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Investigation of Approaching Speed at Highway-Railway Grade Crossing: Songkhla Case Study

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Abstract

A highway-railway grade crossing (HRGC) is a special type of intersection where the right-of-way between the highway authorities and the state railway are shared. The traffic warning devices can be divided into two groups: passive (e.g. stop sign), and active (e.g. flashing lights and automatic barriers). This paper presents an investigation into the approaching speeds of private vehicles (i.e. motorcycles and cars) at four HRGC locations in Songkhla. At each location, the speed data was obtained by a speed gun, whereas the driving behavior involving safety issues was collected by video recording. The results show that the average approaching speed of the crossings was approximately 21 kph for the passive, and approximately 40 kph for the active traffic warning devices. Moreover, the response time to traffic warning devices was 5.3 and 7.5 seconds for active crossings; 9.82 and 9.11 seconds for passive crossings. Although most drivers reduced their speed, some still did not act according to the regulatory signs. This is a critical issue which authorities must take into account.

Keywords: Highway-Railway Grade Crossing, Approaching Speed, Road Safety, Accidents

1. INTRODUCTION

The World Health Organization (WHO, 2009) reported that the global status of road safety will be projected to be the fifth highest leading cause of global death by 2030, after heart disease, cerebrovascular disease, pulmonary disease and respiratory infections. Road accidents are a major public health problem in the world, with some 1.3 million people dying and 20-50 million injuries each year on the world's roads.

The highway-railway grade crossing (HRGC) can be viewed as a special type of intersection where the right-of-way between the highway authorities and the state railway are shared. The components of the highway can be classified into the roadway and the road users, whereas the components of the railroad can be classified into the train and the elements of the track (Ogden, 2007).

In countries that are members of the Association of Southeast Asian Nations (ASEAN), road traffic accidents have caused serious national casualties for a long time. According to the WHO Global status report on road safety, there were more than 670,976 accidents, 63,101 fatalities and 154,053 injuries in 2010 (ESCAP, 2010).

In Thailand, according to a report from the Ministry of Transport from year 2015, there were 69,674 accidents, 6,356 fatalities and 18,362 injuries due to road accidents (MOT, 2016). Some of the accidents during the years 2006 to 2010 occurred at Highway-Railway Grade Crossings (HRGC). According to data from the State Railway of Thailand (SRT), the situation regarding HRGC incidents in Thailand from 2006 to 2014 is quite stable; as demonstrated in figure 1. The figure also shows that 47 people are killed in 138 accidents per year. According to the database of the Emergency Medical Service (EMS), the volume of damage and severity is enormous. The severity index indicated that about 9.09, 15.38 and 14.29 per 100 people could be killed if a motorcycle, a passenger car, or a pickup was involved, respectively (NIEMS, 2008).

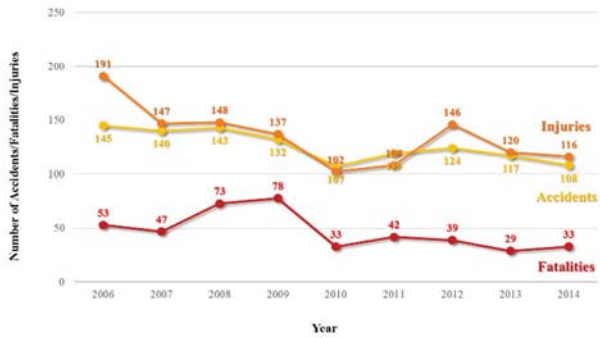

Figure 1 The situation of HRGC crashes in Thailand
Source: Raw data from the SRT report, 2015

In addition to the previous information, the Office of Transport and Traffic Planning and Policy (OTP) reported that there are 2,463 HRGCs in Thailand (as shown in Table 1), of which 1,923 are legal (approved by the SRT) and 540 are illegal (OTP, 2009). Table 1 also shows that 62% of the total crossings are protected by passive control devices, whereas 27.4% are protected by active control devices. For the passive crossings, there are only static signs and markings regardless of the train approaching a HRGC. The drivers approaching a HRGC with a "STOP" sign, often don't obey the sign and do not stop their vehicle at the stop line to look left and right for an approaching train. The active control devices used in Thailand are comprised of three types of grade crossings: flashing lights, automatic half width lifting barriers and manned full lifting gate barriers; all of which require drivers and riders to slow down and stop when there are flashing light signals, and activated audible device

Table 1 Rail routes and types of crossings in Thailand.

Route	Active control			Overpass/ Underpass	Passive control		Total
	Type I	**Type II**	**Private**		**Signs**	**Illegal**	
North	92	62	2	44	133	31	264
Northeast	101	51	0	33	344	30	559
East	80	60	0	110	119	35	404
South	137	86	3	74	392	444	1,136
Total	410	259	5	261	988	540	2,463
Category	674 locations (27.4%)			261 locations (10.6%)	1,528 locations (62.0%)		2,463 locations (100.0%)

Note: Type I includes fully electrical and half width lifting barriers.
Type II includes automatic half width lifting barriers and open crossings with automatic flashing lights.
Source: OTP, 2009

1.1 Objectives

The objectives of this paper are as follows:

- to investigate the approaching speed at different types of HRGC based on their control devices;
- to compare the behavior of private vehicles (motorcycles and cars) before they approach the HRGC; and
- to recommend counter- measures for the improvement of HRGC safety to the SRT and highway authorities.

1.2 Literature Reviews

An analysis of the literature reveals several contributing factors to HRGC accidents. According to a HRGC accident report by Los Angeles County Metropolitan Transportation Authorities, there are sixteen contributing factors. One of the key factors is human behavior (LAC/MTA, 1999). According to an analysis of the factors contributing to HRGC accidents in Canada, there are six contributing elements: unsafe acts, individual difference, train visibility, passive signs and markings, active warning systems, and physical constraints (Caird et al, 2002).

According to the Audit of the HRGC Safety Program in the United States, accidents at HRGC over the past 10 years from 1994- 2003; continue to be a significant concern to the railroad industry, and a large proportion of the accidents have resulted from driver error (Office of the Inspector General, 2004). This is consistent with the study of HRGC Safety by Rizavi, who found that 71% of the crashes resulted from "Driver Error" (Rizavi and Veeregowda, 2005). To better understand the issues of driver behavior at the HRGC, Carroll indicated that evaluating the effectiveness of motorist signs, treatment, and researching driver behavior, should be classified as top priorities (Carroll et al., 2010).

In addition to the above, Australian accident statistics reveal that, amongst the major crashes at HRGC, 13% of cases were related to weather and road conditions, 46% were unintended motor vehicle driver error, 9% were alcohol or drug use by motor vehicle driver, 7% were related to excessive speed of the vehicle driver, 3% were caused by a fatigued motor vehicle driver and the remaining 3% were other risks taken by the motor vehicle driver (Australian Transport Safety Bureau, 2002). It may be inferred from the information in the above, that human factors are a major cause of the HRGC accidents.

Anandarao and Martland (1998) applied the multi-factorial approach to investigate the cause of HRGC accidents. The results showed that the major cause of the HRGC accidents was the driver's "Ignorance of Warning". Indications are that they did not notice the warnings in time to stop. It is also conceivable that some drivers chose to ignore the warning and voluntarily entered the crossing. Khattak (2008) compared driver behavior at HRGC between Waverly and Fremont in the United States. The results indicate that drivers respond differently to the same type of traffic control devices at different locations.

In Thailand, a few studies related to human behavior and speeding at HRCG have been conducted. For example, Phatthanawat et al. (2012) who studied HRGC accidents, found that a combination of factors such as: the physical characteristics of the railroad crossing combined with traffic signs, the lack of visibility from the driver, damaged traffic signs, electric lights hindering the ability to see clearly, were some of the major causes of accidents.

2. METHODOLOGY

This section presents the methodology of the study. The details are as follows.

2.1 Study Locations

The locations were selected from existing HRGC in Songkhla province. A preliminary survey was conducted by using the Google Earth to search and establish HRGC locations along the SRT Southern line. It was found that there were 42 locations in Songkhla. For the field survey, there were only 25 usable HRGCs, these consist of 8 active control crossings and 17 passive control crossings. As for the study locations, 4 locations were selected to represent 2 passive crossings and 2 active crossings, which are selected based on the following criteria: accident history and geometric features, different types of HRGC safety devices, traffic volume and train frequency. There are altogether four types of HRGC: stop signs, flashing lights, barriers and illegal crossings. It is necessary to compare the driver behavior in each of the HRGC types.

The data regarding the approaching speed and the compliance behavior of the driver was collected from crossings which have 2,000 or more vehicles per day. The location which was selected first was SKA1, it is an illegal crossing without a stop sign; shown in Figure 2a). The rail track crosses a rural road at a 45° angle. The roadway is a two-lane two-way road, class two with flat crossing slope. The second location is SKA2, which is controlled by a stop sign (Figure 2b). The track crosses a rural road, with one lane, class three in each traffic direction, at a 90° angle. The crossing is located approximately 450 meters from Na Mom train station. The third crossing is SKA3, it is controlled by automatic solar flashing lights; this is demonstrated in Figure 2c). The flat slope crossing crosses a rural road class three, a two lane with rumble strips at a 90° angle. The fourth crossing is SKA4, this is controlled by flashing red lights, a warning bell and half width lifting barriers, this is shown in Figure 2d). The warning system is manually controlled. The train track crosses a four-lane two-way at a 45° angle. It is located approximately 150 m near Sa Dao train station. The characteristics of the locations that are studied involve the following factors: crossing types, lanes/track, train frequency and traffic volume; as shown in Table2.

a) Illegal crossing

b) Stop signs

c) Flashing lights

d) Half lifting barriers

Figure 2 HRGC Traffic warning devices

Table 2 Characteristics of the study locations.

Site	Crossing type	Lanes/ Track	Crossing angle	Train volume (trains/day)[a]	Traffic volume (vehicles/day)[b]
SKA1	Illegal crossing	2/1	45°	10	2,112
SKA2	Stop signs	2/1	90°	10	2,784
SKA3	Flashing lights	2/1	90°	10	1,920
SKA4	Half barriers	4/1	45°	10	28,128

Note: [a] Train Volume was retrieved via field surveys.
[b] Traffic Volume was based on field surveys.

2.2 Driving Behavior Observation

The driving behavior data was recorded by a portable video camera. The location for the video recording must be selected in such a way that does not attract the drivers' attention, as it could affect their behavior. The camera was placed near the HRGC to capture the approaching vehicles from the stop line; as shown in Figure 3. The data was recorded in daylight (08:00 AM – 17:00 PM). Four vehicle types (motorbikes, cars, trucks and buses) were considered in the study.

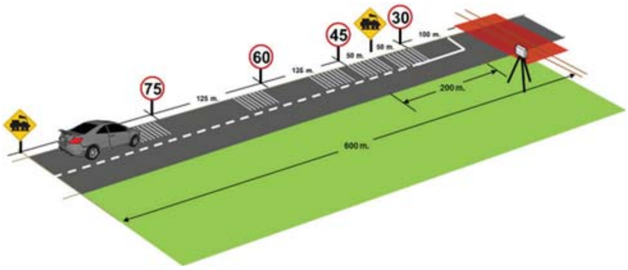

Figure 3 Setting up the station for field data collection

2.3 Speed Measurement

The speed measurement was recorded by using a speed radar gun. The approaching speed profile was recorded 200 m. before the stop line and 5 m. before the HRGC. A comparison between the regulatory speed limit and the actual approaching speed was made in order to determine the maximum speed, median speed and minimum speed.

3. RESULTS

The data retrieved from the video recordings of human behavior at 25 HRGC crossings are shown in Figure 4. A comparison of the compliance behavior of the driver approaching the HRGC was made based on four types of traffic control: illegal, stop signs, flashing lights and half lifting barriers. The compliance percentage for passive crossings (0.75%) was lower than those that involved active crossings, flashing lights (0.62%) and half barriers (3.49%).

3.1 Results of driving behavior study

The compliance percentage with the half lifting barrier (3.49%) was higher than other crossings, the flashing light (0.62%), the stop sign (0.25%) and the illegal crossing (0.50%). As for the non-compliance percentage, there were two instances where the vehicle movement activated the vehicle's brake lights.

The term 'stop' describes the action wherein the driver stops in front of the stop line. The term 'Slow-Down' refers to all cases where the road user reduces their approach speed, and 'Drive-Through' refers to a situation where the driver tries to pass the crossing at a speed higher than when they approached the HRGC.

The results show that the drivers are inclined to not obey the regulatory signs, and do not stop the vehicle at the HRGC. Despite not obeying the signs, most did however, slow down before driving through the crossing. Different results often occurred at passive and illegal crossings. In Figure 4, it was discovered that the drivers were more inclined to show non-compliance, most slowed down (54.74%) and drove through (42.41%) at the half lifting barrier. As for the flashing lights, drivers slowed down (57.11%) and drove through (28.67%). At the passive crossings, they slowed down at the stop sign (68.26%) and drove through (29.28%). Finally, for non-compliance behavior, drivers slowed down at illegal crossings (56.84%) and drove through (39.92%). As for the relationship between compliance behavior and HRGC types, the Chi-squared tests indicate that driver compliance at passive crossings was statically different at a rate of 95% (α=0.05) confidence level at active crossings (between SKA4 and SKA1, x^2= 0.023; between SKA4 and SKA3, x^2= 0.001), similarly the compliance rate at active crossings (between SKA4 and SKA2, x^2=0.023) and the passive crossings at illegal crossings (between SKA3 and SKA4, x^2=0.027). While the difference in driver compliance was significant between active crossings and illegal crossings (between SKA1 and SKA3, x^2=0.263).

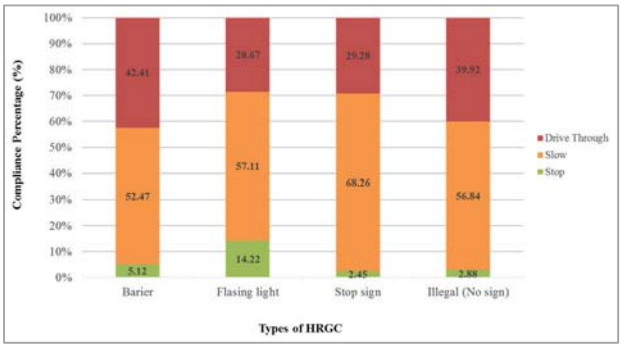

Figure 4 Complying behavior

3.2 The results of the speed study

As shown in Figure 5 – 8, a profile of the approaching speed for each type of HRGC in this research shows the 'before' and 'after' of each marked spot. The results indicate that the drivers tend to drive at a speed below the speed limit (30 km/h) while on the approach zone, wherein the vehicle approaches the crossing.

3.2.1 The speed profile at unregistered (illegal) crossings

The speed profile on illegal crossings is shown in Figure 5. The graph demonstrates the 'before' and 'after' speed for four types of vehicles: motorcycles (MC), passenger cars (PC), trucks (TU) and busses (BU), these are restricted to Barrier cases. The speed profiles for the 'before' of vehicles approaching the HRGC were higher than 'after'.

The 'before' samples of the approaching speed were collected at a distance of 200 m. before the crossing. The trends of the 'before' speed indicate that most drivers use high speeds at the illegal crossings, this is shown in Figure 5. The median speeds are 23 km/h for MC, 25 km/h for PC and 29 km/h for TU. The maximum speed of vehicles at an illegal crossings was more than the speed limit of 30 km/h. The whiskers show that they used the maximum speed of 44 km/h for MC, 40 km/h for PC and 35km/h for TU.

As for the 'after' approaching speed, the box plots indicate that overall the drivers reduced their speed at illegal crossings. The median speeds are 20 km/h for MC, 20 km/h for PC and 12.5 km/h for TU. The maximum speed of vehicles on illegal crossings was more than the 30 km/h speed limit; and the whiskers show that they used the maximum speed 36 km/h for MC, 31 km/h for PC and 30 km/h for TU.

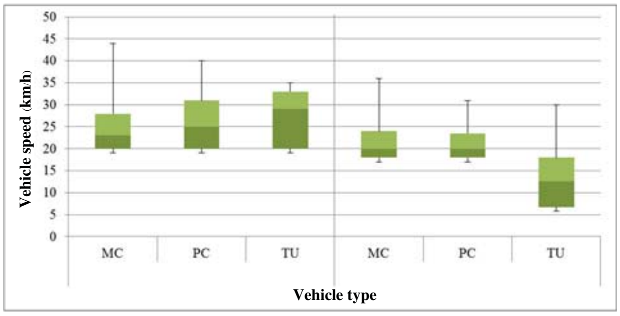

Figure 5 The speed profile at unregistered crossings

3.2.2 The speed profile at a stop sign crossing

The results for the stop sign demonstrate high speeds from motorcycles, where the maximum speed is up to 35 km/h for MC, 32 km/h for PC and 27 km/h for TU; these are based on 'before' approaching speed conditions. In the 'before' approaching speed, the median speeds are 25.5 km/h for MC, 21 km/h for PC and 18.5 km/h for TU; whereas the speeds are later reduced to 23 km/h, 18 km/h and 18 km/h in the 'after'. The 'after' speed conditions indicate a low speed length, most drivers try to reduce their vehicle speed, however the maximum speed of the 'after' conditions were more than the speed limit permitted by law (30 km/h) for motorcycles; there was also a maximum speed of 31 km/h for MC, 27 km/h for PC and 21 km/h for TU, as shown in Figure 6.

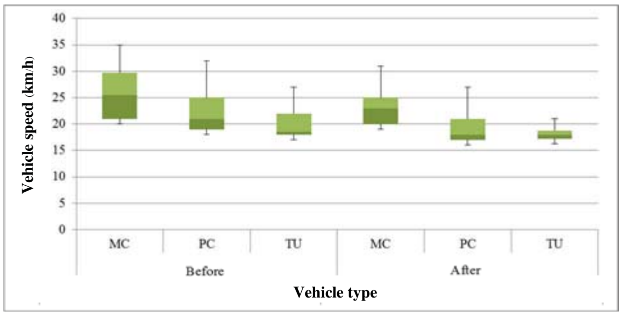

Figure 6 The speed profile at stop signs

3.2.3 Speed profile at flashing light crossings

The flashing lights resulted in high median speeds up to 25.5 km/h for MC, 28 km/h for PC and 32 km/h for TU, however they were reduced to 22.5 km/h, 22 km/h and 20 km/h in the 'after' shown in Figure 7. The maximum speeds were also high at the crossings, the respective speeds were 44 km/h for MC, 35 km/h for PC and 36 km/h for TU. This is followed by the following data in the 'after'; 36 km/h for MC, 28 km/h for PC and 23 km/h for TU.

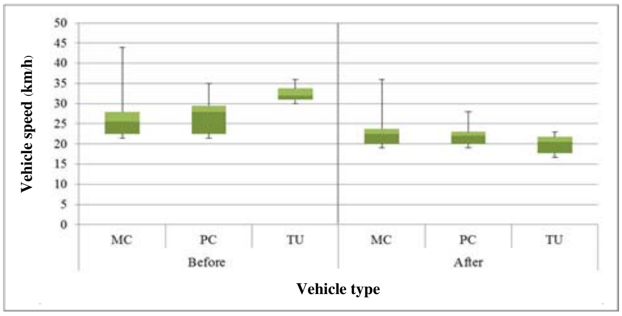

Figure 7 The speed profile at flashing lights

3.2.4 Speed profile at half lifting barriers crossing

The barriers' medians revealed the following results: 36 km/h for MC, 46 km/h for PC, 40 km/h for TU and 33 km/h for BU, these are reduced to 27 km/h, 42 km/h and 33.5 km/h and 35 km/h respectively. This is indicated in Figure 8.

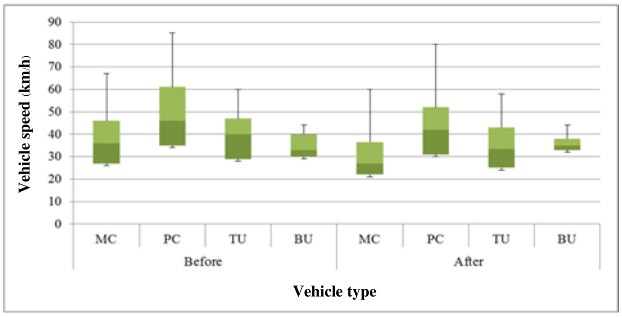

Figure 8 The speed profile at barriers

3.3 The speed of Vehicles approaching the STOP line

The results for the vehicle approaching speed of each of the HRGC types are shown in Figure 9. Overall, the vehicle speed decreases as it approaches the HRGC. Similar results have been attained by Moon and Coleman in 1999, their results indicate that when a vehicle draws near a HRGC, there is a tendency for vehicle speeds to be reduced when the driver the approaches the lane and moves towards the crossing zone. (Moon and Coleman, 1999).

In Figure 9, the speed profile of the red line (illegal), shows that the speed of the orange line (the stop sign) is closer than the violet line (flashing lights) and that the last line is the green line (barriers). The data that was gathered for 'the time required to stop' was acquired by using a stopwatch to time the distance from the stop line. The drivers chose to use lower speeds when they wanted to cross HRGCs that involved active crossings, this may be because the geometric elements at passive crossings and illegal crossings were in poorer condition.

As for the flashing lights, the stimulus did not increase the drivers' response regarding the presence of a HRGC. So they used high speeds at these crossings. At the half lifting barriers, most drivers also used high speeds. The drivers understand the conditions involved with how the barrier operates and are confident enough to use high speeds to approach the crossings. There are many factors that influence a driver's behavior when they want to cross a HRGC. Roadside information regarding the difference of HRGC types has little influence. These assumptions are supported by Shope, a study done in the year 2006; which gave six categories of driving behavior, driving ability, driving experience, individual factors, demographics, the perceived environment and driving experience. (Shope, 2006)

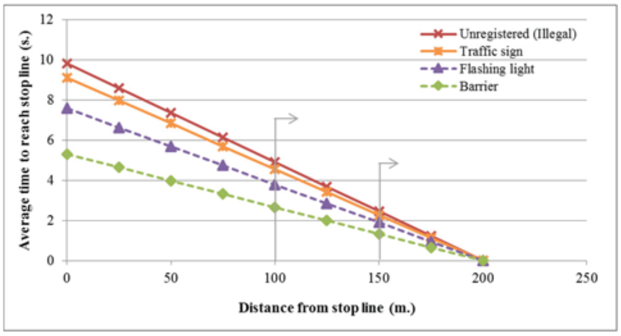

Figure 9 The speed of a vehicle approaching a stop line

The average time required to stop over a distance of 200 meters differs slightly, this depends on the passive type; it is approximately 9.82 seconds for illegal crossings and 9.11 seconds for traffic signs. In cases of active control devices, the crossing time is much faster than the passive crossings. The stopping time for the same distance of 200 meters for flashing lights is about 7.5 seconds, and it is 5.3 seconds for the barrier.

4. CONCLUSION AND RECOMMENDATIONS

The HRGC situation in Songkhla province has been described based on 25 locations comprising different traffic control devices: 6 barriers, 2 flashing lights, 4 stop signs and 13 illegal crossings were investigated. Four selected locations consisted of 4 types of traffic control devices, these locations were used to study human behavior at HRGC. The results show that human behavior is a major contributing factor of HRGC accidents; in most cases the drivers did not obey the regulatory signs at these locations.

The compliance behavior in terms of a comparison between 'stop', 'slow-down' and 'drive-through' in this paper has helped to provide an increased understanding of human behavior at different types of HRGC in Thailand. The Chi-squared tests indicate that driver compliance at passive crossings was statically different at a rate of 95% (α= 0.05) confidence level at active crossings (between SKA4 and SKA1, x^2=0.023; between SKA8 and SKA2, x^2=0.001), similarly the compliance rate at active crossings (between SKA4 and SKA1, x^2= 0.023) and the passive crossings at the illegal crossings (between SKA3 and SKA4, x^2=0.027). While the difference in driver compliance was significant between active crossings and illegal crossings (between SKA1 and SKA3, x^2=0.263). These results demonstrate that most drivers reduce their speed, and slow down when they approach a HRGC. In examples involving illegal crossings, drivers reduced their speed from an average of 40 km/h to 30 km/h for all vehicle types.

The time required to stop in time for the four selected locations shows that drivers go at a higher speed when approaching active crossing control devices such as flashing lights and barriers. At active crossings, the drivers took 5.3 and 7.5 seconds to cover a 200 meter distance; while at the passive crossings, they took 9.82 and 9.11 seconds to travel the same distance. These situations raise the question as to whether or not the speed limit is enough for safety at HRGC crossings. In cases where barriers are involved, drivers often ignore the guidance and information that tells them to reduce their speed. They are confident and rely on SRT officers to assist in closing off the traffic before they approach a HRGC.

The authors would like to propose a few recommendations to the responsible organizations such as the State Railway of Thailand (SRT), the Department of Highways (DOH) and the Department of Rural Roads (DRR). This is done in hopes raising awareness on the importance of such issues. This research paper may be utilized to improve the HRGC safety situation in Thailand, and as a result, assist in the reduction of unnecessary road deaths that are outcomes of avoidable HRGC hazards. The authors propose that the governmental organizations and research scholars implement the following countermeasures: (1) Install low – cost warning systems at HRGCs to reduce approaching vehicle speeds at HRGC, (2) Develop a standard design for HRGC construction in Thailand, and (3) Increase road user education on traffic laws, blind spot locations, the causes of HRGC crashes, and how to reduce them through better and safer driving behavior.

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