BEHAVIORAL CHARACTERISTICS AND FACTORS INFLUENCING RAILWAY CROSSING BEHAVIORS

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Abstract

A railway level crossing is a risk area despite installations of the warning signal and arm gate that indicate a train approach. Accidents may nevertheless occur if vehicle drivers violate or fail to conform to the rules. Such action is considered a risk behavior that may cause severe collision, injury, and death. Thus, the driver behaviors are the key factors causing accidents. The objective of this study was thus to investigate the risk behaviors and the factors influencing above behaviors. These behaviors were recorded by a high-resolution video camera and the initial data analysis was based on descriptive statistics. An in-depth analysis of the factors influencing the risk behaviors was performed by using Pearson Chi-square technique and Binary Logistic Regression Analysis. The results showed that the railway crossing behaviors of more than half of the drivers under the study were the risk-taking, followed by opportunistic violation. Most violations occurred during the beginning of the warning signal. Overall, the motorcycle riders were found to be the group with greater chance of violating across the railway during the warning signal than the 4-wheeled vehicle drivers. Especially, during the period between the beginning of the warning signal and the complete arm gate closure, as well as the greater width of the crossing road. This could be due to the higher agility and evasive capability of motorcycle riders than 4-wheeled drivers. Additionally, this study recommends approaches to initially prevent or reduce this risky behavior and can serve as a guideline for enhancing areas with physical characteristics similar to the study area.

Keywords: **Driving behaviors; Rail grade crossing; Road safety; Severe accident; Unsafe action**

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Introduction

Background

The railway level crossing is a vital area in the transportation system, for it functions as the traveling connection of road users. Although the area has been well designed and installed with various controlling measures (warning signals, arm gates) to alert drivers to the arrival of trains and to enhance the safety of road users which has a significant impact on safety. However, conflicts between vehicles and trains still exist. The area is thus another risk zone for accidents if people do not conform to or violate the controlling measures. Such action is unsafe and considered a risky behavior both for oneself and others. An accident here is similar to a collision found at intersections, which are lateral and, even though the chance of happening is little at the zone, the result is severe and of high risk of massive injury and death. This is especially true if it happens to a fragile group such as motorcycle riders. In addition, drivers and train passengers also risk the impact from the collision (Tey *et al*., 2011; Tjahjono *et al*., 2019; Jantosut *et al*., 2021a; Jantosut *et al*., 2021b; Se *et al*., 2023).

According to the State Railway of Thailand (SRT), there are 6 routes of railway service, including the northern, the central, the eastern, the northeastern, the west and the southern routes. On these routes there are altogether 2,684 railway crossings: 192 being overpass crossings (7.16%), 214 being underpass crossings (7.97%), and 2,278 being level crossings (84.87%). It can be seen that most railway crossings in Thailand are level crossings, which means there is a high risk of accidents. The statistics of the State Railway of Thailand related to accidents from 2015 to 2023 years are shown in Figure 1. There were 601 accidents (67 cases annually). Of this number, 540 people were injured (60 cases annually), and 226 died (25 cases annually) (SRT, 2023).

Khon Kaen is another city under development progression where the northeastern railway route passes. The level railway crossings along this route are the conflict points between the train and road users. The accident statistics at the railway level crossings along the northeastern route between Khon Kaen City and Non-Payom from 2015 to 2023 were investigated. There was only one accident, but the injury and death toll was 47 cases (42 injured and 5 dead) (SRT, 2023).

This marked the most massive collision necessitating a study to find a preventive approach that reduces the risk of accidents and losses.

Collisions and safety at railway crossings are of interest all over the world, for collisions impact not only bring impacts on assets and public health (injury and death) but also the economy. The value of expenditure from collisions arising at the crossings, which involved road users during the 3-year period (2007-2009) in Australia amounted to as high as 32 million Australian dollars per year (Tey *et al*., 2011). Similarly, the costs associated with railway accidents in Thailand for the year 2004 amounted to approximately 2,482 million baht. This number represents 2 percent of the total traffic accident costs, which were 153,755 million baht (Settasuwacha *et al*., 2012; Se *et al*., 2023). Based on the data presented above, the value of annual losses from violations are relatively high, if prevention or reduction of chances of collision could be achieved, the expenditure value would be reduced, making it economically worthwhile.

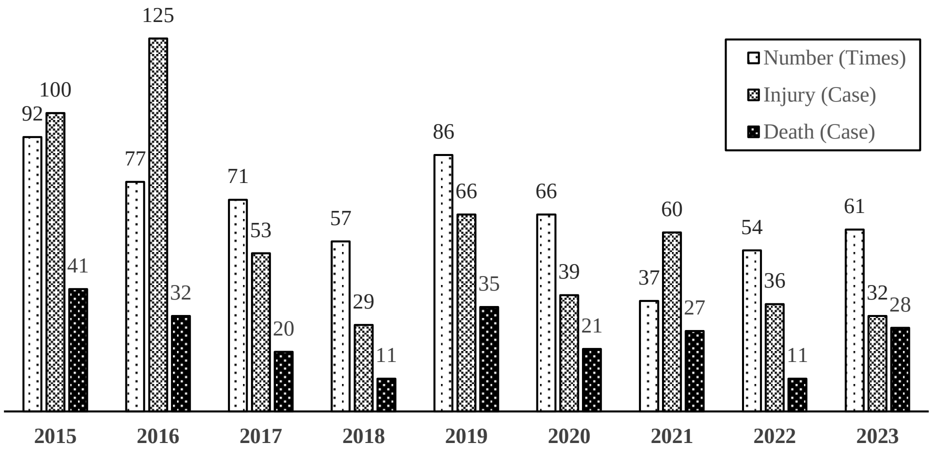


Figure 1. **Collision statistics on railway crossings from 2015 to 2023 (SRT, 2023)**

However, in terms of the worthiness of survival of road users, the value could not be anticipated; it could be generalized that investment would be worth from reduction of just one case of death.

Many previous studies have recognized the importance of studying railway accidents by analyzing risk factors and assessing the severity of risks. This analysis has led to the formulation of policies or strategies aimed at solving problems and reducing the overall risk of accidents (Yan *et al*., 2010; Hao *et al*., 2016; Zhao and Khattak, 2018; Zhao *et al*., 2019; Khales *et al*., 2020; Yan *et al*., 2022a; Yan *et al*., 2022b; Se *et al*., 2023; Yan *et al*., 2023). On the other hand, studies on driving behavior at railway crossings are not widely available, which is important as a contributing factor to accidents.

Driving Behaviors

Almost all cases of railway-level crossing accidents were caused by road users or drivers (95%) (Tey *et al*., 2011), and most showed inappropriate driving behaviors. Over 55% of deaths from road accidents were found to relate to these behaviors (Ma *et al*., 2018), especially at a railway-level crossing, which is the risk point where the chance of death from accidents is high as it is the conflict point between road users and the train. Therefore, the level crossing behaviors of road users are the major factors causing accidents and affecting safety at the crossing. (Tey *et al*., 2011; Burdzik *et al*., 2017; Ma *et al*., 2018). Moreover, the physical characteristics of the railway-level crossing are also important, such as the road surface and visibility or angle of vision at the crossing (Burdzik *et al*., 2017).

Drivers' perception of risk and assessment of danger that may arise greatly influence the decision made for action. This decision process is complicated, differs from one driver to another, and is difficult to understand as it is the internal factor that can be changed any time depending on supporting factors. Thus, if the behaviors or characteristics of behaviors and other related factors could be understood (by observation), a database would be obtained for determining the approach or measure that could prevent or stop the risk behaviors and unsafe action at the railway level crossings.

A recent study conducted on the behaviors of road users at railway-level crossings classified the behaviors of road users in accordance with their actions into 4 types: driving around or through the barrier gate, stopping and then proceeding, failing to stop, and stopping while crossing (Cooper and Ragland, 2007). Another study by Kasalica *et al*. (2012) divided the driver behaviors into 5 groups: stopping in front of train, crossing in front of train, stopping before proceeding, slowing down before proceeding, and not stopping or slowing down. The classification was almost similar to that of Cooper and Ragland. (2007), but with more consideration on the actions. In addition, Ma *et al*. (2018) conducted a study on the behaviors of road users at railway-level crossings by compiling the behaviors from previous studies and classified them into 2 groups: aggressive driving behaviors or violation driving behaviors (driving around or through the arm gate, not stopping, and stopping on crossing) and appropriate driving behaviors (stopping and then proceeding).

Similar studies on the risk behaviors of road users at intersections also divided the behaviors according to the action into 3 groups: law-obeying, risk-taking, and opportunistic (Wu *et al*., 2012; Pai and Jou, 2014; Fraboni *et al*., 2018), and later studies added one more group, i.e., traffic-following, which is a behavior that is consistent with what truly happened at the area (Jantosut *et al*., 2021a; Jantosut *et al*., 2021b).

Associated Factors

Previous studies on the influencing factors or factors directly associated with the driving behaviors of road users at railway-level crossings are few. Most were conducted on presenting the behaviors in the form of descriptive statistics (Tey *et al*., 2011; Kasalica *et al*., 2012; Sato *et al*., 2013).

The most similar study was on the factors related to the severity of accidents in two groups of drivers, namely, the drivers with aggressive driving behaviors or violative driving behaviors and the drivers with appropriate driving behaviors. The dependent variables included the severity levels: property damage only (PDO), injury, and fatality. The independent variables included time periods, vehicle speed, vehicle type, weather conditions, train speed, age, gender, control device type, and area type (Ma *et al*., 2018).

Thus, owing to limitations in data collection, only certain factors were selected for this study, which was similar to the past study, i.e., the vehicle type and area type. Additional factors in this study included road width, length of traffic lights, length of the warning signal until the arm gate closes, length of the warning signal until the train arrives (period from the beginning of the warning signal - arm gate closing - train arriving at the crossing) and the waiting period (period from the beginning of the warning signal - arm gate closing - train passing - arm gate opening). This is shown in Table 2. These factors were assumed to influence or explain the level-crossing behaviors.

Conceptual Framework for This Study

Men, vehicles, roads, and the environment are the principal factors involved in road accidents, while at railway-level crossings, the main components involved are people, roads, and the environment. People are the essential component hard to control due to their complicated driving behaviors that also differ from one period of time to another and depend on the different supporting elements. It is thus important to find the preventive approaches that stop the unwanted behaviors and to carry out continuous research (Chen *et al*., 2019). Understanding of people's behaviors and associated factors that influence the behaviors would be the base data for determining the appropriate solution approaches for each area.

This research thus emphasized the study of behaviors and the characteristics of behaviors of drivers in crossing the railway (Railway Crossing Behavior: RCB). The behavioral characteristics were divided into 4 groups: law-obeying, risk-taking, opportunistic, and traffic-following. The factors influencing or associated with the risk factors were in addition investigated. As the studies on this topic are not widespread, especially in Thailand, the results would be used as the database that leads to the prevention of the behaviors, reduction of severity, chances of accidents and losses, and indications for further studies in other places.

Methodology

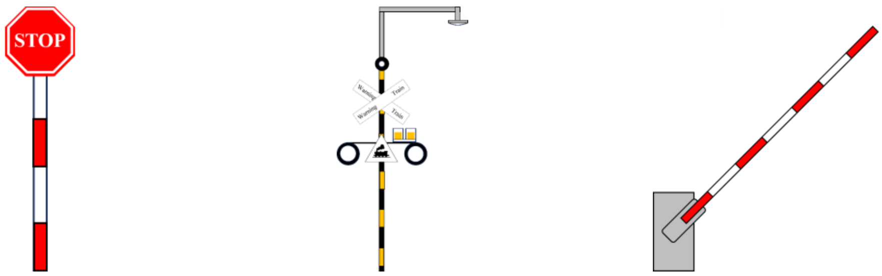
Study Area

The study area included the railway level crossings between the northeastern railway route and the road from Khon Kaen City to Non-Payom, where the statistics of accidents, injuries, and deaths were reported. The place also contains the physical characteristics of the level crossing with the said statistics. Besides, there is a level crossing installed with a warning signal, arm gates, and an integrated traffic system for road users to cross. The level crossings along the study area included the crossings at Ban Non-Thon, Ban Pia-Fan, Ban Don-Ya-Nang, Ban Nong-Kung 1, and Ban Nong-Kung 2, as shown in Figure 2. The traffic components, warning systems, and physical characteristics of each of the crossings are shown in Figure 3 and Table 1, respectively.

Data Collection

Data collection was divided into 2 groups: the level crossing behaviors of road users and the physical characteristics of the study area including

Figure 2. **Location of selected studies**



(a) Stop Sign **(b) Flashing Light** **(c) Half Boom Barrier**

Figure 3. **Warning system of selected studies**

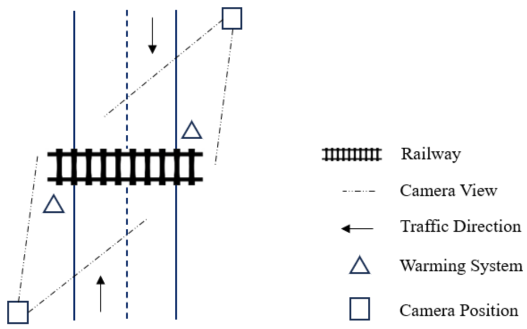


Figure 4. **Installation of camera for field survey**

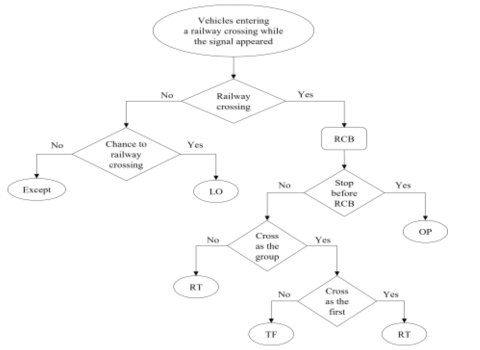


Figure 5. Decision process for railway crossing behaviors (RCB)

Table 1. **The characteristics of selected studies**

No.	Selected studies	No. of tracks	Warning systems	Road crossing		Crossing angle
				No. of lane	Width (m.)	
1.	Nong-Kung 1	1	a, b, c	2	7.0	vertical
2.	Nong-Kung 2	1	a, b, c	2	5.0	
3.	Don-Ya-Nang	1	a, b, c	2	5.0	
4.	Pia-Fan	1	a, b, c	2	6.0	curvy
5.	Non-Thon	1	a, b, c	2	6.0	

Table 2. **Definitions of Railway Crossing Behaviors**

Railway Crossing Behavior	Definition
Law-Obeying (LO)	The drivers had a chance to cross the railway but did not. These drivers stopped and waited until they received the right to cross.
Risk-Taking (RT)	The drivers entered the railway crossing and decided to cross during the warning signal without stopping.
Opportunistic (OP)	The drivers stopped at the railway crossing when the warning signal appeared, but left before receiving the right to cross.
Traffic-Following (TF)	The drivers crossed the railway in a slow-speed platoon when the warning signal appeared, without stopping.

Remark : Adapted from the study of Jantosut et al. (2021a, 2021b)

other information that was anticipated to explain the behaviors of road users' railway crossing. These factors were derived from past studies, and more was added to this study.

Data was collected on the level railway crossing behaviors of road users during the warning signal period, using a high-resolution video camera to record the driving behaviors of road users. The installation conditions were: 1) The angle of vision covered a clear picture of the railway level crossing, showing the flash light, the arm gates, and the movement across the railway of the driver. 2) The installation point of the camera was not obvious or could be easily seen by the road users, to avoid impact on their crossing behaviors (Pai and Jou, 2014; Jensupakarn *et al*., 2018; Porter and England, 2000).

The installation and angle of vision are shown in Figure 4. The study was approved by the Human Research Ethics Committee.

Other physical information of the study area and other information anticipated to explain the railway crossing behaviors of road users included the railway crossing location, road width, vehicle types, length of warning signal time until the arm gate closed and the waiting time (from the beginning of the warning signal - arm gate lowering - train passing - arm gate opening). These are shown in Figure 3.

Data collection was done only during the daytime period when train passed, on weekdays, excluding holidays, rainy days or when there were other activities making the traffic there irregular (Jensupakarn *et al*., 2018; Porter and England, 2000).

Data Analysis

The railway crossing behaviors of road users were divided into 2 main groups: law-obeying and violating groups. The second group was sub-categorized according to their behaviors into: risk taking, opportunistic, and traffic-following (Jantosut *et al*., 2021a; Jantosut *et al*., 2021b). The definitions and considering process are shown in Table 2 and Figure 5.

Overall information of railway crossing behaviors was analyzed and initially presented by descriptive statistics.

Pearson Chi-square Test (Jantosut *et al*., 2021a; Jantosut *et al*., 2021b) was applied to verify the primary relationship between the anticipated factors and the railway crossing behaviors. The factor with the relationship at a significant level of 0.05 will be selected for further analysis to explain the risky behavior.

The Binary Logistic Regression Technique (BL) was then applied (Jensupakarn *et al*., 2018; Porter and England, 2000; Jantosut *et al*., 2021a; Jantosut *et al*., 2021b) to analyze the factors influencing risky behavior. It presents the chance of occurrence of each factor by odds ratios (OR), as shown in Table 3.

Results and Discussion

Railway Crossing Behaviors

Observation of the railway crossing behaviors of road users during the warning signal and the initial descriptive statistics analysis showed that the proportion of violation of motorcyclists (45.90%) was higher than the 4-wheeled motorists (21.60%). When classified according to their behavioral actions, both groups were similar. They only violated in the form of risk-taking and opportunistic risk (27.90% and 5.90%, respectively). More than half were risk-taking, followed by opportunity-taking (18.00% and 5.90%, respectively), as shown in Figure 6.

Upon considering the period of violations, (Figure 7), almost all of the two groups violated at the beginning (the first 5 seconds) of the warning signal. This corresponded to the study by Jantosut *et al*. (2021a) and Jantosut *et al*. (2021b) who stated that most risk factors occurred at the beginning and the end of the warning red light. This could be due to the driver's perception, when entering the railway crossing during the warning signal until the arm gate closed, that the train would not be arriving at the moment and there was a lapse of time before the train finally arrived. The driver assessed that it was safe and so decided to cross. This action could happen during a short period of decision making while the driver was entering the railway crossing area. The action is considered a risk-taking behavior (RT), which is mostly found among 4-wheeled drivers in this study (15.70%), as shown in Figure 7.

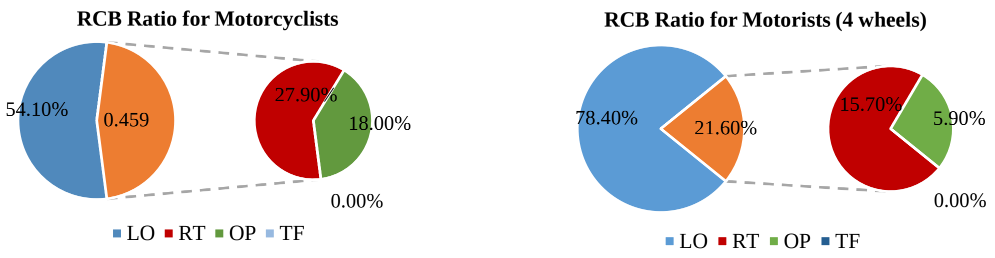


Figure 6. RCB by vehicles

Table 3. Factors anticipated to influence the railway crossing behaviors

Factors	Group Coding	Reference
Dependent variables		
Railway Crossing Behavior (RCB)	0 = law-obeying 1 = Non-compliance (risk-taking, opportunistic, and traffic-following)	Jantosut *et al*. (2021a); Jantosut *et al.* (2021b); Fraboni *et al.* (2018); Pai and Jou. (2014); Wu *et al.* (2012).
Independent variables		
Railway crossing location	0- urban area 1 - rural area	
Road width	1 - 5 meters 2 - 6 meters 3 - 7 meters	
Vehicle type	0 - 4-wheeled 1 - motorcycle	Ma et al. (2018)
Period between warning signal - barrier closing.	0 - less than 15 seconds 1 - more than 15 seconds	
Period between warning signal - barrier closing - train arriving.	0 - less than 70 seconds 1 - more than 70 seconds	
Waiting time	0 - less than 91 seconds 1 - more than 91 seconds	

Remark: 1) 15 and 91 seconds are the averages at the study area. 2) waiting time is during time from the beginning of warning signal until the arm gate closes - train passing - arm gate opening

Likewise, a driver could be in an uncertain state of safety to cross and thus decided to pause. When reconsidering the condition, he might perceive the safety or see the benefits in crossing and thus decided to cross. This action is considered opportunity-taking (OP), which was mostly found in this study among motorcyclists (16.39%), as shown in Figure 7.

Both behaviors were the actions occurring during the decision-making process of the driver, which was only a few seconds and was considered risky. Although the decision was based on the belief in safety, if it recurred, it could form a habit of carelessness that led to error of decision or unanticipated situation during the crossing. It also increased the chance of a severe accident and loss of life and assets, especially when it happened to motorcyclists who were more agile in crossing than their 4-wheeled counterparts and were the most fragile road users.

Factors Influencing RCB

Pearson chi-square Test and Binary Logistic Regression (BL) analyses conducted to determine the initial relationship (shown in Table 4) revealed that the factors significantly associated with the railway crossing behaviors at 0.05 level were: vehicle type, road width and the period of time from the warming signal until the arm gate closed. These factors were analyzed to find the influence of each that explained the railway crossing behaviors, based on the Binary Logistic Regression. Three factors could explain the railway crossing behaviors at the 0.05 level of significance as follows:

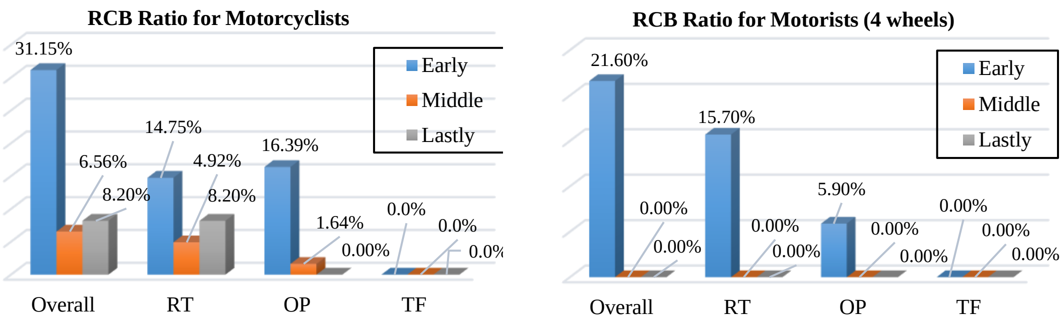


Figure 7. Elapse times of RCB

Table 4. Proportion of behaviors, results of Pearson Chi-square Test and Binary Logistic Regression analyses

Variables	Law-obeying (N=146)	Law-obeying (N=146)	χ^2	BL analysis β	Sig.	OR
Railway level crossing point			0.533	-	-	-
Urban area	76	44		-	-	-
Rural area	70	34				
Vehicle type			<0.001**			
4-wheeled	80	22				1.000
Motorcycles	66	56		0.890	0.005**	2.436
Road width (two directions)			0.016*			
5 meters	52	14				1.000
6 meters	50	30		0.773	0.050*	2.167
7 meters	44	34		0.982	0.016	2.669
Period between warning signal - barrier closing.			0.034*			
≤ 15 seconds	74	28				1.000
> 15 seconds	72	50		0.619	0.048*	1.858
Period between warning signal - barrier closing - train arriving.			0.316			
≤ 70 seconds	96	46		-	-	-
> 70 seconds	50	32		-	-	-
Waiting time			0.992			
≤ 91 seconds	86	46		-	-	-
> 91 seconds	60	32		-	-	-
Constant				-2.152	<0.001**	0.116
-2LL				265.761		
Adjusted R^2				0.139		

Remark: 1) OR means odd ratio 2) χ^2 is the values from Pearson Chi-square Test 3) β is the coefficient of the variable 4) ** significant at 0.01 level 5) * significant at 0.05 level, 6) 15, 70, and 91 seconds are the averages at the study area, 7) -2LL is -2 Log Likelihood

The first factor: vehicle type - Motorcyclists had 2.436 times more chance to cross the railway crossing during the warning signal than the 4-wheeled motorists, possibly due to the agility in riding that allowed them more chance to adopt risk behaviors.

The second factor: road width - The railway level crossing where the road widths were 6 and 7 meters allowed 2.167 and 2.669 times, respectively, more chances for drivers to cross during the warning signal than the road width of 5 meters. This means that the wider the road the higher the chance for drivers to adopt risk behaviors.

The third factor: the period from the beginning of the warning signal until the arm gate closes - The drivers at the crossing where the period from the beginning of the warning signal until the arm gate closed was more than 15 seconds were found to have 1,858 times more chance to cross than those at the crossing where the period was less than 15 seconds. This means that the longer the period between the beginning of warning signal until the arm gate closes, the greater the chances of the drivers to adopt risk behaviors, especially among motorcyclists with more agility in riding. In other words, that makes a greater chance leading to massive accidents that cause losses and death.

Conclusion and Recommendations

This study was conducted on the drivers' crossing behaviors at railway level crossings and the factors influencing the behaviors. The study area was along the northeastern railway route from Khon Kaen to Non-Payom, on 5 crossing points. Observation of drivers' behaviors was conducted by means of a high-resolution camera to record the entering behaviors towards the railway level crossings during the warning signal period. The primary data analysis was based on descriptive statistics, the results of which were used to present the behavioral information and the characteristics of the risk behaviors. Next, the Pearson Chi-square Test was performed to test the relationship followed by the Binary Logistic Regression analyses to determine the anticipated influence of each factor on the risk behaviors.

The results of the study revealed that the proportion of motorcyclists crossing the railway during the warning signal was higher than the 4-wheeled drivers (motorcycles accounting for 45.90% and 4-wheeled vehicles accounting for 21.60%). When considering violations in accordance with the actions, more than half of both groups were risk taking, the remaining proportion was opportunistic. Most violations occurred at the beginning of the warning flashlight, which was the violating action done before the train arrived. If an error or unexpected situation happened from the decision, then the driver risked severe collision and loss. Such action is considered a risk behavior or unsafe action that affects the driver himself and others.

When considering the factors influencing the railway crossing behaviors, the study showed that the decision of drivers, entering the railway crossing during the warning signal, to violate or not significantly depended on the period of time from the beginning of the warning signal until the barrier closed, the road width, and the type of vehicle at the statistical level of 0.05. The chance that the driver would risk was high when the flash light operated longer until the barrier closed, and the width of the road increased. This was especially true among the motorcycle riders with more agility and capacity to avoid obstruction.

The results of the study can be used as the database for finding the approach to control or reduce the chance of such risk behaviors. In general, risk taking was found during the beginning of the warning signal. The action was intentional and the decision process was complicated. The consideration on the safety or assessment of risk was low, and thus the decision was made to act. This process occurred only in few seconds. If such actions recurred, they would become a habit that leads to carelessness, erratic decisions, an unexpected situation, and a severe accident.

Initial approaches could be building or instilling safety attitudes among drivers to make them perceive the massiveness or losses that arise from accidents. They should be informed that the action is risky and unsafe. The attitude or perception of each driver differs and is the element that influences the intention to act. Warning approaches should be increased for road users (Burdzik *et al*., 2017) by adding warning signs or signals on the pavement and an example picture of an accident from not conforming to traffic rules. These could be installed at a point before road users enter the risk area or the railway level crossing. In addition, the warnings could be increased by using the sensor technology or AI to detect the arrival at or approach the railway level crossing in real-time so that road users would recognize the arrival of the train before they made the cross.

The approaches mentioned above could be integrated in parallel with traffic management regulations (Burdzik *et al*., 2017) by improving the physical aspect at the railway level crossing such as adding the central island or equipment indicating the route direction to reduce the road width. Past studies indicated that these are 75-80% efficient. The arm gates can also be lengthened to cover the width of the road that intersects in order to lessen the chance taking to cross the railway before the train arrives. A previous study showed that the efficiency of this measure was 75% (Cooper and Ragland, 2007). Both approaches could be integrated. Finally, law enforcement could be used by detecting traffic violations with the use of technology, which is a measure popular in many countries, and past studies have shown an efficiency of 72% (Cooper and Ragland, 2007).

The approaches recommended above are made based on the results of this study and the implementation in previous studies. They could be the solution and preventive approaches against risky behavior. However, each area has its complications and context. The behaviors of road users also change according to different supporting factors. Therefore, continuous studies should be conducted to find the appropriate means or measures that will sustainably lead to reduced risky behavior and losses in each area.

For further study, if there is a change in the data analysis method as the random parameter model (Wisutwattanasak *et al*., 2022; Wisutwattanasak *et al*., 2023). It may be able to explain more about this risky behavior and reduce the chance of omitted variables from the Pearson Chi-square Test.

Declaration of Competing Interest

The authors have no conflicts of interest in relation to the study described in this journal article.

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