bureau of Transport and Regional Economics, 2002). There are approximately 100 incidents at Australian crossings every year and these incidents result in the death of an average of 37 people (Australian Transport Council, 2010). During the years 2007 to 2009, there was an average of 55 collisions at crossings involving road vehicles each year (Australia Transport Safety Bureau, 2010). The financial cost of RLX collisions has been estimated at AUD$32M per year excluding rail operators and infrastructure losses (Bureau of Transport and Regional Economics, 2002). There are approximately 9,400 public crossings in Australia. They are protected either passively (64%) or actively by automated systems/devices (28%) (Ford and Matthews, 2002). Passive crossings provide only stationary signs without train information. Drivers have to look for the presence of a train before clearing the crossing. An active protection system activate automatic warning devices (i.e., flashing lights, continuous bell, barrier, etc.) as it detects a train approaching. In Australia, records show a reduction in accidents following the installation of active protection systems (Ford and Matthews, 2002; Wigglesworth and Uber, 1991). However, improving safety at RLX is costly. Cairney (2003) has suggested that the minimum plausible cost of installing conventional active protection in Australia would be in the order of AUD$200,000 per crossing, and an upper order estimate would be in the order of AUD$300,000. The cost of installing conventional active protection at all passive crossings in Australia would therefore be between AUD$1.2 billion and AUD$1.8 billion. In addition, on-going maintenance costs would be considerable in view of the remote location of many current passive crossings. Therefore, searching for new cost-effective technologies becomes essential. This has been identified in the National Railway Level Crossing Safety Strategy 2010-2020 as one of the key actions that must be addressed (Australian Transport Council, 2010).

Considerable research and innovation has occurred in some countries on low cost RLX protection systems applied at the crossing, on trains or in vehicles. A recent comprehensive state-of-the-art literature review identified approximately 50 different systems (Tey, 2009). Although many of these protection systems have been invented their effect on safety and driver acceptance is unknown. There are opportunities for immediate application of some low-cost innovative protection systems for RLX available worldwide, subject to their effectiveness and adaptation to Australian conditions. The effectiveness of these alternative protection systems needs to be assessed to reflect safety improvements at RLX. However, to date, there has been no systematic approach available to evaluate these systems for implementation in Australian conditions other than before-and-after implementation studies.

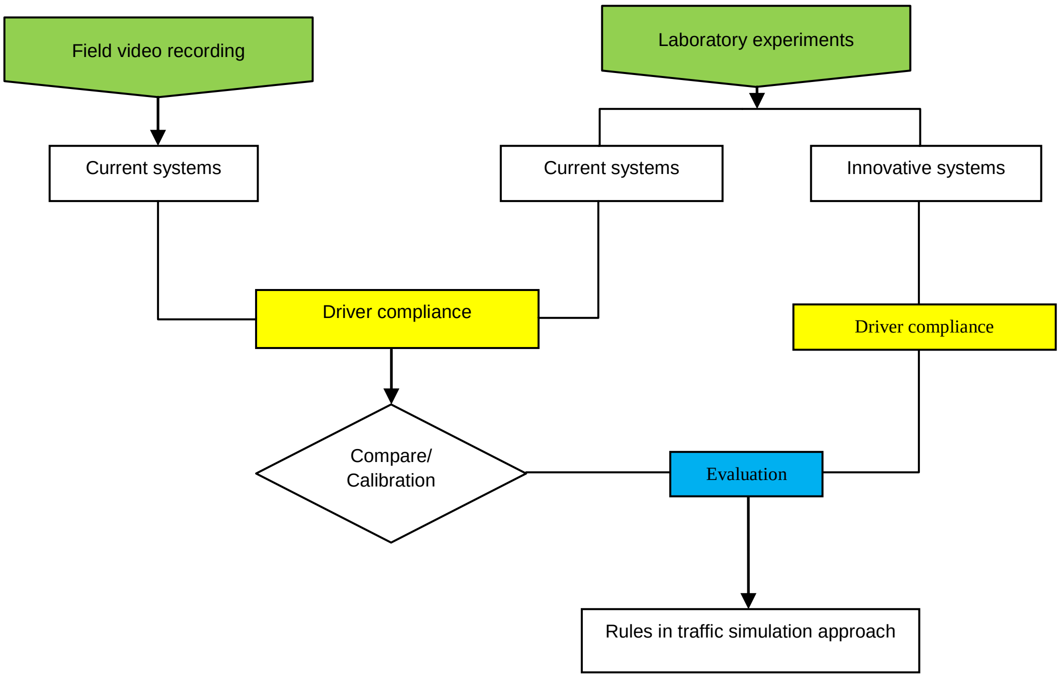
To compare the effectiveness of these innovative systems with currently used systems, it is necessary to assess driver behaviour. 'Driver compliance' is one of the parameters commonly used to test driver behaviour at RLX. This parameter was adopted in some studies of both existing systems and newly invented systems (Carlson and Fitzpatrick, 1999; English and Murdock, 2005; Hirou, 1999; Meeker et al., 1997; Shinar and Raz, 1982). Abraham et al. (1998) presented a possible association between violations of road rules and past crash histories at RLXs. The current paper compares driver compliance with different existing protection systems currently in use. This paper is structured as follows: Section 2 provides a description of the study's background and methodology of data collection; Section 3 presents and compares the results from the field surveys, and Section 4 concludes the main findings.

2. Methodology

2.1 Background

The field results reported in this paper are part of a study aimed at developing a methodology to evaluate innovative RLX protection systems from the aspects of engineering considerations and human factors. For engineering evaluations, a few potential systems which would suit the objective of the research were selected as examples using multi-criteria analysis technique (Tey et al., 2009). For the human factor aspect, driver responses towards protection systems were measured both in the field as well as in the laboratory using a driving simulator. One of the important driver responses considered is driver compliance to the protection systems since higher records of violations may indicate a higher possibility of collisions with trains. Figure 1 briefly outlines the interface between the two approaches. The driver compliance rate measured from different types of existing protection systems in the field will be compared to the results of driver compliance from driving simulator experiments in the next stage of the study. Subsequently, driver compliance (and other driver responses) to innovative protection systems will be assessed. Driving simulator experiments have been designed to involve human factors in determining contributing variables of driver behaviour to different types of protection systems. The results can be incorporated into a microscopic traffic simulation approach. The interface of driver behaviour results from the driving simulator into a traffic simulation approach will enable innovative RLX protection systems to be evaluated in laboratory controlled conditions. The output of this study will contribute to the evaluation process of innovative RLX protection systems taking into consideration both engineering and driver behaviour factors.

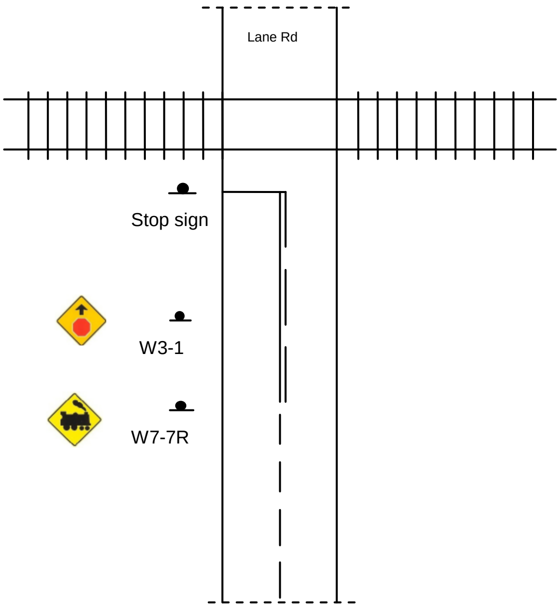
Figure 1: Driver compliance evaluation with field survey and driving simulator experiments



2.2 Study sites

Four RLX sites in and around Brisbane were selected, two being passive and two active. Three types of protection systems are used at the four sites: signage, alternately flashing red lights/bell and a half-boom barrier. One of the passive crossings selected (Site 1), is equipped with an approaching train sign (W7-7R), an approaching stop sign (W3-1) and a stop sign at the crossing (Assembly RX-2) complying with MUTCD Part 7 (Standards Australia, 2007) as shown in Figure 2 (a) and (b). This RLX crosses Lane Road at 90 degrees. The roadway is a two-lane two-way road which branches out from a major collector linking towns between Ipswich and Toowoomba with a posted speed limit of 80 km/hr. The crossing is located more than 1km away from the major collector. The train track serves weekly passenger trains between Brisbane and Toowoomba and coal trains to the Port of Brisbane. The second studied site (Site 2) is another passive crossing located at a local residential street (Videroni Street), approximately 250m away from a major local street (Stafford Street). It crosses Videroni Street at 90 degrees. As shown in the schematic layout in Figure 3 (a), there is a row of approximately 30 residential units from the crossing to the cul-the-sac. Opposite this row of units is a horse racing club. On the other side of the crossing there are two rows of residential units. The crossing is equipped with an approaching train sign (W7-7R), an approaching stop sign (W3-1) and a stop sign (as show in Figure 3 (b)) complying with MUTCD Part 7 (Standards Australia, 2007). The train track serves mainly a tourist train and occasionally coal trains travelling between Swanbank Power Station and the Port of Brisbane. Two different types of stop signs were observed at Site 1 and 2.

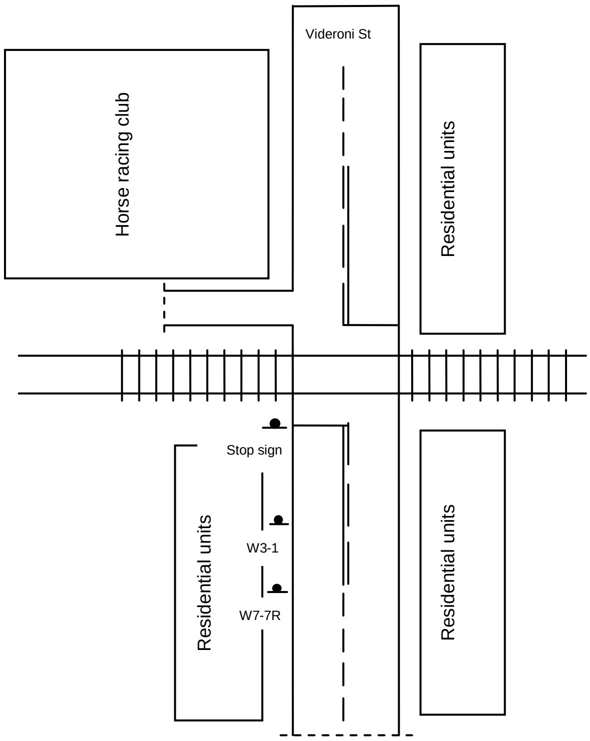
Figure 2: (a) Layout of Site 1; (b) Stop sign at Site 1



(a)

(b)

Figure 3: (a) Layout of Site 2; (b) Stop sign at Site 2

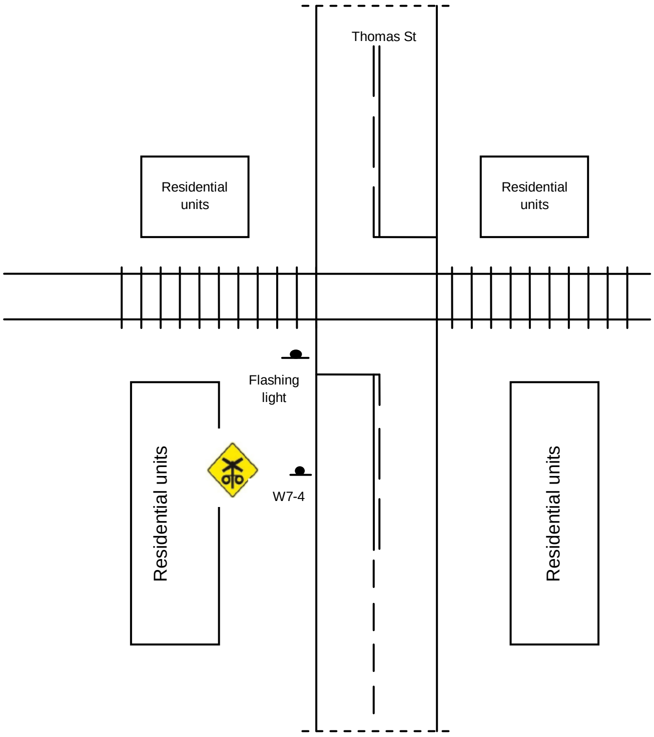


(a)

(b)

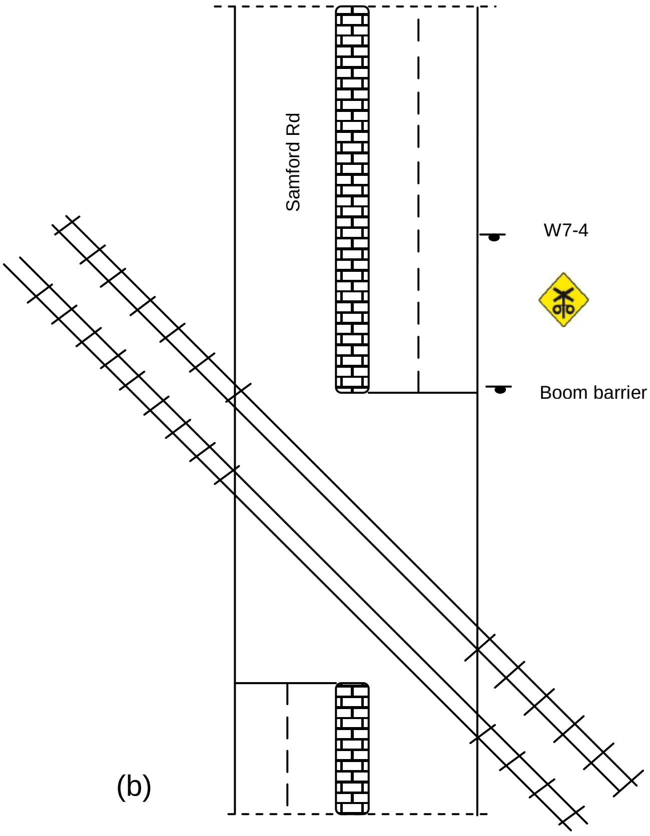
The other two study sites were active crossings. The crossing at Site 3 crosses Thomas Street at 90 degrees (as shown in the schematic layout in Figure 4 (a)). Thomas Street is a major two-lane two-way local street. The crossing is located approximately 400 metres away from the adjacent T-junction. Site 3 is equipped with a flashing red light and ringing bell. The flashing red light signal as shown in Figure 4 (b) consists of twin red round lights arranged horizontally and equipped to flash alternately. The train track serves mainly for holiday/tourist trains and occasionally for coal trains travelling between Swanbank Power Station and the Port of Brisbane. Site 4 is equipped with flashing red lights, a ringing bell and supplemented by a half-boom barrier (as shown in Figure 5 (a)). As the RLX protection system detects an approaching train, the flashing red signal and the bell are activated, followed 7-8 seconds later by the boom barrier, which starts to descent from its upright position to a horizontal position in approximately 8 seconds, blocking the traffic from entering the crossing. After the train passes the crossing, the boom barrier lifts gradually to its original vertical position in approximately 10-12 seconds; followed by deactivation of the flashing lights and bell approximately 0-2 seconds later. The train track crosses at 45 degrees a four-lane two-way local major road (Samford Road) with a median strip as shown in Figure 5 (b). The crossing is located approximately 500 metres from the adjacent signalised T-junction. The train track is part of the Brisbane city passenger train network that operates daily. The characteristics of the four study sites are summarised in Table 1. Posted speed limits at all four study sites are from 50 to 70 km/hr. The three protection systems described at the four sites are the most commonly used at RLXs in Australia.

Figure 4: (a) Layout of Site 3; (b) Flashing light at Site 3



(a) (b)

Figure 5: (a) Boom barrier at Site 4; (b) Layout of Site 4



(a) (b)

Table 1: Specific characteristics of selected study sites

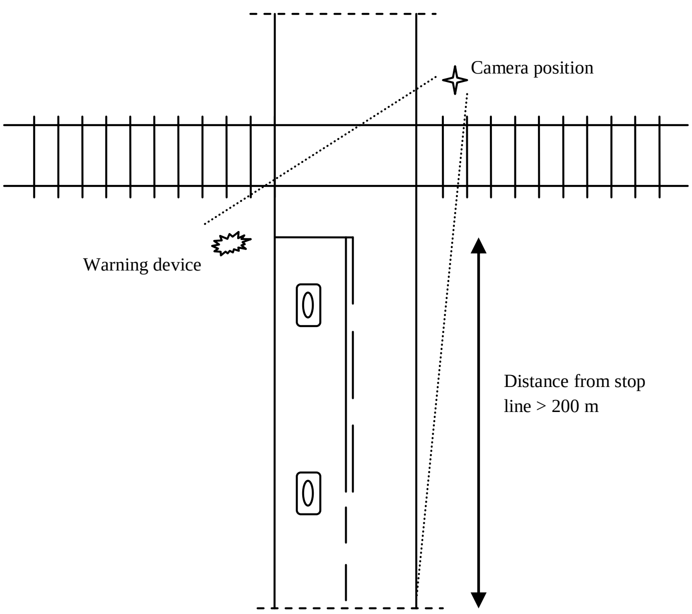
Site	Protection Systems	Number of tracks	Train volume[1]	Traffic lane per direction	Average Daily Traffic[2] (vpd)	Crossing Angle (°)
1	Stop sign	2	60-70 trains/week	1	< 80	90
2	Stop sign	1	< 10 trains/week	1	<150	90
3	Flashing light	1	< 10 trains/week	1	3500	90
4	Boom barrier	2	approx. 100/day	2	6000	45

Note: [1] Train volume is estimated from Queensland Rail National (2008), Rail Australia (2009) and TransLink Transit Authority (2009).
[2] Traffic volumes are estimated from field surveys and The State of Queensland – Main Roads (2009).

2.3 Video recording setting

Data was collected with a portable traffic surveillance camera. A telescopic flag-pole of 1.5 to 5 metres high was modified to hold the camera in order to attach it to a suitable support near the four sites, such as a traffic sign pole or tree. A monitor was connected during the setting up process for adjusting the angle and view of the camera. A remote control was then used to zoom in and out to the required coverage. The selected study sites were carefully investigated so that the camera was installed in such a way that it was hidden from motorists' attention so it would not affect their driving behaviour. The camera set was erected near the RXLs to capture the operations of the warning devices as well as a roadway section of more than 200 metres from the stop line as schematically shown in Figure 6. Video footage was captured under normal daylight conditions from 6:00 a.m. to 5:30 p.m. at 25 video frames per second. Data were collected for all vehicle types including passenger vehicles, trucks, and buses. Since the nature of the study was to obtain driver responses to warning devices, data were not grouped separately into each vehicle type.

Figure 6: Setting up of camera for field surveys



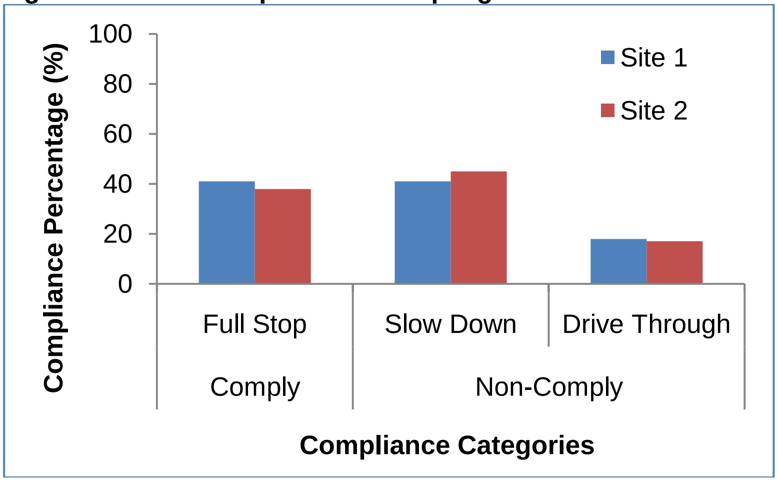
3. Data analysis

‘Driver compliance’ is defined as total adherence to the traffic rules. For instance, crossings with ‘Stop’ signs require a motorist to completely stop in order to visually look for a train presence in both directions. Similarly, motorists should stop when an active control system is activated by an approaching train.

The video images were replayed on a personal computer in order to compile data. ‘Driver compliance’ of each vehicle to the warning devices at Site 1, 2, 3 and 4 was recorded. For Site 1 and 2 with stop signs, three categories of responses were observed: the vehicle stopped (comply); slowed down but did not stop (non-comply); or drove through the crossing, that is, neither slowing down nor stoping (non-comply). For Site 3 with flashing lights and ringing bell, two categories were recorded: the vehicle stopped (comply); or drove through (non-comply). For Site 4, two categories were recorded after warning devices have been activated. In addition, compliances of the vehicles after the warning devices deactivated were noted. The compliance behaviours were categorised into three groups, namely: the vehicle started to move after both boom barrier and flashing light/bell was deactivated (comply); after boom barrier but before flashing lights deactivated (flashing light, non-comply); or before both boom barrier and flashing light deactivated (boom barrier, non-comply).

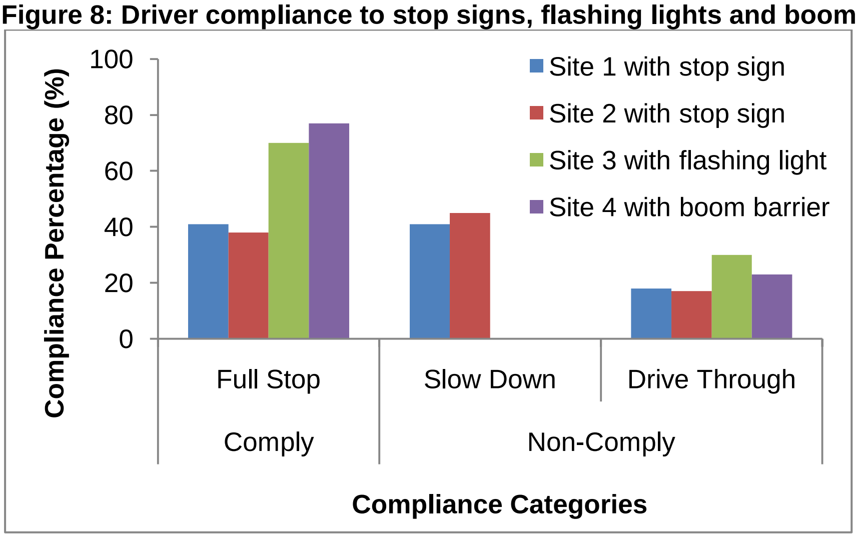
At Site 1, a total of 66 vehicles were recorded in two days. The non-compliance behaviours were observed and sub-categorised to ‘Slow Down’ (reduced speed without fully stopping) or ‘Drive Through’ (neither fully stopping nor reducing speed). These sub-categories could indicate in detail the drivers’ behaviour. Figure 7 shows the compliance percentage of the motorists to stop signs at Site 1 and 2. More than half (59%) of the drivers did not fully stop. Nevertheless, the majority (41%) of this non-compliance group slowed down before crossing the tracks. Similar results were observed at Site 2 where a total of 71 vehicles were recorded in two days. More than half (62%) of the drivers did not fully stop but the majority (45%) of this non-compliance group slowed down before crossing the tracks. It should be highlighted that similar compliance trends (stop, slow down and drive through) at Site 1 and 2 were observed, although the types of stop signs and characteristics of the crossings (i.e., numbers of tracks, land use, roadway hierarchy, visibility, etc.) are different. A study by Ward and Wilde (1996) suggested that ‘visibility’ would not significantly affect driver behaviour as drivers tend to maintain their safety margin regardless of improvement of visibility. Their study showed that improvement of lateral sight distances resulted in an upstream shift towards longer search durations and a tendency towards faster approach speeds, but failed to produce a calculated net safety benefit. Comparison of driver compliance results between Site 1 and 2 from this current study supports the notion that visibility might not influence driver behaviour at passive crossings because Site 1 had better visibility (no visibility restriction by building) compared to Site 2. Even with the introduction of advance warning signage, there was no evidence of an increased number of vehicles coming to a full stop at the passive crossings (Ward and Wilde, 1995). Ignoring stop signs may lead to a crash, as human have been found unable to accurately judge the speed and distance of an oncoming train (Cohn and Nguyen, 2003; Cooper and Ragland, 2008).

Figure 7: Driver compliance to stop signs at Site 1 and Site 2



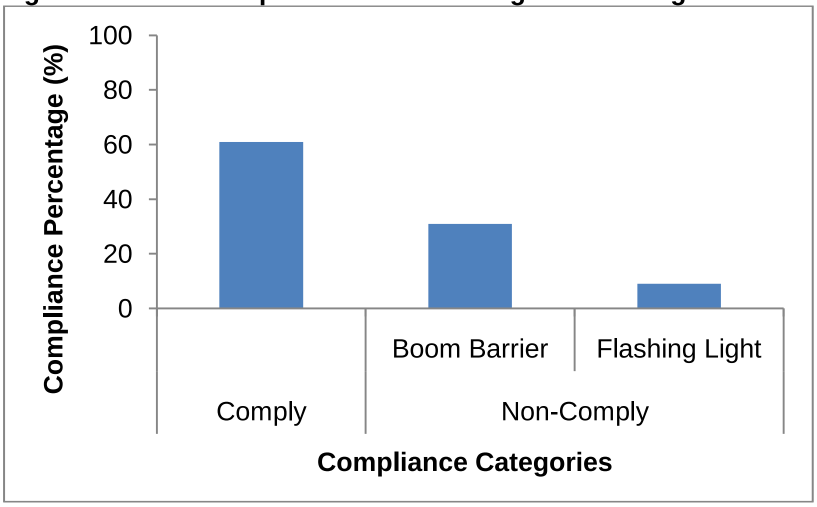
For Site 3 and 4 with active systems, the ‘driver compliance’ of each vehicle after the warning devices had been activated was determined and categorised according to their compliance behaviours into ‘Comply’ or ‘Non-Comply’. The numbers of vehicles recorded for Site 3 and 4 were 27 and 204 respectively. Data from Site 3 were collected during three weekends since the train only operated on weekends. Only one day was allocated for data collection at Site 4 where there is high traffic and train volume. For these two sites, often no speed reduction was observed resulting in non-compliant behaviour. Therefore, the non-compliance category of ‘Slow Down’ was not included. As shown in Figure 8, driver compliance at Site 3 and Site 4 were 70% and 77% respectively. The compliance rate at the boom barrier (77%) was slightly higher than at the flashing lights (70%). Similar results have been reported by various studies (Carlson and Fitzpatrick, 1999; Meeker et al., 1997; Shinar and Raz, 1982), although Abraham et al. (1998) found that drivers tended to commit more violations at the gated level crossings compared to those which had only flashing lights. These differences exist due to different localised site conditions, driver behaviour and environmental conditions. However, comparison between the aggressive behaviour of driving through crossings without reducing speed is shown in Figure 8. It shows that drivers tend to be more cautious at passive crossings (18% and 17% for Site 1 and 2 respectively) than at active ones (30% and 23% for Site 3 and Site 4 respectively). This scenario is likely to be observed due to drivers’ scanning for train information which is readily available at RLXs with active protection systems.

Figure 8: Driver compliance to stop signs, flashing lights and boom barrier at all sites



For the total of 157 vehicles that complied with the boom barrier at Site 4, their compliance behaviour after the warning devices had been deactivated was investigated. Once the train was detected leaving the crossing, the warning devices would be deactivated, first by lifting of the boom barrier to its vertical position taking approximately 10-12 seconds, followed by cessation of the flashing lights after 0-2 seconds. Thus, vehicles waiting at the crossing for the train to pass were investigated for their compliance with the warning devices and categorised into 'Comply' (moved after both boom barrier and flashing light had deactivated); 'Boom barrier' (moved before boom barrier fully lifted); or 'Flashing Light' (moved after boom barrier fully lifted, but before lights had stopped flashing). This scenario was investigated because it is important for 'second train collisions'. Figure 9 shows that 61% of the drivers complied, 31% of the drivers crossed before the boom barrier was fully lifted, while 9% of the drivers crossed before the flashing light had stopped. These violations indicate the possibility of intentional action is high rather than due to unintended error.

Figure 9: Driver compliance after warning devices began to deactivate at Site 4



Chi-squared tests (contingency table technique) were performed to compare the significance of compliance variation among the three different types of protection systems. First set of null hypotheses tested was:

H_o = there is no significant different in driver compliance between each individual site (Site 1 to 2; Site 2 to 3; Site 3 to 4; Site 1 to 3; Site 1 to 4; and Site 2 to 4).

The compliance variation between Site 1 and 2 (χ^2=0.1189, α=0.01), as well as between Site 3 and 4 (χ^2=0.5709, α=0.01) was not statistically significant. On other hand, the differences were statistically significant at the 99% confidence level between Site 1 and 3 (χ^2=6.6533, α=0.01); Site 2 and 3 (χ^2=8.2154, α=0.01); Site 1 and 4 (χ^2=29.8588, α=0.01); and Site 2 and 4 (χ^2=36.057, α=0.01). In other words, driver compliance at passive crossings (Site 1 and 2) are statistically different from active crossings (Site 3 and 4), while differences in driver compliance are not significant within both passive and active crossings.

The second null hypothesis tested was:

H_o = there is no relationship between driver compliance and the types of protection systems.

In order to test the hypothesis, results from Site 1 and 2 were averaged since the two sites represent the same type of protection system (stop sign) and their results were not significantly different. These averaged values (from Site 1 and 2) together with results from Site 3 and 4 were used in testing the relationship between driver compliance and types of protection systems. The Chi-square test indicates that driver compliance at RLXs is significantly (at 99% confidence level) influenced by the varying protection systems used (χ^2=33.1078, α=0.01).

4. Conclusions

Drivers approaching a RLX with a 'stop sign' are expected to obey the regulatory sign to stop the vehicle before the stop line, to look left and right for train traffic, regardless of the presence of a train. For active protection systems, either the 'flashing light' or 'half boom barrier with flashing light', drivers are required by the road rules to stop when the red light is activated by an approaching train. As expected, the road rules always give priority to the train at a crossing. However, the operational characteristics of these warning devices, for several reasons (i.e., passive/active, lack train information, lack attraction, etc.), 'produce' different driver responses. The field results presented here show that the compliance level at passive crossings is considerably lower than at active crossings. Such an observation was expected, as there is less attention by the driver to the lower level of passive warning devices compared to active systems which are more conspicuous and provide approaching train information. Comparison among the RLXs in terms of 'driver compliance', clearly indicates that drivers react differently to different protection systems, particularly the passive protection systems which are commonly used in rural areas in Australia. Based on the field results it is concluded that on average there is less driver compliance to passive crossings than to active ones. The Chi-square test indicates that driver compliance at RLXs is significantly (at 99% confidence level) influenced by the varying protection systems used. Some reasons for non-compliance behaviours have been reported in previous studies: driver familiarity of the particular level crossing (Abraham et al., 1998; Caird et al., 2002; Pickett and Grayson, 1996); traffic control devices used (Abraham et al., 1998; Jeng, 2005; Smith, 2004); drivers' intentional action or/and unintended error (Davey et al., 2007; Pickett and Grayson, 1996; Witte and Donohue, 2000). A future stage of the current study will concentrate on evaluating driver responses to both current and innovative protection systems at RLXs in a laboratory environment using a driving simulator.

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