Factors Affecting Driver Yielding Behavior at a Mid-Block Zebra Crossing

Wirach Hirun [#1]

[#] Department of Civil and Environmental Engineering, Kasetsart University Chalermphrakiat Sakon Nakhon Province Campus 59 Moo 1 Chiangkear subdistrict, Muang district, Sakon Nakhon province, Thailand.
[1] wirach@hotmail.com

***Abstract* — Zebra crossing is one of an important pedestrian facility but a number of mid-block zebra crossings for pedestrians in Thailand are not yet utilized. Although the law requires drivers to yield the right-of-way to pedestrians at crossing, within a marked crosswalk in Thailand, a number of drivers still will not yield for a pedestrian. This situation affects the safety of pedestrians and needs urgent attention of the relevant authorities/agencies to improve the situation, before the zebra crossings becomes a safety hazard. The objective of this paper is to investigate the driver behavior at zebra crossings and the factors that are affecting driver yield behavior are also explored. The questionnaire was produced by a Google Form and the drivers were recruited using a snowball sampling technique via a Facebook and Application LINE. Friends and family of the researcher were invited to complete the survey via Facebook and Application LINE and were also asked to pass on the questionnaire to their friends and family. A total of 445 people completed the survey. The descriptive statistics and the logistic regression were employed for analysis. The binary logit model was used with six attributes: age, sex, education, experience, type of vehicle, and knowledge of pedestrian's right-of-way law was developed. The results indicated that more than 50% of drivers do not have an understanding of the pedestrian's right-of-way law. The developed model revealed that the yielding behavior of the driver depends on age, education, and knowledge of the pedestrian right-of-way law. The odd number of knowledge of the pedestrian right-of-way law is 1.588. For this reason, educating the drivers to the pedestrian right-of-way law is a beginning point to improve the safety for pedestrians at a zebra crossing in Thailand.**

Keywords: Driver behavior, Yielding behavior, Zebra crossing, Road safety, Pedestrian.

I. INTRODUCTION

The pedestrian is one of major components of the urban transportation system. Walking is appropriate for very short trip and become the feeder mode for other urban transportation modes such as taxi, bus, and mass transportation. Moreover, walking achieves an advantage in less energy use and less negative environmental impact compare to other modes of urban transport. In Bangkok, a for-hire motorcycle is unsafe and makes more pollution, it is the most popular mode of transportation instead of walking. This is both for short trips and and is used as a feeder mode for mass transit at a number of mass transit stations. A reason for being unpopular is that walking in Bangkok is not acceptable for pedestrians. Thus, provisions of adequate and safe pedestrian facilities may increase the pedestrian traffic instead of the for-hire motorcycle and be used to increase the safety for the walker.

Zebra crossing is one of the most important pedestrian facilities. The zebra crossings were provided at a number of intersections and a number of mid-blocks for the pedestrian in Thailand, but itis not utilized. Although, the law requires drivers to yield the right-of-way to pedestrians crossing within a marked crosswalk in Thailand, a number of drivers still do not stop. Moreover, in some situations, the driver flashes their head lights or use the horn to stop pedestrians from crossing the road at a zebra crossing. The unsafe status of a zebra crossing is alarming and needs urgent attention of relevant authorities/agencies to improve the situation, before the zebra crossing becomes a safety hazard.

Although, pedestrians are at a greater risk of being injured in a traffic accident than the vehicle occupants, pedestrians are frequently the most overlooked. In Thailand, the level of research for pedestrian and vehicular behavior is still in its preliminary stage. The objective of the paper is to investigate the driver behavior at a zebra crossing and the factors that affect the driver yield behavior are also explored. The results will be the beginning of a spot-light to upgrade safety for the pedestrian in Thailand.

II. LITERATURE REVIEW

The problem of a driver yielding for a pedestrian was mentioned in the past two decades. It was observed in field study in Sweden showed that three out of four drivers maintained the same speed or accelerate and only one out of four drivers slowed down or used brakes at zebra crossing (Varhelyi's, 1998). The study in Malaysia found that out of 96 instances of pedestrian crossing, at a crosswalk there were only 6 cases that gave way to a pedestrian (Ibrahim, 2005). To overcome the problem, previous studies had examined the relationship between

the driver yielding behavior and the signage, marking the road, signalization, and roadway design treatments were needed to find a means for enhancing the driver yielding rate for a pedestrian. Knoblauch et al (2001) indicated that marked crosswalk have no effect on the yielding behavior of drivers, but there is a slight reduction in the speed by drivers approaching a pedestrian in a marked crosswalk compared to an unmarked crosswalk. While, Ragland and Mitman (2007) indicated that drivers are more likely to yield to pedestrians at marked crosswalks rather than at unmarked crosswalks. Another research that was done in rural/recreational locations found that drivers at unmarked crosswalk locations were less likely than drivers at marked crosswalk locations to yield the right-of-way to pedestrians (Mitman et al 2010). Huang and Cynecki (2001) found that none of the treatments (refuge islands at zebra crosswalks) had a significant effect on the percentage of pedestrians for whom motorists yielded. Hakkert et al (2002) indicated that a new type of uncontrolled pedestrian crossing: a system for detecting pedestrians near the crosswalk zone and for warning drivers on pedestrian presence, can bring about a decrease of 2–5 kph (kilometres per hour) on an average vehicle speeds, near the crosswalk zone; this showed an increase in the rate of giving way to pedestrians. Fitzpatrick et al (2014) found that a noticeable improvement was made in the number of yielding vehicles that were studied before and after installation of the pedestrian treatment of a rectangular rapid-flashing beacon and a pedestrian hybrid beacon. Studies have also explored differences in driver yielding rates based on pedestrian and driver characteristics. Another research attempted to discover the yielding behavior, Goddard et al (2014) revealed that black pedestrians were passed by twice as many cars and experienced wait times that were 32% longer than white pedestrians. Piff et al (2012) indicated that upper class drivers were significantly more likely to drive through the crosswalk without yielding to the waiting pedestrian. Hatfield et al (2007) found that there was some misunderstanding of rules regarding pedestrian right-of-way in various road-crossing situations. There are a few researches with pedestrian and driver interaction in Thailand, almost all of the researches focused on the pedestrian behavior, Jampangen et al (2014) employed a logistics regression to model the pedestrian behavior toward a push-button pedestrian crossing system. Sangphong and Siridhara (2014) found that the proportion of pedestrians running/crossing the road by using and not using the footbridge was 47% at the four lanes crossing with an island in between and heavy traffic.

III. METHODOLOGY

A. Questionnaire design

The questionnaire was divided into two parts: the first is demographic information of the respondent including: age, sex, education, driving experience, type of vehicle, knowledge of the pedestrian right-of-way law, and the region of hometown (central, northern, north eastern, southern, and eastern). The second is the driving behavior and yielding behavior. The respondents were asked to answer the level of yielding rate that they personally used which was divided into four levels (seldom, often, sometimes, and always).

B. Sample size and survey method

Since, the sample was collected from all of the regions of the country, to represent the driver behavior of the country, an online survey was used to collect data. The questionnaire was produced by Google Form which could provide the multiple choice answer, and the drivers were recruited using a snowball sampling technique (Schneider and Sanders, 2015) via a Facebook and Application LINE. Friends and family of the researcher were invited to complete the survey via Facebook and Application LINE and were also asked to pass on the questionnaire to their friends and family. The collected data were summarized by Google Form and then prepared for analysis.

C. Data Analysis

When a driver approaches a zebra crossing, the driver either yields or does not yield to the waiting pedestrian and different drivers have a different approach. For this reason, this binary behavior (yield or no yield) can be modelled to quantify the effect of each different driver characteristics factors on propensity of driver yielding using the logistic regression. The motorist yielding probability can be predicted by

$$P(i) = \frac{1}{1+e^{-u_i}}$$

where P(*i*) denotes the probability of choosing alternative *i*. In this case it is the estimated probability of yielding. The term e is the basis of the natural logarithm, and U_i is the utility of choosing the alternative *i* which linearized regression equation expressed in the form:

$$U_{in} = \alpha + \beta_{i1}X_1 + \beta_{i2}X_2 + \beta_{i3}X_3 .... \beta_{in}X_n$$

where α is the constant, *i* is the number of alternative, X_{i1}, X_{i2},…, X_{in} are variables associated with a utility alternative of *i*, n is the number of independent variables, and β_1, β_2,…, β_n are the coefficients of the n explanatory variables. The maximum likelihood estimation method is used for model estimation.

Sun et al (2003) used a binary logit model with five attributes: age, gender, vehicle type, the number of pedestrians waiting, and opposite direction traffic condition to predict the motorist yield. The developed model achieved a high correct prediction performance (87.1% at 1% accuracy level). Hatfield et al (2007) used a binary logit model to model behaviors of the pedestrian and driver relating to the right-of-way for pedestrians crossing at traffic signals, zebra crossings, and unmarked sections of road in a variety of situations. They developed a model using various factors from a questionnaire and field observation such as in an area (metropolitan Sydney versus rural NSW), age, gender, language spoken at home, and license status.

IV. RESULTS

A. Data description

A total of 445 people from all regions of country (central 33.9%, northern 5.3%, north eastern 53.9%, southern 2.5%, and eastern 4.4%) completed the survey and the characteristics of the respondents are summarized in Table I. Most respondents (52.81%) were male. Most respondents were between the ages of 30 and 39. Most respondents (59.55%) indicated their education was a Bachelor degree and the driver that had a higher than Bachelor degree is 30.79%. Among the respondents, approximately 6.5% had less than 1year experience, 17.7% had 1-5 years' experiences, 16% had 6-10 years' experiences and 59.8% had more than 10 years' experiences. The vehicle of the drivers was: pickup, normal passenger car, expensive passenger car was 28.99%, 54.61% and 16.14% respectively. Only 42.02 percent of respondents knew about the pedestrian right-of-way law.

TABLE I. Demographic characteristics of the respondents

Characteristics		**percent**
Age	Less than 20 years	1.35
	20-29	24.04
	30-39	35.28
	40-49	20.67
	50-59	8.09
	More than 60 years	10.56
Sex	Male	52.81
	Female	47.19
Education	Primary school	0.90
	Secondary school	8.76
	Bachelor degree	59.55
	Higher than Bachelor degree	30.79
Experience	Less than 1 year	6.52
	1-5 Years	17.75
	6-10 Years	15.96
	More than 10 Years	59.78
Type of vehicle	Pickup	28.99
	Normal passenger car	54.61
	Expensive passenger car	16.4
Knowledge of the pedestrian right- of-way law	Don't know	57.98
	Know	42.02

B. Driving Speed

Most drivers reduced speed when near or stop when they approached a zebra crossing (86.61%) while 12.93% of the drivers reduced speed slightly. However, the drivers who keep same speed were only 0.46%. The result indicated that most drivers were aware of the pedestrian at a zebra crossing.

TABLE II. Statistical of the model

Driving speed	**Percent**
Keep same speed	0.46
Reduce speed to near or stop	86.61
Reduce speed slightly	12.93

C. Yielding behavior

The yielding behavior of the driver classified by age, education, experience, vehicle types, and knowledge of pedestrian right-of-way law is shown in figure 1 to figure 5. The 60-year old drivers yield for pedestrian more than the younger drivers. The comparison between education of the driver shows that the drivers with Bachelor degree always yield for pedestrian than the secondary school driver and higher than driver with higher than Bachelor degree. There is slight difference in the yielding behavior between vehicle types while the driving experience show the difference in yielding behavior. The knowledge of pedestrian right-of-way data indicate quite a large difference in yielding behavior. A total of 55 percent of drivers who know the pedestrian right-of-way law always yields for pedestrian while only 42 percent of drivers who do not know the pedestrian right-of-way law always yields for pedestrian.

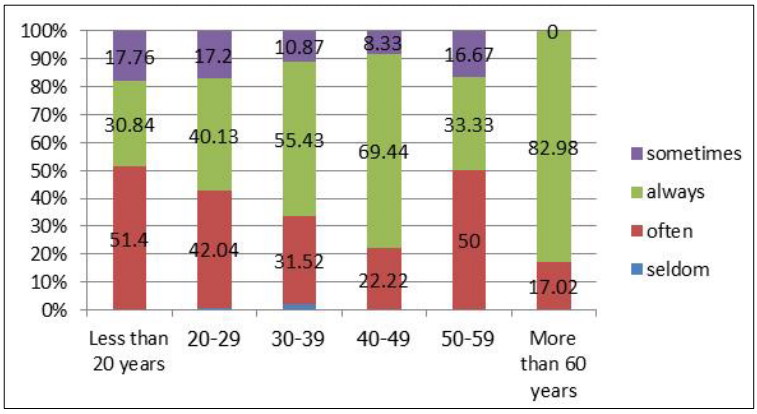

Fig. 1. Yielding behavior of driver versus age of driver

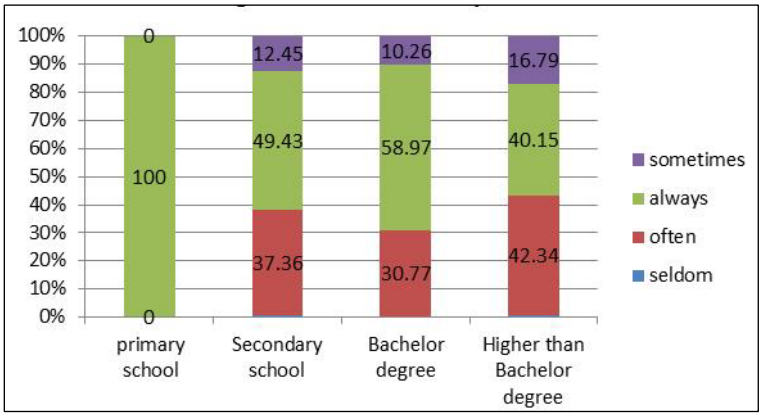

Fig. 2. Yielding behavior of driver versus driver' education

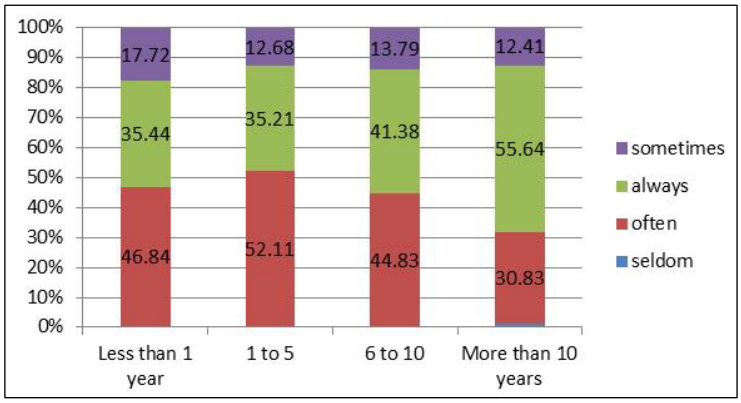

Fig. 3. Yielding behavior of driver versus driving experience

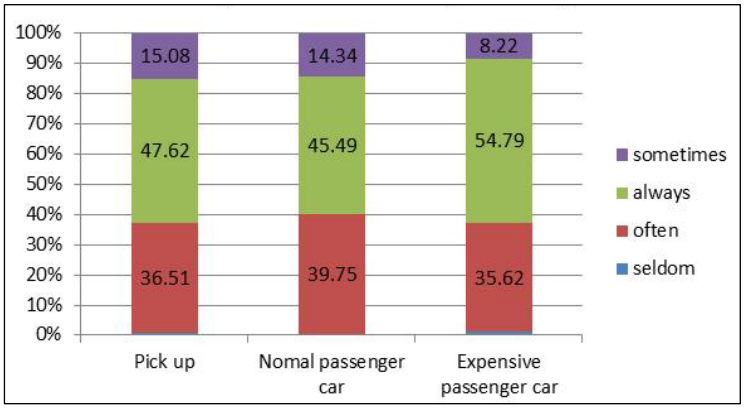

Fig. 4. Yielding behavior of driver versus vehicle type

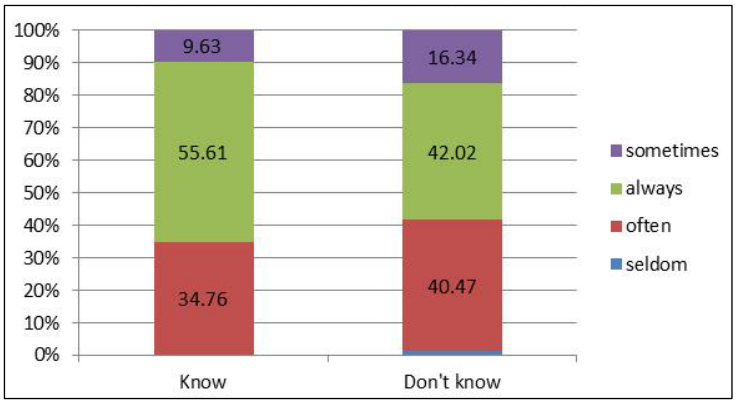

Fig. 5. Yielding behavior of driver versus knowledge of pedestrian right-of-way law

D. Model development

The objective of model developing was to determine the probability of a driver to yield for a pedestrian under associated factors. For the binary logit model, the probability was compared between the binary behavior (yield or no yield behavior) of the driver. The questionnaire was designed to ask the respondents to answer the level of yielding rate which was divided into four levels (seldom, often, sometimes, and always). However, the always yield behavior is the expected manner of the driver for pedestrian thus the others answer (seldom, often, sometimes) will be interpreted as they did not yield in the model. Six variables: age; sex; education; experience; type of vehicle, and knowledge of the pedestrian right-of-way had been added to the model. The algorithm with a p = 0.05 threshold were employed to get stable regression coefficients. The Cox & Snell R Square and Nagelkerke R Square were employed to verify the performance of the model.

TABLE III. Description of the variable in the model

Variable	**Variable Characteristics**	**value**
Age	Less than 20 Years	1
	21-30 Years	2
	31-40 Years	3
	41-50 Years	4
	51-60 Years	5
	More than 60 years	6
Sex	Male	1
	Female	2
Education	Primary school	1
	Secondary school	2
	Bachelor degree	3
	Higher than Bachelor degree	4
Experience	Less than 1 year	1
	1-5 Years	2
	6-10 Years	3

	More than 10 Years	4
Type of occupancy vehicle	Pickup	1
	Normal passenger car	2
	Expensive passenger car	3
Knowledge of the law	Don't know	1
	Know	2
Yielding behavior	Always yield	1
	Others (seldom, often, sometime)	0

The results of logistics regression are presented in Table 4 and Table 5. Model I and Model II and have an overall accuracy of 64.5 % and 66.1% respectively in predicting yielding decisions. On the other hand, Models III have an overall accuracy of 67.0 %. Therefore, Model III appears to have a better performance than the other models based on the -2LL score, Cox & Snell R Square, Nagelkerke R square and t-values from variables included in the model. Moreover, the model III estimation results support the initial hypotheses that knowledge of pedestrian right-of-way law may affect the yielding probabilities.

TABLE IV. Model estimation results

Variable	**β**	**S.E**	**Wald**	**Sig.**	**Exp B**
Model I					
Age	0.568	0.087	42.950	.000	1.764
Constant	-2.019	0.309	42.814	.000	0.133
Model II					
age	0.624	0.090	48.262	.000	1.866
education	-0.659	0.171	14.777	.000	0.517
Constant	-0.095	0.576	0.027	.870	0.910
Model III					
age	0.613	0.091	45.414	.000	1.845
education	-0.678	0.173	15.349	.000	0.508
law	0.462	0.210	4.864	.027	1.588
Constant	-0.649	0.632	1.055	.304	0.523

TABLE V. Statistical of the model

Statistic	**Model I**	**Model II**	**Model III**
-2 Log likelihood	566.377	550.627	545.745
Cox & Snell R Square	0.106	0.137	0.146
Nagelkerke R Square	0.141	0.183	0.195
Percentage collect	64.5	66.1	67.0

According to the p-values of the coefficients' estimates, the significant predictors for the model are age, education, and knowledge of the pedestrian right-of-way law with p-value<0.05. The utility of yielding behavior which linearized regression equation is expressed in the form:

$$U_{yeild} = 0.613\text{A}ge - 0.678Education + 0.462Law$$

Cox & Snell R Square and Nagelkerke R Square indicate that the model which includes the three independent variables explains between 15.5% and 20.6% of the variation in yielding probability.

V. DISCUSSION

The developed model revealed that age, education, and knowledge of the pedestrian right-of-way law are significant characteristics of the driver for their yielding behavior. The Exp (B) column presents an odds ratio and indicated that the older drivers always yield for a pedestrian than younger drivers which was presented by odds ratio (1.845) while higher education of the driver reduced the yielding probability. The odds ratio of knowledge of the pedestrian right-of-way law reveals that the driver who knows the law is 1.588 times more likely yield for pedestrian than to not yield. Although, the knowledge of pedestrian right-of-way law is used to predict the yielding for pedestrian, only 42.02% of the driver knows about the law. A reason the people do not know about the law is law enforcement. There is no law enforcement present for driver who does not yield for pedestrian at zebra crossing. For this reason, the driver may be imagining that there is no law for right- of-way of the pedestrian and becomes normal for the driver to think that there is no responsibility of the driver to yield for a pedestrian. Moreover, the driver thinks that stopping for pedestrians crossing the street at a crosswalk is

too generous for pedestrians. Therefore, educating the driver about the pedestrian right-of-way law and adding law enforcement is an important task to improve the driver yielding rate.

VI. CONCLUSION

The zebra crossing is one of the most important pedestrian facilities but a number of mid-blocks zebra crossing for pedestrian in Thailand are not put in place. The safety of the zebra crossing is alarming and needs urgent attention of relevant authorities/agencies to improve the situation before the zebra crossing becomes a safety hazard. Understanding driver yielding behavior and its influencing factors is important for guiding informed design, planning, and even policy decisions are needed to improve zebra crossing in Thailand. The internet questionnaire (Google form) survey via Facebook and Application LINE were employed to collect data. The logistics regression was employed to model the driver yielding behavior using a total of 445 respondent drivers in all regions of Thailand. Six variables: age, sex, education, experience, type of vehicle, and knowledge of pedestrian right-of-way had been added to the model. An algorithm with a $p = 0.05$ threshold was employed to get stable regression coefficients. The final model revealed that the significant predictors for the model were age, education, and knowledge of the pedestrian right-of-way law. The developed model provided sufficient evidence that knowledge that pedestrian right- of- way law was significant predictors for the driver yielding behavior. The odds ratio indicates that knowledge of pedestrian right-of-way law was 1.588 times more likely to make driver yield for pedestrian than not to yield. The insights gained from this paper showed that educating a driver about pedestrian right-of-way law and providing law enforcement was a beginning point to improve the safety for the pedestrian at zebra crossing in Thailand.

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