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Research Article

Factors Influencing the Violation Intentions of Pedestrians, Motorcycle Riders, and Car Drivers at Midblock Crosswalks

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ABSTRACT

Traffic rule violations at midblock crosswalks by road users are a critical road safety issue, particularly in developing countries like Thailand. This study aims to explore the factors that influence the intentions behind these violations. Data were collected from 500 pedestrians, 300 motorcycle riders, and 350 car drivers through a questionnaire survey based on the theory of planned behavior (TPB). To assess the validity, reliability, and consistency of the factors, confirmatory factor analysis (CFA) was employed, followed by structural equation modeling (SEM) to examine the factors influencing the intentions to violate traffic rules. The results indicated that attitude was the key predictor of pedestrians' intentions to cross outside the designated crosswalks. Subjective norms were most influential for motorcycle riders, while perceived behavioral control significantly affected car drivers' intentions to not yield to pedestrians. Moreover, the study found that raised platforms and signalized crosswalks have significantly increased pedestrians' and drivers' compliance with traffic rules compared to zebra crossings. These findings suggest that effective road safety interventions could include altering road users' attitudes through licensing programs and road safety campaigns. The subjective norm can communicate the dangers and consequences of traffic rule violations. Traffic engineering measures (e.g., lane narrowing) and strict law enforcement by police officers (e.g., surveillance cameras, license plate recognition cameras) should be used to enhance perceived behavioral control.

Keywords: Factors, Intention, Violation, Midblock crosswalks, Theory of planned behavior.

INTRODUCTION

Pedestrians are vulnerable road users exposed to relatively risky crossing conditions in mixed-traffic environments [1]. Road traffic crashes involving pedestrians constitute a significant road safety problem worldwide [1-2]. According to the WHO report [2], approximately 0.35 million pedestrian fatalities occur each year, accounting for about 23% of all road traffic deaths. The vast majority of pedestrian deaths (92%) occur in low-income and middle-income countries, particularly in developing countries [2].

In developing countries like Thailand, pedestrian fatalities present one of the critical road safety problems [3]. In recent years, the number of pedestrians involving fatalities accounts for more than 6% of total casualties in road traffic crashes on national highways, resulting in an approximate toll of 350 pedestrian deaths per year [4-5]. These statistics indicate the alarming situation of pedestrian safety. Before developing countermeasures, it is essential to identify the factors contributing to pedestrian-related deaths, particularly in Thailand's pursuit of achieving zero road deaths and promoting a safe transport mode for pedestrians [6].

Numerous studies have highlighted the pivotal role of pedestrian and driver behaviors in road traffic crashes and fatalities, for example [7-16]. Regarding pedestrian violations, illegal crossings and disregard for traffic signals are common occurrences driven by convenience and time-saving motives [7-10]. Pedestrians preferred to cross unmarked crosswalks anxiously instead of walking further to cross the designated crosswalk. In addition, many pedestrians who decide to cross the street do not look for oncoming vehicles and dash across without exercising caution [11-14]. On the other hand, dangerous driver behaviors, such as reckless driving, speeding, and failure to yield to pedestrians, significantly heighten collision risk and severity of pedestrian-related crashes [15-16]. Such violations are not due to momentary lapses in judgment but rather represent deliberate deviations from regulations [15-16].

Addressing traffic violations is a complex challenge influenced by various factors. Previous studies have attempted to understand why pedestrians and drivers break traffic rules and offer insights into pedestrian and driver behaviors using the Theory of Planned Behavior (TPB) [8,13,19-24,28-40,42-43,46,48,50-63]. This theory helps explain human behavior by considering attitude, subjective norms, and perceived behavioral control as key psychological factors [17-19]. Most studies [8,13,19-24] indicate that attitude, subjective norm, and perceived behavioral control are significant predictors of pedestrian and driver intentional deviations from traffic rules. For instance, regarding pedestrian behavior, a study in Australia found that the attitude of pedestrians was the most significant factor influencing to cross outside designated crosswalks [13]. Attitude, subjective norm, and perceived behavioral control are the most reliable and essential predictors of pedestrian outside designated crosswalks [19]. Considering driver behavior, research in France [8] and the UK [24] found that the drivers' attitudes strongly indicated intentions to speed and not yield to pedestrians, while perceived behavioral control was a strong predictor of driver intentions not yield to pedestrians [24]. The previous research has predominantly focused on developed countries or cities. In addition, the influence of risk perception on pedestrians' and drivers' intentions to violate traffic rules had not previously been investigated. To bridge these gaps, insight into the differences in the significant factors influencing pedestrians' and drivers' intentions to violate traffic rules in developing countries should be thoroughly investigated.

This study reduces the knowledge gap and provides insights into the complexity of the risky intentions to violate traffic rules of pedestrians and drivers. The study aims to investigate the factors that influence the intentions of traffic rule violations at midblock crosswalks of pedestrians and vehicle drivers (i.e., motorcyclists and passenger car drivers) in developing countries like Thailand. Additionally, it explores the influence of risk perception of traffic rule violation at crosswalks (e.g., zebra crossings, raised pedestrian platforms, and signalized crosswalks) on pedestrians' intentions to cross outside the crosswalk area and motorcycle riders and car drivers' intentions to not yield to pedestrians. The findings provide valuable insights into the factors contributing to road crashes and offer practical recommendations for implementing control measures to address violations by pedestrians, motorcycle riders, and car drivers at midblock crosswalks.

The rest of this paper is structured as follows: following this introduction, Section 2 reviews previous research on the theory of planned behavior and factors influencing pedestrians' and drivers' intentions to violate traffic rules. Section 3 presents the research methodology used in this study, and Section 4 presents a comprehensive discussion of the key findings based on this study. Finally, Section 5 summarizes the significant contributions and suggests future research directions.

LITERATURE REVIEW

1. Theory of planned behavior

The theory of planned behavior (TPB) is one of the most significant theoretical frameworks for forecasting human behavior. TPB is a modified version of the theory of reasoned action that incorporates attitude, subjective norms, and perceived behavioral control for predicting behavioral intentions [17,25-26]. A concept of TPB is that behavioral intention is the most proximal determinant of human social behavior. Intention is influenced by three core constructs: attitude (AT), subjective norm (SN), and perceived behavioral control (PBC) [17]. AT is a person's overall positive or negative evaluation of their behavior. SN is a person's estimate of the social pressure to perform or not perform the target behavior. PBC describes an individual's perception of the ease or difficulty of performing any given behavior. As a rule, the more intention influences behavior, the more PBC increases and behavior is more likely to be performed [17,25-26].

2. Factors influencing pedestrians' intentions to violate traffic rules

Crashes involving pedestrians are attributable not solely to drivers' violations but also to the violations and lapses by pedestrians. The low level of pedestrian safety is often due to non-compliance with traffic rules and unsafe attitudes among pedestrians [27-29]. Numerous studies have employed the TPB to explain the factors influencing pedestrians crossing the road violating the pedestrian lights at midblock crosswalks [10,13,19-21,28-40]. Some previous studies applying TPB to pedestrian crossing behavior indicated that attitude, subjective norm, and perceived behavioral control are the most significant predictors of pedestrians' intentions to cross outside the designated crosswalks [19].

A study by Diaz et al. [20] found that attitude was the strongest predictor of pedestrians' intention to cross the road in front of automated vehicles in risky situations, followed by subjective norm and perceived behavioral control, respectively. The study by Bilema et al. [28] demonstrated that pedestrian behavior significantly affects their intention to comply with traffic regulations or their willingness to take risks by illegally crossing the road. Attitude plays a crucial role; respondents agree that attitudes strongly influence the intention and behavior of pedestrians illegally crossing the road. Several researchers, including Hou et al. [29], Xu et al. [30], Hashemiparast et al. [31], Suo and Zhang [32], Koh and Mackert [33], and Sundararajan et al. [34], have shown that attitude, subjective norms, and perceived behavioral control significantly impact pedestrians' intentions to cross outside the designated crosswalks. A study by Barton et al. [35] found that attitudes and perceived behavioral control are the most significant predictors of pedestrian-distracted crossing behavior and intention to cross outside the designated crosswalks. Specifically, perceived behavioral control is the strongest predictor of pedestrian behavior, suggesting that individuals are more likely to engage in risky situations if they perceive the situation to be easy to perform.

Furthermore, research on applying the TPB to safe road-crossing behavior found significant positive relationships between safe road-crossing behavior and attitude and perceived behavioral control [30]. In contrast, there was a statistically insignificant relationship between safe behavior and subjective norms [36]. Research by Sun et al. [37] indicates that perceived behavioral control and attitude are the strongest predictors of pedestrians' intentions to cross outside the designated crosswalks, while subjective norms were statistically insignificant. Conversely, Piazza et al. [38] found that attitude, subjective norm, and perceived behavioral control significantly predict the intention to use a mobile device while crossing the road. In their study, attitude towards the behavior emerged as the strongest predictor of the pedestrians' intentions to cross outside the designated crosswalks, while perceived behavioral control was the weakest. Findings from Demir et al. [39] demonstrate that perceived behavioral control is the most important predictor of pedestrians' intentions to cross outside the designated crosswalks.

Based on the preceding research, numerous studies have utilized the traditional TPB [10,20,28,32,35,37-38], while others have expanded upon it by incorporating new variables [13,19,21,29-31,33-34,36,39-40]. These extended TPB constructs have been applied to investigate various situational factors and implement control measures to address pedestrians' intentions to cross outside the designated crosswalks. For instance, Evans and Norman [10] showed that moral norms, anticipated affect, and self-identity significantly predicted pedestrians' road-crossing intentions. According to the study of Zhao et al. [13], the TPB was extended by adding new factors, including perceived risk and trust in the vehicle. The results showed that pedestrians had significant intentions to cross the road with a lower risk perception of crossing and greater trust in vehicles. A study by Zhou et al. [21] stated that after adding a descriptive norm, subjective norm and the conformity tendency became robust to predict pedestrians' intentions to cross outside the designated crosswalks. A conformity tendency is a tendency to change behavior when other people perform the same action, such as when a pedestrian has a greater chance to cross the road when other pedestrians cross. Hou et al. [29] added mobile phone involvement and situations to predict pedestrians' distracted behavior while crossing streets in China. The results show that using a mobile phone while crossing reflects a pedestrian's intentions to cross outside the designated crosswalks.

Moreover, research by Xu et al. [30] indicated that a pedestrian's decision to cross the road illegally is influenced by their past behavior, while personal norms and perceived control can predict pedestrians' intentions to cross outside the designated crosswalks. Hashemiparast et al. [31] demonstrated that individuals with low perceived risk and severity exhibit higher risk-taking behavior, leading to more road crashes. Koh and Mackert [33] found that personal norms, self-efficacy, and perceived risks statistically predicted the pedestrians' intentions to cross outside the designated crosswalks. Sundararajan et al. [34] identified perceived consequence and perceived safety as factors positively related to safe pedestrian behavior. Precisely, perceived consequences predict pedestrian involvement in safe crossing, and perceived safety is improved through traffic engineering measures for pedestrian safety. Hemmati and Gharlipour [36] added that the determinant of safe behavior in road crossing significantly impacts pedestrian-safe behavior. Findings from Demir et al. [39] compared the TPB with the prototype willingness model to predict pedestrians' intentions to cross outside the designated crosswalks, showing that willingness is a predictor of pedestrian violation behavior. Improving crosswalks can reduce the willingness to commit violations by removing opportunities for such behavior. Lastly, Soathong et al. [40] introduced habit and social norms as factors, revealing that pedestrians' intentions to cross outside the designated crosswalks are primarily driven by habit and attitude, which are linked to saving travel time and reducing walking distances.

3. Factors influencing drivers' intentions to violate traffic rules

Several prior studies have underscored the significant toll of fatalities and injuries resulting from drivers violating traffic rules [8,24]. The TPB has been a pivotal framework for understanding and predicting drivers' intentions to violate traffic rules, encompassing various behaviors such as reckless driving, speeding, and failure to yield to pedestrians [24,41-42]. The TPB posits that drivers' intentions to not yield to pedestrians may be influenced by their attitudes, subjective norms, and perceived behavioral control [41-42]. Attitude has been identified as the best determinant of intentions for risky driving and speeding, whereas perceived behavioral control is the best indicator for safe driving [42]. Additionally, drivers' yielding behavior may be influenced by their attitude, subjective norms, and perceived behavioral control [41-42].

According to Atombo et al. [15], the TPB effective results revealed that attitude strongly predicted drivers' intentions towards unsafe driving and not yielding to pedestrians. Similarly, Castanier et al. [8] found that attitude significantly positively predicted drivers' intentions to not yield to pedestrians. A study by Rowe et al. [22] designed a questionnaire based on the TPB to identify driver beliefs underlying intentions to drive over the speed limit. Their results indicated that attitudes, subjective norms, and perceived behavioral control affected speeding violations. Another study [43], which conducted an online survey to explore driving behavior in China using the TPB framework, showed that attitude, subjective norm, and perceived behavioral control were significantly correlated with risky driving intentions, which in turn strongly correlated with driving behavior. Additionally, attitudes, subjective norms, and perceived behavioral control influenced drivers' intentions to not yield to pedestrians [44].

Regarding driving behavior, including risky driving and speeding, studies have shown that attitude is the best indicator of intention to engage in risky driving behaviors, while perceived behavioral control is the best predictor of intention to drive safely [15,23,24]. Overall, the results indicate that attitude is the most crucial determinant of intention among the three TPB variables, and intention contributes more significantly to driving behavior than perceived behavioral control. Conversely, subjective norms have an insignificant impact on drivers' intentions to not yield to pedestrians [24,45]. Chan [46] identified that attitude was the strongest predictor of drivers' intentions to not yield to pedestrians. However, Moan and Rise [47] reported that perceived behavioral control significantly affects the drivers' intentions to not yield to pedestrians. Furthermore, a driver's risk perception is critical in determining driving behavior [48-49]. Studies have found that the more robust drivers' intentions to not yield to pedestrians, the risk their behavior tends to be [50-54].

In addition, previous studies have extended the TPB construct by adding new variables to obtain more accurate results in various situations [8,24,42,48,51,55-5960]. For example, descriptive norms are the most important factor influencing drivers' speeding violations in France [51] and Japan [57], traffic violations and unsafe driving practices in Sweden [55-56], and traffic violations in Thailand [58]. Past behavior is the most important factor influencing speeding violation intention in the UK [24], traffic violation intention in France [8], the UK [42,53], Scotland [54], Sweden [55], Japan [57], and Thailand [59], and unsafe driving intention in France [48] and the UK [52]. Moral norms are the most important factors influencing drivers' speeding violations, unsafe driving, and drivers' intentions to not yield to pedestrians in the UK [24,52-53]. Perceived risk, direct risk experience, and facilitating circumstances are the most important factors influencing drivers' unsafe driving in France [48]. Moreover, negative and positive attitudes and intentions significantly predicted traffic violation behavior in France [60].

In summary, previous research [8,10,13,19-21,24,28-40,42-63] primarily delves into the intricate details of factors influencing pedestrian and car driver intentions to violate traffic rules, particularly in developed countries. However, the factors influencing pedestrians, motorcycle riders, and car drivers' intentions to violate traffic regulations at midblock crosswalks have not been investigated. Moreover, this study seeks to fill a gap in the literature by investigating the issue comprehensively through an extended TPB framework, focusing on the risk perception of traffic rule violation at crosswalks (e.g., zebra crossings, raised pedestrian platforms, and signalized crosswalks) to predict the relationship between risk perception and the intentions to violate traffic regulations. Hence, it would be interesting to provide valuable insights into the factors contributing to road crashes and offer practical recommendations for implementing control measures to address violations by pedestrians, motorcycle riders, and car drivers at midblock crosswalks. Details of the research methodology are presented in the next section.

METHODS

1. Study area

This study was conducted in Hat Yai, the largest city in Songkhla province and the fifth-largest city in Thailand [64]. The midblock crosswalk is in front of the Hat Yai Hospital. The road section considered in this study is known for its high-speed traffic, poor enforcement, pedestrians crossing outside the designated area, and drivers not yielding to pedestrians, which are some of the most dangerous behaviors and a significant safety problem. In addition, there is a lack of safety countermeasures for traffic calming. The above-mentioned circumstances and issues have resulted in a substantial risk of vehicle-pedestrian collision at midblock crosswalks in this area. To decrease this risk, the crosswalk has been upgraded from a typical zebra crossing to a raised pedestrian platform, leading to a notable reduction in vehicle speed owing to better visibility of the crosswalk and a significant increase in the rate of drivers yielding to pedestrians. However, land use and roadside areas along the crosswalk corridor are a mix of residential buildings, commercial buildings, convenience stores, and high pedestrian activities. The mixed traffic environment continues to pose risks and traffic violations for pedestrians, motorcyclists, and car drivers. The problems in this study area can also be found in many other cities in Thailand.

Regarding traffic data before the upgrade, it was observed during the morning peak hours (7:00 a.m.-9:00 a.m.) and afternoon peak hours (4:00 p.m.-6:00 p.m.) and found that the average number of pedestrian crossings was 195 persons per hour. Most pedestrian crossings use hospital services, including patients, relatives of patients, and hospital staff. Children and the elderly also use this crosswalk. The average vehicle traffic volume was found to be 2,680 vehicles per hour. The proportion of vehicles during the peak hours was observed that passenger cars accounted for 57% of all transport modes, followed by motorcycles (41%) and other vehicles (2%). Thus, this study focused on pedestrians, motorcycle riders, and car drivers.

2. Research hypotheses and the proposed models

This study utilizes the extended theory of planned behavior and then investigates the impact of each factor using structural equation modeling. Accordingly, this study proposed the following hypotheses:

• H1: Intention positively affects behavior.

• H2: Attitude positively affects intention.

• H3: Subjective norm positively affects intention.

• H5: Perceived behavioral control positively affects intention.

• H5: Risk perception positively affects intention.

• H6: Zebra crossing positively affects risk perception.

• H7: Raised pedestrian platform positively affects risk perception.

• H8: Signalized crosswalks positively affect risk perception.

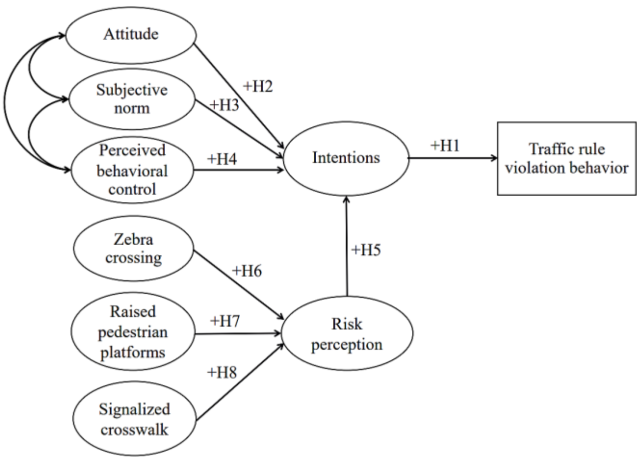


Figure 1. Hypothetical model explaining pedestrians/drivers' intentions to traffic violation behavior.

3. Data collection

3.1 Sample group and participants

The sample group consisted of pedestrians, motorcycle riders, and car drivers who held driving licenses and traveled by passenger vehicles (cars and pickup trucks) in the study area. The study determined the sample size (n) according to the structural equation analysis, which states that the sample size should be greater than 100, and the number of variances minus the total variance of the observed variables (P), which is equal to P(P+1)/2 or 10-20 times the number of observed variables (P) [17]. This study has a total of 19 observable variables (p); therefore, the sample size must be no less than max ((19*20)/2, 15*19) = 285 samples. Therefore, the study will collect no less than 300 samples.

The formal survey was conducted in the crosswalk area by personal interviews with pedestrians at the crosswalk and with drivers of vehicles parking in the study area. Respondents were randomly selected, individually approached, and asked if they would participate in the interview. Under their agreements, respondents completed a written questionnaire in a public place. The steps in the interview were: 1) explaining the background of the research and the parts of the questionnaire, 2) the informants answered the questionnaire approximately 10-20 minutes, and 3) the researcher collected the questionnaire and ensured the completion of the questionnaire.

3.2 Questionnaire design

Data for this study were collected from the survey. A carefully designed questionnaire was the first step to ensure that the data were reliable and valid for further analysis. The questionnaire was divided into two main parts. The first part consisted of questions measuring the demographic data of pedestrians and drivers. The second part developed psychological questionnaires to examine the latent variables following the TPB framework [17-18].

3.2.1 Demographic survey questions

Demographic data of pedestrians and drivers were collected, including gender, age, educational background, frequency of violating traffic rules, frequency of crossing the road, driving frequency, driving experience, and involvement in active or near-miss crashes in the last three years.

3.2.2 TPB survey questions

In this study, some scenarios of pedestrians and drivers violating traffic rules at midblock crosswalks were generated and explained to encourage respondents to imagine themselves in the scenario described. Regarding pedestrian behaviors, the traffic rule violation was focused mainly on crossing outside the crosswalk area. On the other hand, traffic rule violations concerning car driver and motorcycle rider behaviors were considered primarily due to not yielding to pedestrians crossing. The survey questions in the TPB questionnaire were a total of 19 questions that were considered to elicit participants' responses on TPB. Each question was on a five-point Likert scale related to the pedestrians' and drivers' intentions to violate traffic rules at the midblock crosswalk.

This study also focused on the type of midblock crosswalk and how it affects road users' risk perception of traffic rule violations at crosswalks. Three types of midblock crosswalks, as shown in Figure 2, include a) zebra crossing in the study area before the upgrade, b) raised pedestrian platforms in the study area after the upgrade, and c) signalized crosswalk (if there is an upgrade to a signalized crosswalk). The last two types of crosswalks were included in the study because they could reduce vehicle speed and increase driver yielding to pedestrians [65-69]. However, in Thailand, most drivers and riders continue to engage in risky behaviors, such as accelerating during the yellow light and running through the signalized crosswalk during the red light. In addition, the raised pedestrian platform is not yet widely implemented on urban streets in Thailand, but internationally, it has effectively decreased conflicts between pedestrians and vehicles and reduced violations by both pedestrians and drivers [68-69]. It is interesting to explore the influence of pedestrians' and drivers' psychological responses differently to determine a more effective type of midblock crosswalk. Therefore, additional questions were asked regarding the preferred type of crosswalks (zebra crossing, raised safety platform, or signalized crosswalk).

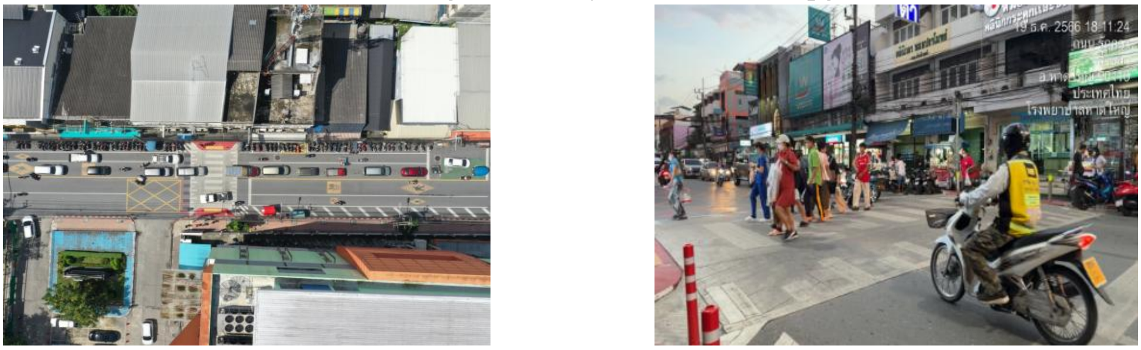
3.3 Questionnaire survey

The questionnaire survey was collected on weekdays during the 18th and 19th of January 2024 and on weekends during the 20th and 21st of January 2024. Note that the questionnaire survey was conducted three months after the raised pedestrian platforms were implemented to observe long-term intention and behavioral changes in pedestrians crossing outside the crosswalk area. Motorcycle riders' and car drivers' not yielding to pedestrians were also expected to reduce.

3.4 Data screening

Participants were 520 pedestrians, 315 motorcycle riders, and 370 car drivers who volunteered to participate in the study. A careful examination was conducted in the survey, and questionnaires were returned. Respondents with missing data were removed after removing incomplete and extreme data (i.e., respondents had incomplete responses with more than 10% missing data of all questions). Out of the distributed questionnaires, 20 pedestrians, 15 motorcycle riders, and 20 car drivers missed answering more than 10% of the questions or failed to answer the screening questions. After the data screening process, the remaining data from 500 pedestrians, 300 motorcycle riders, and 350 car drivers were ready for further analysis. This sample size was consistent with previous studies [13,39-40,42,53].

a) Zebra crossing in the study area before the upgrade



b) Raised pedestrian platforms in the study area after the upgrade

c) The example of a signalized crosswalk

Figure 2. Three types of pedestrian crossings

4. Data analysis

4.1 Descriptive analysis of the respondent's characteristics

The data analysis initially examined descriptive statistics to observe general trends and variability in pedestrian, rider, and driver characteristics, demographics, and the distribution of observed variables. This summary encompassed vital measures, including the frequency distribution.

4.2 Confirmatory factor analysis

Confirmatory factor analysis (CFA) is a subset of structural equation modeling focusing exclusively on measurement models. CFA with principal component extraction was performed to investigate the underlying structure of TPB items. It examines the connections between observed measurements or indicators and latent variables or factors. CFA can be used for measurement invariance analysis, construct validation, and method effect identification [70]. The most common use of CFA is to investigate the latent structure of a test instrument during scale development. In this study, after performing CFA, convergent reliability was evaluated using composite reliability (CR), average variance extracted (AVE), and Cronbach's alpha [70]. The CR value of each latent variable was computed, as indicated in Equation (1),

$$\mathrm{CR} = \frac{(\sum_{i=1}^{n} FL_i)^2}{(\sum_{i=1}^{n} FL_i)^2 + (\sum_{i=1}^{n} ME_i)} \tag{1}$$

Where FL_i denotes the standardized factor loadings of measurement item i, n denotes the number of items within a factor, ME_i refers to the error in measurement.

The AVE is a metric for comparing the variation captured by a construct to the variance resulting from measurement error, as indicated in Equation (2),

$$\mathrm{AVE} = \frac{\sum_{i=1}^{n} FL_i^2}{n} \tag{2}$$

The acceptable values for CR and AVE are considered more significant than 0.6 and 0.5, respectively [70]. Additionally, comparisons between the AVE square roots and correlation estimates demonstrated the discriminant validity of the measurement. Discriminant validity was assessed using the square root of AVE. Each latent variable had acceptable discriminant validity when the square root of its AVE was more significant than the correlation between this variable and the other latent variables [70]. Cronbach's alpha test was performed on each factor to determine the reliability of the constructed latent variables before initiating the CFA model. Following [71], this study set a cut-off value for each factor to be greater than 0.7.

4.3 Modeling of pedestrians' and drivers' intentions to violate traffic rules

This study developed structural equation modeling (SEM) for the pedestrian, motorcycle rider, and car driver models to identify attitude, subjective norm, perceived behavioral control, and risk perception associated with influencing the pedestrian intentions outside the crosswalk area and driver's (or rider's) intentions not yielding to pedestrians at midblock crosswalks in the study area.

SEM combines CFA and regression analysis, allowing for the modeling of complex regression structures (path models) at the level of latent variables. SEM was employed to investigate relationships involving one or more independent variables, both continuous and discrete, and one or more dependent variables. This study utilized the SEM to analyze the factors (attitude, subjective norm, perceived behavioral control, and risk perception) positively related to the pedestrian's intentions to cross outside the designed area and the driver's intentions not yield to pedestrians at midblock crosswalks. The SEM equation was calculated, as indicated in the Equation (3),

$$\eta_j = \alpha + \mathrm{B}\eta_j + \Gamma x_j + \zeta_j \tag{3}$$

Where η_j represents the j-th endogenous latent variable, α is an intercept vector, B is a matrix of structural parameters governing the relations among the latent variables, Γ is a regression parameter matrix for regressions of latent variables on observed explanatory variables, x_j is the j-th exogenous variable, and ζ_j is a vector of structural disturbances or error terms associated with the endogenous latent variable.

This study considered several fit indices to validate the model and its overall fitness. The standardized estimate value for all items of the latent variables was more significant than 0.8 [72]. The chi-square freedom ratio was used to represent the weighted analysis of the model's freedom ratio of less than 2.0 [71]. The cut-off values for the modification and goodness-of-fit indices (GFI, CFI, AGFI, NFI, and TLI) were more significant than 0.9. The values for the overall fitness of the model, RMSEA, and SRMR were less than 0.08, and RMR was less than 0.10. [71-73].

RESULTS AND DISCUSSION

1. Results of descriptive statistics of respondents

Table 1 presents the results of descriptive statistics on the demographic characteristics of all respondents. Regarding the pedestrians, 48.4% were male, while 51.6% were female. Most (39.4%) were between 25 and 35 years old, indicating a young adult demographic. Regarding educational background, a significant % of pedestrians (67.0%) held a bachelor's degree. Furthermore, 46.9% of the pedestrians reported crossing the study road 1-2 times per week. The survey also assessed the frequency of traffic rule violations. The results showed that 40.5% of pedestrians sometimes crossed the road outside the designated area, while 25.9% often did.

Considering the drivers and riders, the demographic characteristics of motorcycle riders and car drivers and driving behavior trends were quite similar. Among the respondents, more than 55% of motorcycle riders and car drivers were male, with the remaining being female. The age distribution varied between the two groups; most motorcycle riders (40.5%) were 36-45 years old, while most car drivers (48.6%) were 25-35 years old. Regarding educational background, 51.8% of motorcycle riders had bachelor's degrees, and 47.3% had educational qualifications below a bachelor's degree. Conversely, for car drivers, 47.8% had bachelor's degrees, followed by those with educational qualifications above a bachelor's degree (27.5%).

Concerning driving frequency, motorcycle riders and car drivers reported traveling through the study area 3-6 times weekly, with an average driving experience of 6-10 years. The survey also assessed the frequency of traffic rule violations at midblock crosswalks, particularly not yielding to pedestrians. The results indicated that motorcycle riders were more likely not to yield to pedestrians sometimes (45.2%) compared to car drivers (36.7%), representing a difference of 8.5%.

Table 1. Demographic characteristics of respondents

Respondent characteristics	Frequency (%)		
	Pedestrian	Motorcycle rider	Car driver
Gender			
1=Male	48.4%	55.7%	61.4%
2=Female	51.6%	44.3%	38.6%
Age, year			
1=<25	1.8%	2.5%	7.2%
2=25-35	39.4%	38.6%	48.6%
3=36-45	38.6%	40.5%	40.2%
4=>45	20.2%	18.4%	4.0%
Education			
Below bachelor	31.6%	47.3%	24.7%
Bachelor	67.0%	51.8%	47.8%
Above bachelor	1.4%	0.9%	27.5%
Frequency of violating traffic rules			
1=Never	20.4%	10.9%	13.5%
2=Seldom	10.4%	29.8%	32.2%
3=Sometimes	40.5%	45.2%	36.7%
4=Often	25.9%	10.1%	12.3%
5=Always	2.8%	4.0%	5.3%
Frequency of crossing the study road			
1-2 times/month	43.8%	-	-
1-2 times/week	46.9%		
1-2 times/day	8.6%		
More than 2 times/day	0.7%		
Driving frequency			
Every day	-	8.5%	10.6%
5-6 days/week		29.4%	30.8%
3-4 days/week		48.6%	46.5%

Respondent characteristics	Frequency (%)		
	Pedestrian	Motorcycle rider	Car driver
1-2 days/week		13.5%	12.1%
Driving experience (years)			
< 3 years	-	11.2%	6.6%
3-5 years		28.4%	32.6%
6-10 years		39.8%	41.5%
> 10 years		20.6%	19.3%
N	**500**	**300**	**350**

2. Results of confirmatory factor analysis

Table 2 shows the results of Cronbach's alpha, CR, and AVE values, demonstrating that reliability and validation followed an excellent internal consistency rule, thereby suggesting adequate convergence. The CR and AVE values represent all factors greater than 0.6 and 0.5, respectively [70]. As a result, these values explain the factors influencing the pedestrians' intentions to cross outside the crosswalk area and motorcycle riders' and car drivers' intentions to not yield to pedestrians.

The results of the reliability scales and correlation matrix for the TPB model are outlined in Table 3. All factors (AT, SN, PBC, and RP) correlated with the IN variable at the 0.1% levels of significance. The IN variable of pedestrians has the highest correlation coefficient with AT; motorcycle riders' highest correlation is attributed to SN. On the other hand, the highest correlation between car drivers is attributed to PBC.

Furthermore, Table 4 presents the parameter estimates for the CFA model. The correlation test results showed that Cronbach's alpha value of all factors was more significant than 0.7, indicating high reliability and internal consistency of the factor structure [71-73].

Table 2. Reliability estimation and construct validation for TPB item

Factors	Models											
	Pedestrian				Motorcycle rider				Car driver			
	SD.	α	CR	AVE	SD.	α	CR	AVE	SD.	α	CR	AVE
IN	2.5	0.89	0.77	0.75	1.7	0.90	0.85	0.70	1.4	0.89	0.82	0.71
IN1	2.2	-	-	-	1.8	-	-	-	1.5	-	-	-
IN2	2.0	-	-	-	2.0	-	-	-	1.6	-	-	-
IN3	1.9	-	-	-	1.6	-	-	-	1.1	-	-	-
AT	2.5	0.75	0.73	0.67	2.4	0.87	0.80	0.69	1.6	0.86	0.79	0.73
AT1	2.0	-	-	-	2.1	-	-	-	1.8	-	-	-
AT2	2.2	-	-	-	2.1	-	-	-	1.4	-	-	-
AT3	1.8	-	-	-	1.9	-	-	-	1.7	-	-	-
AT4	1.9	-	-	-	1.8	-	-	-	1.3	-	-	-
SN	1.8	0.88	0.68	0.58	2.3	0.89	0.77	0.71	1.6	0.90	0.80	0.68
SN1	2.0	-	-	-	1.8	-	-	-	1.2	-	-	-
SN2	1.9	-	-	-	1.6	-	-	-	1.2	-	-	-
SN3	2.4	-	-	-	1.7	-	-	-	1.7	-	-	-
PBC	2.3	0.84	0.66	0.53	1.4	0.85	0.74	0.68	1.4	0.87	0.75	0.67
PBC1	2.0	-	-	-	1.3	-	-	-	1.8	-	-	-
PBC2	2.0	-	-	-	1.8	-	-	-	1.9	-	-	-
PBC3	2.4	-	-	-	1.6	-	-	-	1.5	-	-	-
RP	2.4	0.79	0.80	0.71	1.6	0.87	0.76	0.74	1.6	0.85	0.73	0.69
RP1	2.2	-	-	-	1.5	-	-	-	1.8	-	-	-
RP2	2.1	-	-	-	1.8	-	-	-	1.4	-	-	-
RP3	2.0	-	-	-	1.9	-	-	-	1.2	-	-	-

Factors	Models											
	Pedestrian				Motorcycle rider				Car driver			
	SD.	α	CR	AVE	SD.	α	CR	AVE	SD.	α	CR	AVE
ZC	2.6	0.89	0.69	0.69	1.4	0.81	0.71	0.69	1.3	0.83	0.76	0.65
ZC1	2.4	-	-	-	1.4	-	-	-	1.1	-	-	-
ZC2	2.0	-	-	-	1.3	-	-	-	1.0	-	-	-
ZC3	2.1	-	-	-	1.7	-	-	-	1.0	-	-	-
RPP	2.3	0.91	0.62	0.58	1.8	0.90	0.74	0.65	1.3	0.88	0.70	0.69
RPP1	1.8	-	-	-	1.5	-	-	-	1.2	-	-	-
RPP2	2.4	-	-	-	1.6	-	-	-	1.4	-	-	-
RPP3	2.3	-	-	-	1.4	-	-	-	1.1	-	-	-
SC	2.3	0.90	0.65	0.65	1.6	0.89	0.75	0.67	0.9	0.87	0.77	0.70
SC1	2.2	-	-	-	1.8	-	-	-	1.5	-	-	-
SC2	1.9	-	-	-	1.9	-	-	-	1.2	-	-	-
SC3	2.4	-	-	-	1.5	-	-	-	1.4	-	-	-

Note: SD= Std. Deviation α = Cronbach (alpha), CR =Constructe Reliability and AVE =Average Variance Extracted

Table 3. Correlations with intentions to violate the traffic rules

Factors	Correlations (r)*		
	Pedestrian	Motorcycle rider	Car driver
AT	0.64	0.48	0.46
SN	0.40	0.60	0.51
PBC	0.45	0.55	0.58
RP	0.43	0.50	0.40
ZC	0.38	0.42	0.34
RPP	0.35	0.40	0.36
SC	0.39	0.45	0.39

Note: * All latent variables are significant at a 0.1% level of significance

Table 4. Parameter estimate and factor loading for the CFA model

Factors	Indicator	Models					
		Pedestrian		Motorcycle rider		Car driver	
		Std. Error	Standardized estimates	Std. Error	Standardized estimates	Std. Error	Standardized estimates
IN	IN1	0.09	0.86	0.04	0.85	0.05	0.86
	IN2	0.07	0.88	0.05	0.86	0.06	0.89
	IN3	0.08	0.82	0.07	0.87	0.06	0.85
AT	AT1	0.07	0.84	0.06	0.85	0.08	0.85
	AT2	0.07	0.81	0.06	0.81	0.07	0.81
	AT3	0.06	0.86	0.04	0.82	0.10	0.82
	AT4	0.09	0.89	0.08	0.87	0.09	0.87
SN	SN1	0.08	0.90	0.09	0.89	0.09	0.89
	SN2	0.08	0.91	0.08	0.90	0.08	0.90
	SN3	0.09	0.85	0.11	0.87	0.07	0.87
PBC	PBC1	0.10	0.83	0.10	0.90	0.05	0.90
	PBC2	0.09	0.87	0.13	0.91	0.05	0.91
	PBC3	0.11	0.89	0.07	0.89	0.06	0.89

Factors	Indicator	Models					
		Pedestrian		Motorcycle rider		Car driver	
		Std. Error	Standardized estimates	Std. Error	Standardized estimates	Std. Error	Standardized estimates
RP	RP1	0.08	0.90	0.05	0.88	0.07	0.88
	RP2	0.08	0.94	0.06	0.86	0.07	0.86
	RP3	0.07	0.93	0.06	0.87	0.06	0.87
ZC	ZC1	0.09	0.89	0.07	0.93	0.08	0.93
	ZC2	0.06	0.87	0.09	0.88	0.10	0.88
	ZC3	0.08	0.84	0.10	0.89	0.09	0.89
RPP	RPP1	0.08	0.93	0.07	0.89	0.06	0.89
	RPP2	0.07	0.95	0.09	0.90	0.07	0.90
	RPP3	0.08	0.91	0.11	0.91	0.07	0.91
SC	SC1	0.07	0.86	0.05	0.87	0.10	0.87
	SC2	0.07	0.84	0.07	0.84	0.11	0.84
	SC3	0.08	0.88	0.08	0.83	0.08	0.83

Note: Statistically significant is set at a 1.0% level

3. Factors influencing pedestrian and driver intentions to violate traffic rules

The estimated goodness-of-fit (GOF) measurements and parameters are presented in Table 5. The results highlight the factors influencing the indexes with standardized path coefficients for pedestrians, motorcycle riders, and car drivers. Concerning modification indices, the values obtained for GFI, CFI, AGFI, RMR, RMSEA, SRMR, NFI, and TLI indicate that the model fit passes several recommended fit indices [71-73]. Therefore, the model fits the theoretical and observational constructs. Figures 3 to 5 display the SEM results with standardized path coefficients for pedestrians, motorcycle riders, and car drivers. The standardized estimate values of all items related to each latent variable were more significant than 0.8, indicating a strong relationship between an item and a factor [73]. Based on the SEM results, the research hypothesis was confirmed to be statistically significant. Overall, the results illustrate that attitudes, subjective norms, perceived behavioral control, and risk perception significantly influence pedestrians' intentions to cross outside the crosswalk, and motorcycle riders' and car drivers' intentions to not yield to pedestrians.

3.1 Factors influencing pedestrians' intentions to cross outside the crosswalk area

Figure 3 illustrates that TPB explained 39% of the variance in the pedestrians' intentions to cross outside the crosswalk area. The variance explained by the actual pedestrians' behavior to cross outside the crosswalk area was 42%.

Regarding the factors affecting pedestrians' intentions to cross outside the crosswalk area, the attitude had a significant positive and more substantial effect on the intentions to cross outside the design area, with a standardized path coefficient of 0.53. Pedestrians may perceive the benefits of crossing outside the crosswalk area, such as saving time or reaching their destination more quickly. This finding is consistent with previous studies [21,28,38], which found that attitude was the most significant factor that strongly influenced pedestrians' intentions to cross outside the crosswalk area. Implications in application for changing pedestrians through public awareness campaigns and education on the dangers of crossing outside designated crosswalks using media, including social media, billboards, and public service announcements. Emphasize risk perception by highlighting real statistics on pedestrian crashes.

Meanwhile, subjective norms positively affect pedestrians' intentions to cross outside the crosswalk area. Pedestrians may be influenced by the behavior and opinions of their social circle, such as friends or family. If a prevailing norm violates acceptable or standard traffic rules, pedestrians may be more inclined to follow them. In other words, the actions of family members and friends are more influential on pedestrians than they approve of the behavior. This finding is consistent with a previous study [13,19-20,40] indicating that pedestrians were influenced by their family members or friends. However, the result in this study contradicts another study [39], which found that subjective norms did not significantly pedestrians' intentions to cross outside the crosswalk area. This inconsistency may be due to differences in pedestrian safety measures, enforcement practices, and adherence to traffic rules across countries. The implications for subjective norms influencing pedestrians' are crucial to shifting peer influences to discuss road safety and act as role models by using designated crosswalks, which can emphasize the importance of using crosswalks.

Perceived behavioral control significantly impacted pedestrians' intentions to cross outside the crosswalk area. Pedestrians believe they have control over factors (e.g., traffic flow and gap acceptance) affecting their ability to violate traffic rules. Pedestrians take risks only when they are fully confident in their ability and feel complete control over the traffic situation. This finding is consistent with previous research [37-39], which showed that perceived behavioral control influenced intentional deviations outside crosswalks. To enhance perceived behavioral control and discourage pedestrians from crossing outside designated crosswalks, it is essential to reduce perceived barriers, increase perceived ease of compliance, reduce waiting times at signals, and ensure well-maintained pedestrian infrastructure. Additionally, enforcement measures, such as visible police presence or automated monitoring, can increase pedestrians' sense of external control over their behavior.

Additionally, risk perception can significantly affect pedestrians' intentions to cross outside the crosswalk area. Pedestrians perceive lower risks associated with violating pedestrian rules and may be more inclined to engage in such behaviors. Similarly, pedestrians perceive that the risk of adverse outcomes, such as crashes or fines, is low; they may be more likely to intentionally deviation from traffic rules. Traffic-calming measures, such as flashing warning signs, speed bumps, and pedestrian countdown signals, can make crossing at designated locations feel safer and more predictable. Law enforcement efforts, including warnings and penalties for violations, can also reinforce the perceived consequences of unsafe crossing.

Regarding the type of crosswalks, a zebra crossing had significantly stronger adverse effects on pedestrian risk perception than a raised pedestrian platform and a signalized crosswalk, with a standardized path coefficient of 0.54. The zebra crossing makes pedestrians less visible, particularly under adverse weather conditions (e.g., raining, fogging) or at night. Its minimal safety equipment for pedestrians and lack of maintenance can influence pedestrians' psychological perception of safety. This finding is consistent with previous research [65-67], which showed that zebra crossings are still unsafe, and pedestrians may perceive a higher risk because they are exposed to high traffic volumes and vehicles speeding over the limit. Installing high-contrast pavement markings, raised crosswalks, and pedestrian-activated signals can increase driver awareness and encourage pedestrian compliance. Reducing crossing distances through curb extensions or median refuges can make zebra crossings more convenient and attractive.

On the other hand, a signalized crosswalk significantly and positively affected pedestrian risk perception. One possible reason pedestrians might disobey signalized crosswalks is impatience or time constraints, which compels them to judge the speed and distance of oncoming vehicles quickly. Pedestrians become more alert and anxious when drivers ignore signals. The uncertainty about whether drivers will stop or not increases the perceived risk of crossing, even if the pedestrian signal indicates it is safe. These findings align with previous studies [65-67], which demonstrate that the signalized crosswalk significantly influences pedestrian risk perception and that non-compliance with signals is associated with crash rates. Reducing pedestrian wait times by optimizing signal cycles and implementing pedestrian-activated signals can increase compliance, particularly for vulnerable pedestrians. Law enforcement measures, such as fines or automated pedestrian violation detection, can further reinforce compliance.

Lastly, a raised pedestrian platform significantly and positively impacted pedestrian risk perception, as pedestrians were perceived as having a lower risk than a zebra crossing. The physical elevation of the platform gradually slows down approaching vehicles and allows pedestrians to be more visible at the crosswalk area. The elevated position of the platform also allows pedestrians to assess traffic conditions before crossing, thereby contributing to a sense of control and safety. Additionally, the raised platform physically separates pedestrians from vehicular traffic, clearly delineating space and reducing the likelihood of interaction between pedestrians and vehicles. This finding is consistent with the results of previous studies [68-69]. Additional traffic-calming measures, such as speed limits, reflective signs, and overhead lighting can increase platform visibility, making pedestrians more likely to use designated crossings.

3.2 Factors influencing motorcycle riders and car drivers' intentions to not yield to pedestrians

Figures 4 and 5 illustrate that TPB explained 34% and 37% of the variance in the motorcycle riders and car drivers' intentions to not yield to pedestrians at midblock crosswalks, respectively. The variance explained by the actual behavior of motorcycle riders and car drivers not yielding to pedestrians was 38% and 40%, respectively. The results showed that subjective norms emerged as the most crucial predictor of motorcycle riders' intentions to not yield to pedestrians with a standardized path coefficient of 0.40. However, little difference was observed in the effect of subjective norms (0.40) and perceived behavioral control (0.38) for predicting intentions to not yield to pedestrians. In contrast, perceived behavioral control had the highest influence on car driver intentions to not yield to pedestrians, with a standardized path coefficient of 0.48.

The above results imply that motorcycle riders may perceive themselves as more agile, able to maneuver through narrow spaces and circumvent traffic congestion. Their perception of being less conspicuous than car drivers, owing to the smaller dimensions of their vehicles, renders subjective norms a significant determinant of their inclination to intentions to not yield to pedestrians. In contrast, passenger car drivers are typically subject to stricter adherence to traffic norms due to the physical limitations of their vehicles and the higher risks associated with intentions to not yield to pedestrians. Consequently, perceived behavioral control tends to be a more critical factor for car drivers. Car drivers typically offer more excellent stability than motorcycle riders do and have a stronger sense of control over their vehicles. Car drivers may prioritize factors such as their awareness of road conditions and their perceived ability to control their behavior.

Attitude significantly affects motorcycle rider and car driver's intentions to not yield to pedestrians. When drivers believe they did not yield to pedestrians without being caught or causing harm. These attitudes may stem from the belief that the benefits of violating outweigh the potential consequences. Moreover, Thai drivers were often less educated or trained in obeying traffic laws, particularly in crosswalk areas, resulting in higher violations than conventional compliance under Thai traffic laws. This finding is consistent with previous studies [46], which identified attitude as the strongest predictor of intentional deviations from traffic rules. This aspect of the obtained results differs somewhat from existing studies conducted in developed countries [8,22]. The difference in results can be attributed to education levels and awareness in developing countries.

Subjective norms also significantly impacted driver intentions to not yield to pedestrians because drivers often observe the behavior of others on the road, including friends, family members, and other motorists. If they witness others regularly not yielding to pedestrians without consequences, they may perceive this behavior as usual and be more likely to imitate it. The results correspond to the typical collectivist society of Thai culture, in which people are more motivated to conform to group norms. This finding is consistent with the results obtained in a previous study [58], which found that young motorcyclists rely on perceived social pressure to perform red light running and intentions to violate traffic regulations. Similarly, the finding is consistent with international research [42,46,53-54]. Encouraging local communities, and driving schools, to promote pedestrian-friendly driving behavior can shift group norms. Highlighting positive role models (e.g., respected drivers, or law enforcement) can reinforce this norm.

In addition, perceived behavioral control significantly affected driver intentions to not yield to pedestrians. The driver's intentions to not yield to pedestrians appear to be motivated mainly by the driver's perceptual capacity and behavioral autonomy. This positive relationship implies that drivers with higher levels of perceived behavioral control are more confident in their ability to execute driving behaviors, including the decision to not yield to pedestrians. Perceived behavioral control encompasses drivers' evaluations of constraints such as traffic conditions, road infrastructure, and enforcement measures. This result aligns with previous findings in Thailand, indicating that perceived behavioral control significantly affects the intention to violate traffic rules [63] and red-light running behavior [58]. The finding is also consistent with international studies [24,44,47], which found that perceived behavioral control was the most significant factor strongly influencing drivers not yielding to pedestrians. To change perceived behavioral control, interventions should focus on strengthening traffic law enforcement through police presence, and automated enforcement (e.g., red-light cameras and license plate recognition) can deter drivers from ignoring pedestrian right-of-way.

An interesting discovery of this study is identifying new risk perception factors of traffic rule violation at crosswalks (e.g., zebra crossings, raised pedestrian platforms, and signalized crosswalks) on violation intentions not previously recognized in other studies. Among these newly identified factors is drivers' risk perception, which can significantly affect driver intentions to not yield to pedestrians. Drivers believe violating a rule will lead to personal benefits, such as saving time or avoiding inconvenience; they may be more willing to take the risk despite the potential consequences. Factors influencing drivers' risk perception include past driving experience, knowledge of traffic laws, perceptions of road conditions and traffic patterns, and cultural norms. Increasing penalties for failing to yield, such as higher fines, and license points, can heighten drivers' perceived risk of non-compliance.

Regarding the type of crosswalk, a zebra crossing significantly affected driver risk perception and exhibited a more significant difference in standardized path coefficients than a raised pedestrian platform and a signalized crosswalk. The zebra crossing often lacks traffic control devices such as traffic lights and pedestrian signs, leading to uncertainty among drivers about when to yield to pedestrians, thereby increasing their perceived risk of potential conflicts. Drivers may experience uncertainty about yielding, mainly when pedestrian behavior is unpredictable, leading to a heightened perceived risk of collisions. The findings in this study are consistent with previous research [65-67], which illustrates that zebra crossings increase the perceived risk for drivers, as they may have less time to react to pedestrians crossing. Traffic calming measures such as reducing lane widths near zebra crossings, and creating pedestrian refuge islands can enhance driver awareness and make yielding behavior more intuitive.

A signalized crosswalk significantly and positively affected driver risk perception. One likely reason is that the signalized crosswalk enhances visibility to drivers, indicating pedestrians' road rights more emphatically, improving overall traffic management, and reducing the risk of collisions compared to zebra crossings. However, the multiple signal phases and varying traffic flow management can add complexity for drivers when interpreting and yielding to pedestrians. A minority of drivers still do not yield to pedestrians and accelerate during the yellow light or at the beginning of the red-light phase. These findings are consistent with previous studies [65-67]. Implementing advanced signal systems such as smart crosswalks with vehicle detection sensors can adjust signal phases dynamically and penalize drivers who fail to yield at red lights, creating a strong deterrent for non-compliance.

Lastly, a raised pedestrian platform significantly and positively impacted driver risk perception and had a lower effect on risk perception than a zebra crossing and a signalized crosswalk. The raised pedestrian platform serves as a traffic calming measure designed to alter the physical to influence drivers' perception encouraging them to modify their decision-making processes and reduce vehicle speed. The physical elevation of the raised pedestrian platform creates a clear separation between the pedestrian and vehicular traffic lanes. This separation provides a visual cue to drivers that pedestrians have priority in the designated crossing area, minimizing ambiguity and reducing pedestrian-vehicle interactions. This finding is consistent with the results of previous studies [68-69]. Integrating speed-reducing measures such as combining raised platforms with additional traffic-calming measures such as road narrowing, or chicanes can further reduce vehicle speeds, encouraging drivers to stop for pedestrians.

Table 5. Estimated GOF measures and parameters

Index	Model fit	Models		
		Pedestrian	**Motorcycle rider**	**Car driver**
X^2	-	210.71	254.91	268.77
Chi-square/df	<2.00	1.24	1.29	1.49
GFI	>0.90	0.93	0.94	0.97
CFI	>0.90	0.91	0.93	0.96
AGFI	>0.90	0.93	0.93	0.96
RMR	≤0.10	0.05	0.08	0.04
RMSEA	<0.08	0.04	0.06	0.04
SRMR	≤0.08	0.03	0.07	0.04
NFI	>0.90	0.95	0.94	0.97
TLI	>0.90	0.93	0.94	0.95

Model	**Standardized path coefficients**					
	Pedestrian		**Motorcycle rider**		**Car driver**	
	β	**p-value**	***β***	**p-value**	***β***	**p-value**
IN → B (+)	0.39	0.000***	0.32	0.000***	0.38	0.000***
AT → IN (+)	0.53	0.000***	0.31	0.000***	0.35	0.000***
SN → IN (+)	0.34	0.001**	0.40	0.003**	0.43	0.002**
PBC → IN (+)	0.41	0.002**	0.38	0.004**	0.48	0.002**
RP → IN (+)	0.40	0.000***	0.36	0.000***	0.35	0.000***
ZC → RP (+)	0.54	0.000***	0.36	0.000***	0.38	0.000***
RPP → RP (+)	0.31	0.000***	0.29	0.000***	0.26	0.000***
SC → RP (+)	0.42	0.000***	0.32	0.000***	0.32	0.000***

Note: Factors influencing and standardized path coefficients: ***p* < 0.05, and ****p*<0.001.

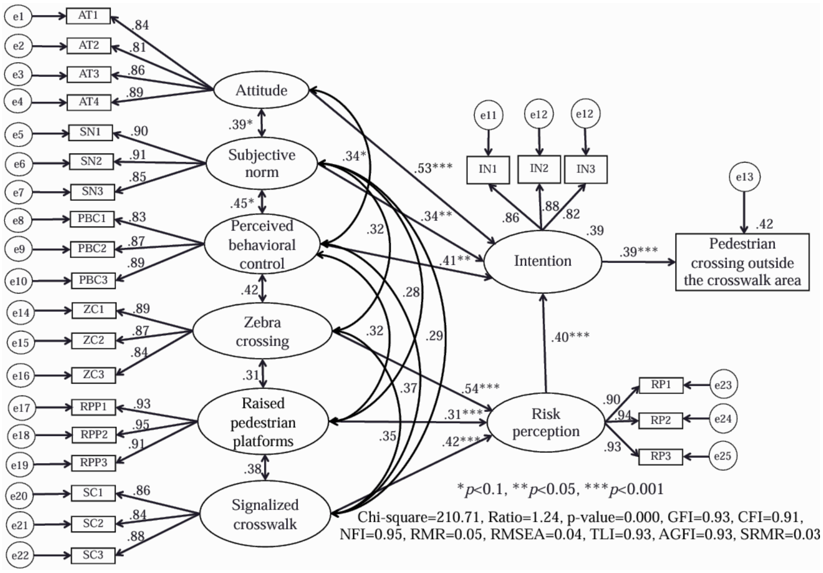


Figure 3. Standardized structural equation model for the case of pedestrians

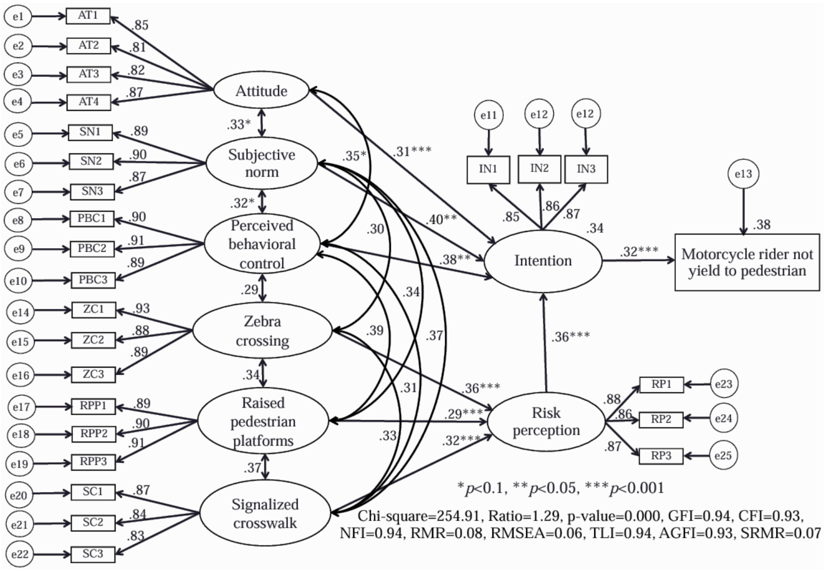


Figure 4. Standardized structural equation model for the case of motorcycle riders

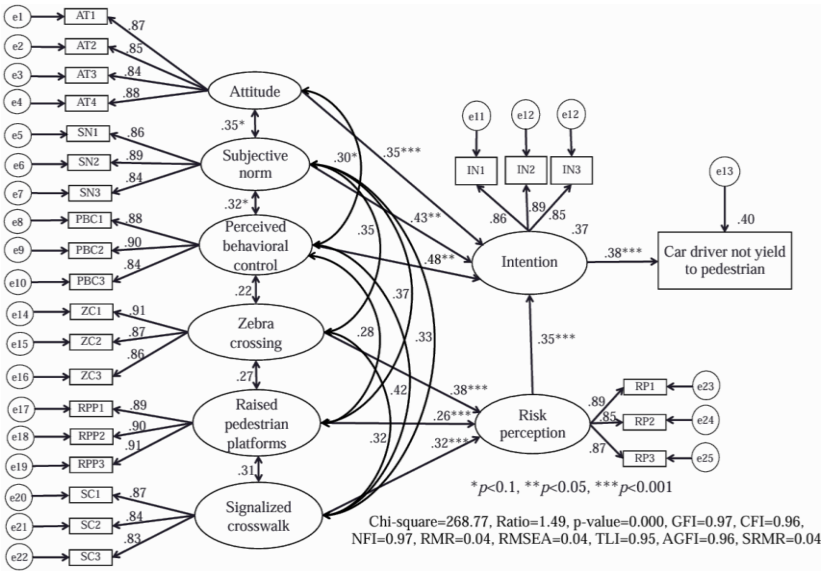


Figure 5. Standardized structural equation model for the case of car drivers

CONCLUSION AND RECOMMENDATIONS

This study investigated the factors influencing pedestrians, motorcycle riders, and car drivers' intentions to violate traffic rules at a midblock crosswalk in Thailand. The findings revealed that attitude was the key predictor of pedestrians' intentions to cross outside the crosswalk area. In contrast, subjective norms were most influential for motorcycle riders, while perceived behavioral control significantly affected car drivers' intentions to not yield to pedestrians. Moreover, the raised pedestrian platform, followed by the signalized crosswalk, has significantly increased pedestrians' and drivers' compliance with traffic rules compared to the zebra crossing. Consequently, the findings of this study can serve as recommendations for practical implications and the implementation of control measures to address violations by pedestrians and drivers.

The practical implications of pedestrians suggest that changing attitudes through promoting awareness, road safety campaigns, and education programs should emphasize that the gain from crossing outside the crosswalk area behavior is marginal and not worth the risk. It is crucial to emphasize the dangers and consequences of such violating behavior to those who realize or underestimate the risk of crossing the road against traffic laws. Additionally, subjective norms can be enhanced through education. Since people's behavior may be influenced by observing others, a campaign can inform pedestrians to cross the road properly (e.g., using the zebra crossing or waiting for the traffic light). Pedestrian safety interventions may focus on physical improvements to alert pedestrian violations, including ground-level signal detection and vocal warnings.

Furthermore, differences and suitable violating control measures are required to control drivers. Specifically, changing the subjective norm of motorcycle riders involves influencing people or social pressure on other motorcyclists. For example, influencers (parents/friends) should explain the dangers and consequences of drivers not yielding to pedestrians to their close relatives and friends. Additionally, influential motorcycle riders and groups should be engaged to promote safe riding practices. Road signage indicating appropriate lanes for motorcycle riders and reminders of traffic laws can help reduce overtaking maneuvers and promote safety among motorcycle riders. Regarding practical implications for car drivers, changing violated control measures depends on perceived behavioral control, so it should target changing actual control. Road traffic engineers can intervene in traffic vehicles through traffic-calming measures, such as rumble strips, further emphasizing lane narrowing, and curb extensions that encourage drivers to yield to pedestrians. Enforcement strategies include using 24-hour CCTV with license plate recognition for detecting violations, aimed at increasing awareness of the consequences of breaking driving rules. This measure, along with police surveillance, can enhance law enforcement. Moreover, changing the attitudes of motorcycle riders and car drivers is recommended. Education and campaign measures should also be incorporated into licensing programs. For example, they could include enhancing knowledge about traffic violations, explaining the dangers of not yielding to pedestrians (such as increasing the risk of collisions and injuries), providing information on the impact of violations and driver survival rates, and focusing on reinforcing negative beliefs about violating traffic laws.

Enhancing the safety of zebra crossings by enhanced visibility measures, such as high-contrast markings, LED-embedded crosswalks, and overhead lighting. Advanced warning signs and speed-calming measures, such as rumble strips or speed bumps, can further reinforce driver compliance. In order to supplement the safety of signalized crosswalks, consider physical improvements, such as dropped curbs, and curb extensions. Enforcement strategies include violation detection cameras, license plate recognition cameras, and intelligent technology for real-time traffic monitoring. To enhance the safety of raising pedestrian platforms, recommended enhancements include optical speed bars, zigzag lines, staged crossings, pedestrian fencing, and traffic signals.

LIMITATIONS AND FUTURE DIRECTIONS

Future studies can build on the findings of this research to provide more detailed insights into the discrepancy between self-reported and actual behavior in traffic rule compliance. Incorporating advanced technologies, such as automated traffic monitoring systems and license plate recognition cameras, could provide accurate data on traffic behaviors to reduce observer bias and capture more naturalistic behaviors. In addition, the beliefs and motivations for the risky behavior of pedestrians and drivers should also be investigated. Another challenge lies in exploring nationality's influence on road users' violation intentions, especially examining how foreigners and locals adapt their behavior to co-exist in traffic harmoniously.

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CONFLICT OF INTEREST

Authors declare no conflict of interest, including any financial, personal, or other relationships with other people or organizations that can influence their work.

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APPENDIX-1

Description of questions in the TPB questionnaire

Factors	Questions	Scoring	Code
Intention	Next 3 months, I will violate traffic rules at the midblock crosswalk	1 = Disagree : 5 = Agree	IN1
	Next 3 months, I want to violate traffic rules at the midblock crosswalk	1 = Disagree : 5 = Agree	IN2
	Next 3 months, I intend to violate traffic rules at the midblock crosswalk	1 = Disagree : 5 = Agree	IN3
Attitude	I think violating traffic rules at the midblock crosswalk is...	1 = Bad : 5 = Good	AT1
	I think violating traffic rules at the midblock crosswalk is...	1 = Harmful : 5 = Benefit	AT2
	I think violating traffic rules at the midblock crosswalk is...	1 = unpleasant : 5 = Pleasant	AT3
	I think violating traffic rules at the midblock crosswalk is...	1 = Unlikely : 5 = likely	AT4
Subjective norm	I think people who are important to me (parent/friend/relative) would think I need to violate traffic rules at the midblock crosswalk	1 = Disagree : 5 = Agree	SN1
	I think these people are important to me (parent/friend/relative) would think I should violate traffic rules at the midblock crosswalk	1 = Disagree : 5 = Agree	SN2
	I think people who are important for me (parent/friend/relative) would think I support to violate traffic rules at the midblock crosswalk	1 = Disagree : 5 = Agree	SN3
Perceived behaviour control	I am confident that to violate traffic rules at the midblock crosswalk is easy for me	1 = Very hard : 5 = Very easy	PBC1
	I am confident that my road traffic sense is good. I can easily negotiate with the traffic even while violating traffic rules at the midblock crosswalk	1 = Unable to : 5 = Able to	PBC2
	My concentration level is very high. I can violate traffic rules at the midblock crosswalk	1 = Impossible : 5 = Possible	PBC3
Risk perception	The possibility of harming pedestrian safety if I violate traffic rules at the midblock crosswalk	1 = Unlikely : 5 = likely	RP1
	The possibility lead to a pedestrian crash if I violate traffic rules at the midblock crosswalk	1 = Unlikely : 5 = likely	RP2
	The possibility of being punished if I violate traffic rules at the midblock crosswalk	1 = Unlikely : 5 = likely	RP3
Zebra crossing	I would get seriously injured if I violated traffic rules at the zebra crossing	1 = Disagree : 5 = Agree	ZC1

	I would risk of crash if I violated traffic rules at the zebra crossing	1 = Disagree : 5 = Agree	ZC2
	I would endanger my life if I violated traffic rules at the zebra crossing	1 = Disagree : 5 = Agree	ZC3
Raised pedestrian platforms	I would get seriously injured if I violated traffic rules at the raised pedestrian platforms	1 = Disagree : 5 = Agree	RPP1
	I would risk a crash if I violated traffic rules at the raised pedestrian platforms	1 = Disagree : 5 = Agree	RPP2
	I would endanger my life if I violated traffic rules at the raised pedestrian platforms	1 = Disagree : 5 = Agree	RPP3
Signalized crosswalk	I would get seriously injured if I violated traffic rules at the signalized crosswalk	1 = Disagree : 5 = Agree	SC1
	I would risk of a crash if I violated traffic rules at the signalized crosswalk	1 = Disagree : 5 = Agree	SC2
	I would endanger my life if I violated traffic rules at the signalized crosswalk	1 = Disagree : 5 = Agree	SC3