A Study of Human Behavior at Highway-Railway Grade Crossings (HRGC) in Thailand

Donyarit SETTASUWACHA [a], Paramet LUATHEP [b], Pichai TANEERANANON [c]

[a, b, c] *Department of Civil Engineering, Faculty of Engineering,*
Prince of Songkla University, 90112, Songkhla, Thailand
[a] *E-mail: choke_ce9@hotmail.com*
[b] *E-mail: paramet007@hotmail.com*
[c] *E-mail: breathislife@yahoo.com*

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 are a stop sign (passive), flashing lights and automatic barriers (active). The human behavior at HRGC is the major contributing factor to the accident. This paper presents the evaluation of existing HRGC in relation to human behavior with the aim of improving safety at HRGC. The data were collected using two approaches at selected sites namely: video recordings and speeding measurement with a radar gun. The paper also compares the human response to different types of traffic warning devices presents average human response time at HRGC.

Keywords: Highway Railway Grade Crossing, Human Behavior, Safety, Accident

1. INTRODUCTION

The World Health Organization (WHO, 2009) reported global status on road safety have been 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 were a major public health problem in the world with some 1.3 million people died each year on the world's roads with 20 - 50 million injuries.

The highway-railway grade crossing (HRGC) can be viewed as a special type of intersection with two categories components of grade crossing location which shared the right-of-way between the highway authorities and the state railway. The highway component can be classified into the roadway and road users. The railroad component is classified into train and track elements (FHWA, 2007).

For the Association of Southeast Asian Nations (ASEAN) countries, road traffic accidents have created serious national casualties for a long time. In addition to the WHO Global status report on road safety, there have been reports on road accidents situation of 10 ASEAN countries where more than 670,976 accidents, 63,101 fatalities and 154,053 injuries have occurred in 2010 (ESCAP, 2010).

In Thailand 2010, according to the police report, there were 83,793 accidents, 7,697 fatalities and 18,452 injuries due to road accidents (MOT, 2010). One of the serious types of accidents during the years 2007 to 2009 was Highway Railway Grade Crossing (HRGC) in which some 70 people were killed in some 140 HRGC accidents per year (SRT, 2009).

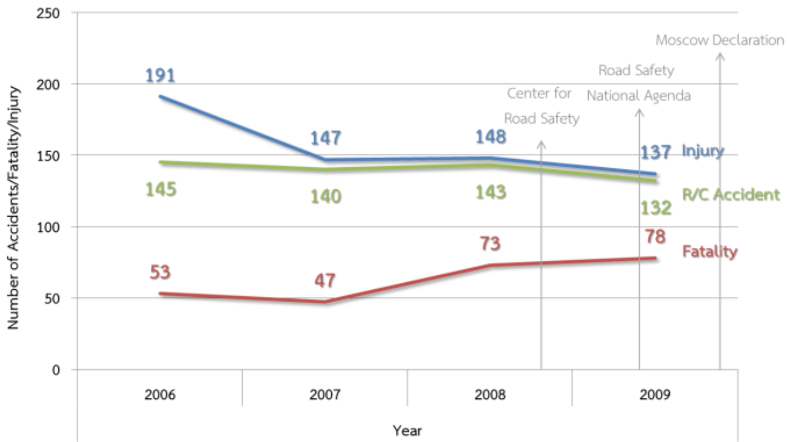

Figure 1. HRGC crashes situation in Thailand
(Source: Raw data from SRT reported, 2009)

From the Emergency Medical Institute of Thailand database, the magnitude of damages and severities can be analyzed and presented by the type of vehicles involved. The severity index indicated that about 9.09, 15.38 and 14.29 people were killed if motorcycles, cars, and pickups were involved respectively (EMIT, 2008).

The Office of Transport and Traffic Planning and Policy (OTP, 2009) reported in a study of (railway network 47 provinces of Thailand) plan for the safety measures at HRGC, There are approximately 2,463 railway crossings in Thailand, of these 1,923 are approved by SRT and about 540 are illegal as shown in Table 1.

Table 1. Rail route and crossing types in Thailand.

Route	Type I	Type II	Private	Overpass/ Underpass	Signs	Unregistered	Total
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 (Places)	410	259	5	261	988	540	2,463
Category	674 Locations (27.37%)			261 Locations (10.60%)	1,528 Locations (62.03%)		2,463 Locations (100%)

Note: Type I is Electrical full and half width lifting barriers.
Type II is Automatic half width lifting barriers and Open crossing with automatic flashing lights only.

They are protected by passive control devices 62% and by active control devices or automated system 27.4%. For the passive crossings, there are only static sign and marking regardless of approaching train to HRGC. The drivers approaching a HRGC with "STOP" sign do not often obey the sign and stop the vehicle at the stop line and look to the left and right for the train appearance. The active control devices used in Thailand comprise three types, flashing light, half width lifting barriers and full gate barriers which require drivers to slow down and stop when the siren and the horn are activated by an approaching train.

Because of the difference in the HRGC which vary with the geometry, average diary traffic (ADT) and train frequency; driver behaviors at HRGC are a major concern as they contribute to the safety at HRGC.

1.1 Purpose and Objectives

The objectives of this study are identifying the major contributing factors of HRGC accidents and highlight the human behavior at the different control devices in Thailand. Two specific objectives of this paper are as follows:

- To compare the compliance driver behaviors and the typical speed profiles of the different HRGC locations; and
- To propose the recommendation to the SRT and highway authorities for HRGC safety enhancement.

1.2 Literature reviews

For the causes of HRGC accidents and the crossing safety literatures, a number of contributing factors in HRGC accidents have been identified. According to HRGC accident report of LA, there were sixteen contributing factors in the HRGC accidents (LAC/MTA, 1999). One of the most important factors in the HRGC accidents is human factor. From the factors analysis of HRGC accidents in Canada, there were six contributors of HRGC accidents: unsafe acts, individual different, train visibility, passive sign and marking, active warning system and physical constraints (A Human Factors Analysis of Highway-Railway Grade Crossing Accidents in Canada, 2002).

According to the Audit of the Highway-Rail Grade Crossing Safety Program over the 10 years period from 1994-2003, accidents at HRGC were continue to be a significant concern to the railroad industry. A large proportion of these accidents resulted from driver errors (Office of the Inspector General, 2004). To better understand driver behavior issues at grade crossings, the US DOT Federal Railroad Administration's Third Research conducted a workshop on Highway-Rail Grade Crossing and Trespass Prevention in 2009; evaluating effectiveness of motorist and pedestrian signs and treatment, researching driver behavior, were classified as top priorities (FRA, 2010).

From the studies of the driver reaction at HRGC, it had been mentioned that 71% of the driver behavior and the human element in the HRGC crashes resulted from "Driver Error" (Rizavi, A. and B.K. Veeregowda, 2005). The Australian accident statistics reported that amongst the major crash at HRGC, contributing factors were related to weather or road conditions (13%), unintended motor vehicle driver error (46%), alcohol or drug use by motor vehicle driver (9%), excessive speed (of motor vehicle driver) (7%), fatigue (of motor vehicle driver) (3%) and other risk taking (of motor vehicle driver) (3%) (Australian Transport Safety Bureau, 2002). From these results, it is clear that human factors are the major cause of the HRGC accidents (total 68%).

In Japan, the HRGC accidents are looked at from comprehensive and multi-factorial approach (Anandarao and Martland, 1998). Based on their result, it was found that the major cause of the HRGC accidents was the driver's "Ignorance of Warning." Indications are that they chose to ignore the warning and voluntarily enter the crossing. In 2008, Khattak compared driver behavior at the HRGC in two cities, the resulted showed that drivers responded differently to the same type of traffic control devices at different locations

(Khattak, 2008).

2. METHODOLOGY

The research uses two approaches, the video recordings and the speed measurement at selected HRGC locations.

2.1 Field video recording

The data were collected using a portable video camera to make traffic observation with the tripod. The must be must be carefully selected so that the camera would not attract the drivers attention, which may have affected their behavior. The camera was located near the HRGC to capture the approaching vehicles on roadway from the stop line as shown in Figure 2.The data were recorded in daylight conditions and included all vehicle types in four categories such as motor cycles, passenger cars, trucks and buses.

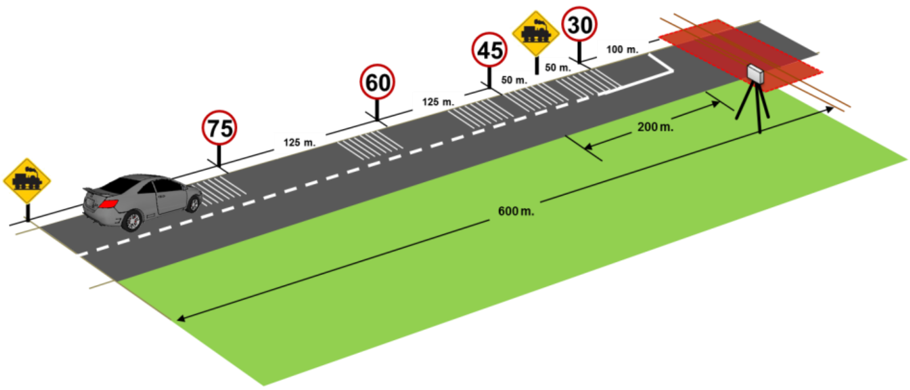

Figure 2. Setting up station for field data collection

2.2 Speed measurement

From the field observations, the speed measurement was recorded by using the speed gun. The approaching speed profile was recorded for the vehicles approaching from 200 m, at the stop line and stopped at stop line or 5 m before the HRGC. Comparison of the regulatory speed limits and actual approaching speed, were made to establish the maximum speed, median speed and minimum speed at the HRGC in each vehicle.

2.3 Study locations

The locations were selected from the existing HRGC in Songkhla province in the Southern Region of Thailand. Preliminary survey were conducted by using the Google Earth to search for the HRGC locations on the SRT Southern line and 42 locations were in Songkhla province. For the field survey, there were 25 available locations for field data found collection. In the present study, there are 8 active control crossings locations and 17 locations are passive control including illegal crossing.

Based on the conditions of the locations selected, the posted speed limit at the study locations were within 30 - 45 km/h. The different types of HRGC depend on geometric features and traffic volumes. In Thailand, there are four types of HRGC: stop signs, flashing lights, barriers and illegal crossing. It is necessary to compare the driving behaviors in each HRGC types in order to highlight compliance behaviors of the driver. The typical speed profile was collected from the crossings which have 2,000 or more vehicles per day. The first selected location, SKA28, is an illegal crossing without stop sign as shown in Figure 3 (a). The rail track crosses a rural road at 90° angle. The roadway is a two lane two way road, class two with flat crossing slop. The second is SKA42, is equipped with stop sign as shown in Figure 3 (b). The track crosses a rural road, with one lane, class three in each traffic direction, at 90° angle. The crossing is located approximately 450 m. near Na Mom train station. The third crossing, SKA11, is equipped with solar automatic flashing lights as shown in Figure 3 (c). The flat slope crossing crosses a rural road class three, two lane with rumble strips at 90° angle. The fourth crossing, SKA08, is equipped with flashing red lights, warning bell and half width lifting barriers as shown in Figure 3 (d). The warning system was manual controlled. The train track crosses a four lane two ways on Thailand national highway at 45° angle. It was located approximately 150 m near Sa Dao train station. The train track is part of Sa Dao and Padang Besar border, the ASEAN railway network of Thailand and Malaysia. Summary of HRGC characteristics, train frequency and traffic volume is as shown in Table2.

a b
c d

Figure 3. (a) Illegal; (b) Stop signs; (c) Flashing lights; and (d) Half lifting barriers

Table 2. The characteristics of speed study sites.

Site	Crossing Types	Rail Track	Roadway Lanes	Crossing Angle	Crossing Slope	Train Volume (trains/day)[a]	Traffic Volume (vehicle/day)[b]
SKA28	Illegal	1	2	45°	Flat	70	2,112
SKA42	Stop signs	1	2	90°	Flat	56	2,784
SKA11	Flashing lights	1	2	90°	Flat	70	1,920
SKA08	Half barriers	1	4	45°	Flat	70	28,128

Note: [a]Train Volume was counted from field surveys.
[b]Traffic Volumes were counted from field surveys.

3. RESULTS

The video recording of human behaviors on 25 locations were shown in Figure 4. The comparison of compliance behaviors of driver approaching the HRGC was made for the four types of traffic control; illegal, stop signs, flashing lights and half lifting barriers. The compliance percentage for passive crossing (0.75%) was lower than that of for the active crossings, flashing lights (0.62%) and half barriers (3.49%). For the relationship between compliance behavior and HRGC types, the Chi-squared tests indicated that driver compliance at passive crossing were statically different at 95% (α=0.05) confidence level from active crossing (between SKA42 and SKA08, x^2=0.023; between SKA42 and SKA11, x^2=0.001), similar the compliance within active crossing (between SKA42 and SKA08, x^2=0.023) and the passive crossing at the illegal crossing (between SKA28 and SKA42, x^2=0.027). While the difference in driver compliance were significant between active crossing and illegal crossing (between SKA08 and SKA28, x^2=0.263).

3.1 Compliance studies

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

The ‘stop’ describes the action that the drivers had stopped in front of the stop line. The ‘Slow-Down’ refers to the cases of the road users who had been reducing approach speed and ‘Drive-Through’ refers to cases of drivers who try to pass the crossing at higher speed when they approach the HRGC.

The resulted shows that the drivers tended to not obey the regulatory sign to stop the vehicle at the HRGC. They did not obey the sign but most did slow down and drive through at the crossing. The different results mostly occurred at passive and illegal crossings. In Figure 4, it was found that the drivers tended to non-compliance, most slow down (35.74%) and drive through (28.89%) at half lifting barrier. For the flashing light, slow down (2.49%) and drive through (1.25%). While for the passive crossing, they slow down at stop sign (6.97%) and drive through (2.99%). Finally, for non-compliance behaviors, drivers slow down with illegal crossing (9.84%) and drive through (6.97%).

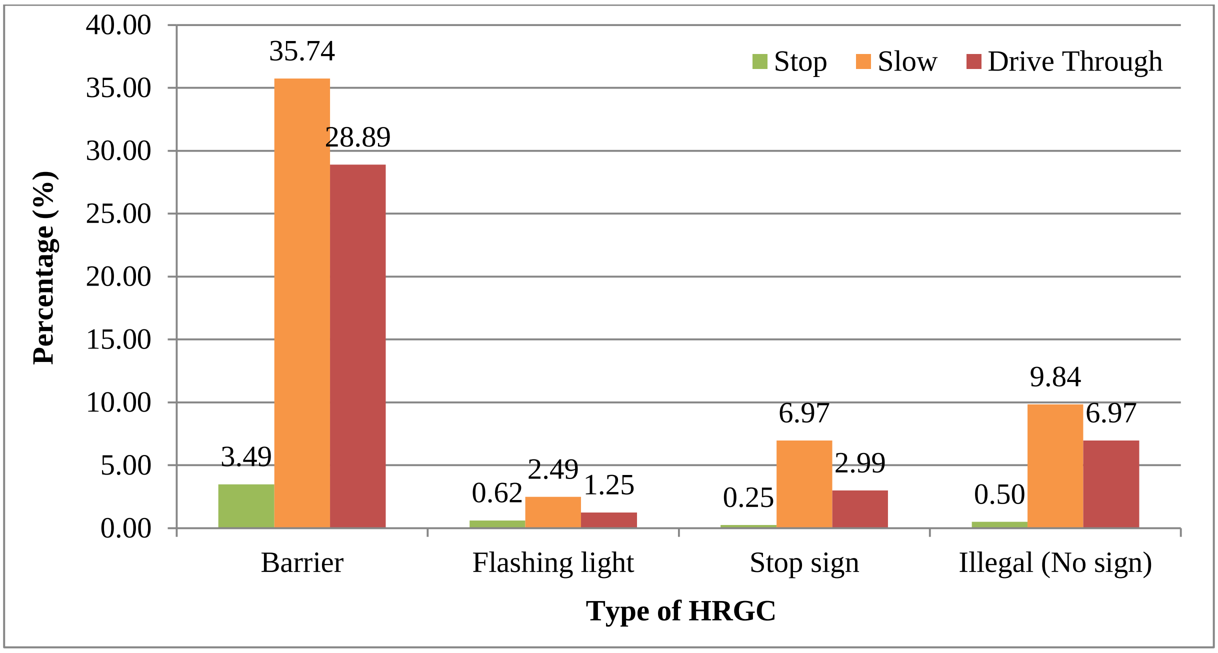

Figure 4. The compliance behaviors

3.2 Approaching speed studies

The approaching speed profile for each types of HRGC in this research were shown for the before and after the marked spot. The results indicate that the drivers tend to use speed below the speed limit (30 km/h) on the approach zone when the vehicle approach the crossing.

3.2.1 Speed profile at unregistered (illegal) crossing

The speeds profiles of illegal crossing are shown in Figure 5. The graphs show the before and after speed of three types of vehicle, motorcycle (MC), passenger car (PC) and truck (TU). The speed profiles before approaching on the HRGC was higher than after.

The before approaching speed were collected at distance 200 m. before the crossing. The trend of the before speed indicates that most drivers use high speed at the illegal crossing as 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 illegal crossing is more than the speed limit at 30 km/h, the whiskers show they used the maximum speed of 44 km/h for MC, 40 km/h for PC and 35km/h for TU.

For after approaching speed, the box plots indicate overall the drivers reduced the speed at the illegal crossing. 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 vehicle with illegal crossing is more than the speed limit at 30 km/h and the whiskers show there used the maximum speed 36 km/h for MC, 31 km/h for PC and 30 km/h for TU.

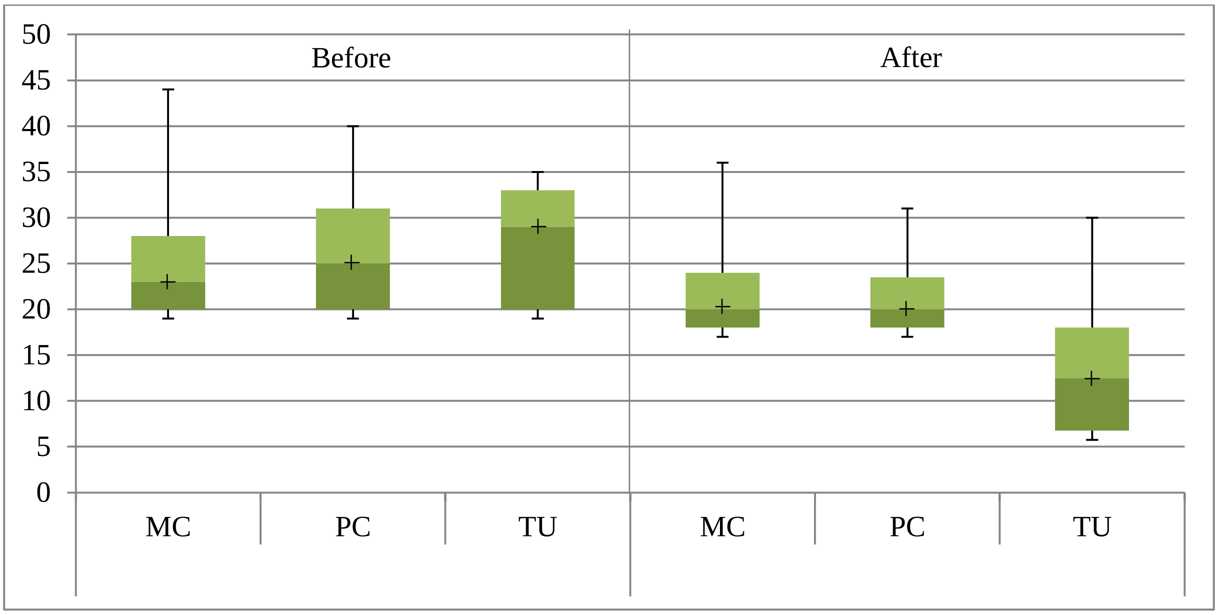

Figure 5. The speed profile at unregistered crossing

3.2.2 Speed profile at stop sign crossing

The results of stop sign are high speed from motorcycles, there are show maximum speeds are 35 km/h for MC, 32 km/h for PC and 27 km/h for TU in before approaching speed conditions.

The median speeds, there are indicating 25.5 km/h for MC, 21 km/h for PC and 18.5 km/h for TU in before approaching speed and the speeds are reducing to 23 km/h, 18 km/h and 18 km/h in after. For the after speed condition, there are show in low speed length, the mostly drivers are trying to reduce the vehicle speed but the maximum speed at the after condition were more than the laws speed limit (30 km/h) for motorcycle, there indicated maximum speed 31 km/h for MC, 27 km/h for PC and 21 km/h for TU as shown in Figure 6.

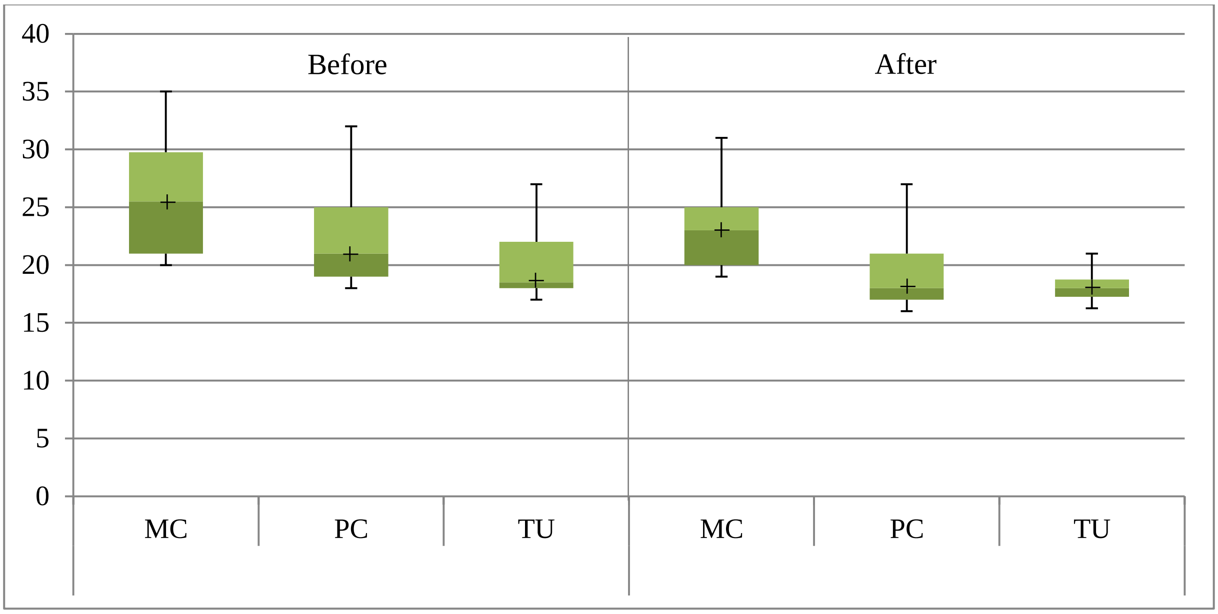

Figure 6. The speed profile at stop signs

3.2.3 Speed profile at flashing lights crossing

The flashing lights are result the high median speeds, there show 25.5 km/h for MC, 28 km/h for PC and 32 km/h for TU and reduce to 22.5 km/h, 22 km/h and 20 km/h in the after as shown in Figure 7. The maximum speeds also high with the crossing, there are 44 km/h for MC, 35 km/h for PC and 36 km/h for TU and indicated 36 km/h for MC, 28 km/h for PC and 23 km/h for TU in the after.

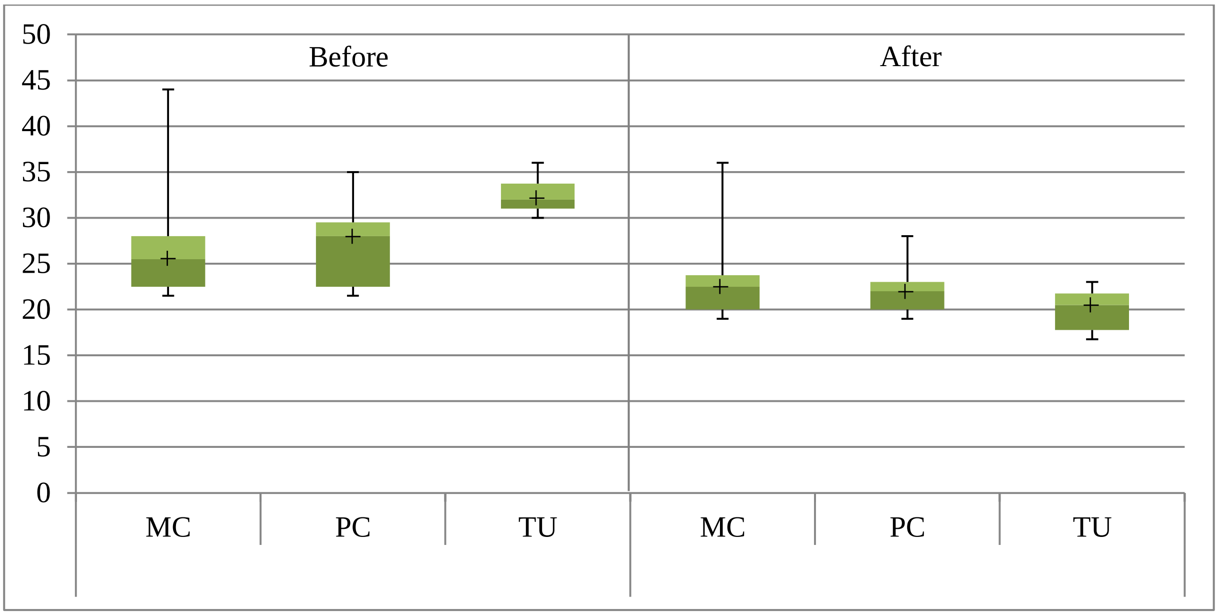

Figure 7. The speed profile at flashing lights

3.2.4 Speed profile at half lifting barriers crossing

The barriers medians are result 36 km/h for MC, PC 46 km/h and TU 40 km/h and BU 33 km/h and reduce to 27 km/h, 42 km/h and 33.5 km/h and 35 km/h. as shown in Figure 8.

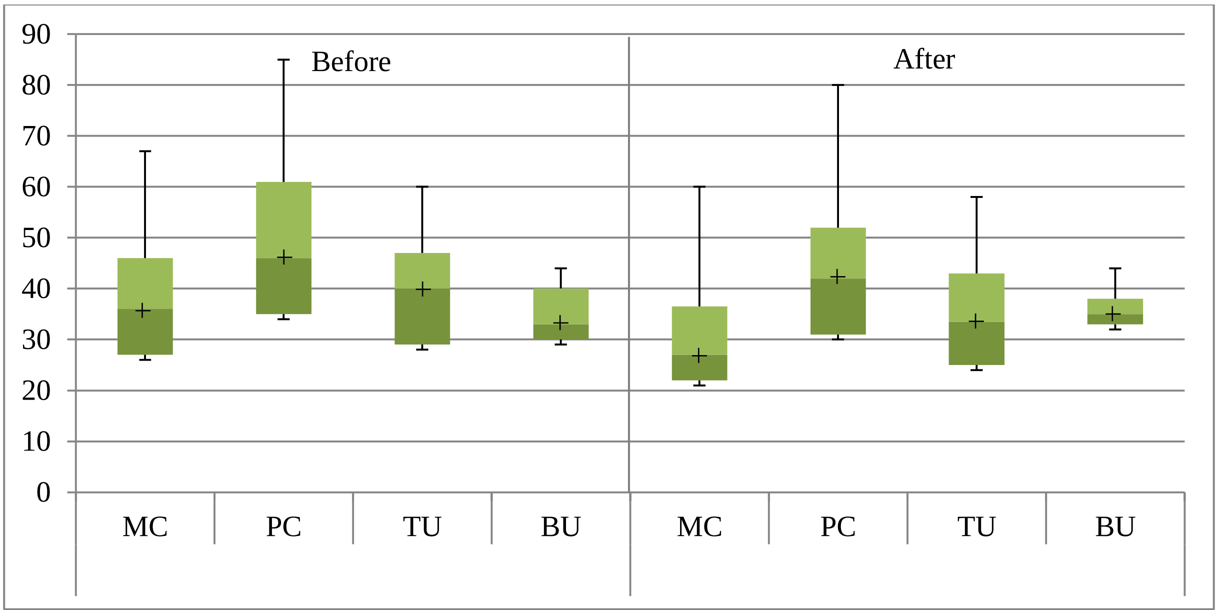

Figure 8. The speed profile at barriers

3.3 Typical speed profile

The results of a typical speed profile for each of the HRGC types are shown in Figure 9. Overall, the vehicle speed decreased as it approached the HRGC. Similar results had been studied by Moon and Coleman in 1999, their results indicate that the trends of the vehicle speed are reduced from the approach lane to the crossing zone when the vehicle was approaching the HRGC (Moon and Coleman, 1999).

In Figure 9, the speed profile of the red line (illegal), there are showing the speed closer to the orange line (stop sign) as compared to the violet line (flashing lights) and last green line (barriers). The time to stop line was collected by using stopwatch for timing on distance from stop line. The drivers selected to use lower speed when they wanted to cross the HRGC than active crossing categories, this may be because the geometric at passive crossing and illegal was in poor conditions.

Under the flashing lights conditions, the stimulus cannot increase the drivers' response to the presence of the HRGC. So they use high speed at this crossing. At the half lifting barriers, most drivers use high speed. They understand the operation of the conditions with the barrier and are confident in using high approaching speed at the crossing. There are many factors that influence driver's behavior when their want to cross the HRGC. The road side information in different of HRGC types has little influence. These assumptions are supported by Shope study in 2006, which gave six categories of driving behavior, driving ability, driving experience, individual factors, demographics, the perceived environment and driving experience. (Shope, 2006)

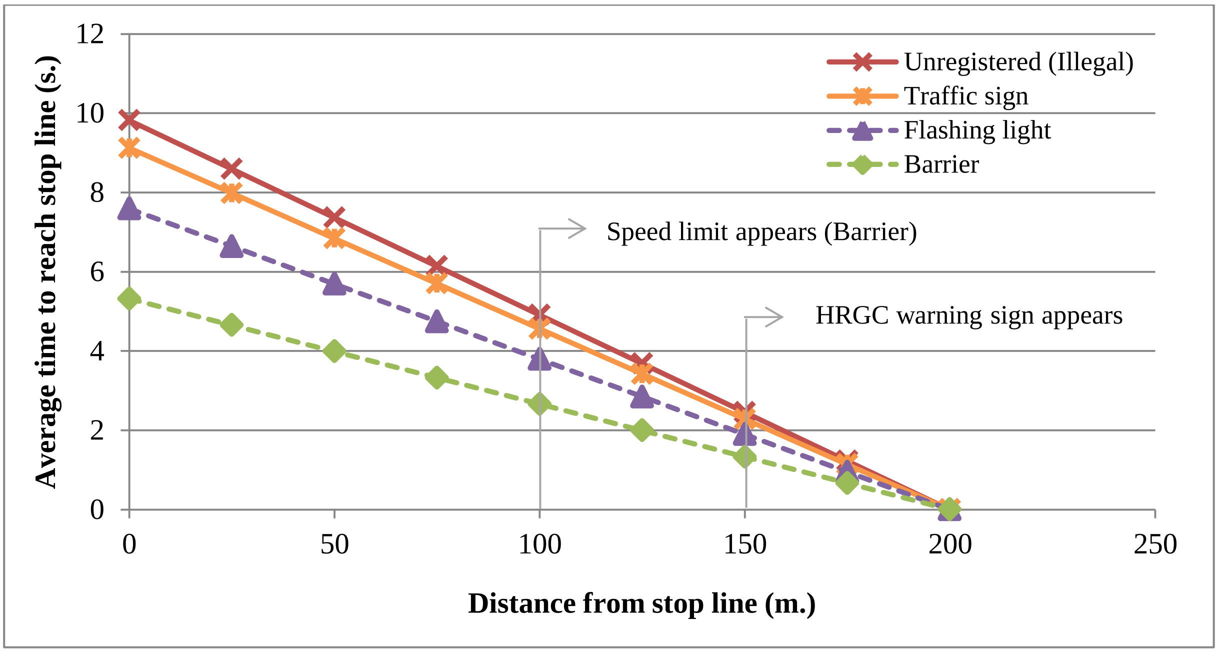

Figure 9. The typical speeding profile

The average times to stop over a 200 m distance differ little in both of passive types; it is approximately 9.82 seconds for illegal crossing and 9.11 seconds for traffic sign. In cases of active control device, the crossing time is much faster than the passive crossing. The stopping time for the same distance of 200 m for flashing light is about 7.5 seconds and the barrier 5.3 seconds.

4. CONCLUSIONS AND RECOMMENDATIONS

HRGC situation in Songkhla province was described in 25 locations comprising different traffic control devices: 6 barriers, 2 flashing lights, 4 stop signs and 13 illegal crossings were investigated. Four selected locations consists 4 types of traffic control used to study the human behaviors at the HRGC. The result shows that human behavior was the major contributing factor at HRGC accidents in which most drivers did not obey the regulatory signs at such location.

The comparison of compliance behavior in terms of ‘stop’, ‘slow-down’ and ‘drive-through’ in this paper has increased the understanding of human behavior at different types of HRGC in Thailand. These results indicated that most drivers reduced the speed, and slowed-down when they approached.

The speed profiles of the four selected locations show that drivers use high speed when approaching active crossing control device such as flashing lights and barriers. At the active crossings, the driver took 5.3 and 7.5 seconds to cover 200 m distance while at the passive crossing, they took 9.82 and 9.11 seconds to travel the same distance.

These situations raise the question whether the speed limit control is enough for safety at HRGC crossing. Drivers often ignore the guidance information that tells them to reduce speed before approaching on HRGC.

For the recommendations to improve the HRGC safety in Thailand, the authors propose that the government should pay attention to: (1) low - cost warning system at HRGC, (2) development of standard HRGC layout, (3) increase road user education on black spot location, accident costs cause of HRGC crashes and how to reduce them through better and safer arriving behaviors.

5. ACKNOWLEDGMENT

The author would like to thank you very much Dr. Paramet Luathep, the lecturer of Department of Civil Engineering, Prince of Songkla University, who gave motivation and inspiration to me, thanks for your time and encouragement of this research study, especially Professor Dr. Pichai Taneerananon for his valuable comments and suggestions on this paper. Thank you all for you time and patience as my advisor.

Last, the author thanks to the State Railway of Thailand for support to accident statistics data documentations and suggestions in this study. Thank to Mr. Pornsutti Thongsard, Chief of Bureau Attached to the Governor and Mr. Theera Rungrojsuwan, SRT transportation engineer, for his generosity in providing SRT data and information.

REFERENCES

Anandarao, S. and C. Martland. (1998) Level-Crossing Safety on East Japan Railway Company: Application of Probabilistic Risk Assessment Techniques. *Transportation*, 25(3): 265-286.

Australian Transport Safety Bureau. (2002) Monograph 10: Level crossing accidents. *Commonwealth Department of Transport and Regional Services*, Canberra, Australia.

Brent D. Ogden, U. S. Department of Transportation, “Railroad – highway grade crossing handbook – revised second edition 2007”, Office of Safety Design, Federal Highway Administration, Washington, D.C., United States of America, August 2007.

Bureau of highway safety, “Highway Railway Grade Crossings Report”, Department of Highways, Ministry of Transport, Thailand, 2010.

Bureau of Highway Safety, “Traffic Crashes on National Highways 2011” Annual Report, Department of Highways, Ministry of Transport, Thailand, 2011.

Carroll, Anya; daSilva, Marco P.; Ngamdung,Tashi. (2010) U.S. DOT Federal Railroad Administration's Third Research Needs Workshop on Highway-Rail Grade Crossing Safety and Trespass Prevention, Federal Railroad Administrator, Washington, D.C.

J.K. Caird, J.I. Creaser, C.J. Edwards, and R.E. Dewar. (2002) Human factors analysis of highway-railway grade crossing accidents in Canada, Transportation Development Centre (TDC), Canada.

Jean T. Shope. (2006) Influences on youthful driving behavior and their potential for guiding interventions to reduce crashes**,** Injury Prevention, vol. 12 (Suppl 1), p. i9-i14.

K.W. Ogden. (1996) Safer Roads: A Guide to Road Safety Engineering, Australia.

Khattak, A. (2008) A comparison of driver behavior at highway-railroad crossing in two cities. In TRB 2009 Annual Meeting CD-ROM. *Transportation Research Board*, Washington D.C.

Los Angeles County Metropolitan Transportation Authority (LAC/MTA) (1999) Metro Blue Line, Grade Crossing Safety Improvement Program, 1999. *Summary of Metro Blue Line Train/Vehicle and Train/Pedestrian Accidents (7/90-9/99).*

Moon, Y.J., Coleman III, F. (1999) Driver’s speed reduction behavior at highway-rail intersection. Transportation Research Record: Journal of the Transportation Research Board 1962 (1), p. 94-105.

Office of inspector general, U. S. Department of Transportation. (2004) Report on the Audit of the Highway-Rail Grade Crossing Safety Program, Washington, D.C., USA, Report No. MH-2004-065.

Office of transportation planning and policy, “A Study Plan for the Safety Measures at Highway–Railway Grade Crossings”, Ministry of Transport, Thailand, 2009.

Rizavi, A. and B.K. Veeregowda. (2005) Safety at Highway-Railroad Grade Crossings. Eng-Wong, Taub & Associates, New York, USA.

State Railway of Thailand - SRT (2009) SRT Accident Data, Ministry of Transport, Thailand.

Thailand Transport Portal. (2010) Transportation Accident Statistics”, Ministry of Transport, Bangkok, Thailand, at http://vigportal.mot.go.th/portal/site/PortalMOT/stat/index7URL/

Transport Research Laboratory. (1991) Towards Safer Roads in Developing Countries: A Guide for Planners and Engineers, Washington D.C.

United Nation. (2010) United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) Road safety in Asia and the Pacific, Bangkok, Thailand.

United States Department of Transportation, Federal Highway Administration (2007) *Railroad – highway grade crossing handbook – revised second edition 2007,* Office of Safety Design, Federal Highway Administration, Washington, D.C., USA.

World Health Organization. (2009) Global status report on road safety: time for action, Geneva, Switzerland.