Red Light Running Behavior of Motorcyclists on Urban Roads: Psychological Factors and Risk Perception

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Abstract. *Red light running (RLR) constitutes a significant road safety challenge encountered by numerous countries. Especially among motorcyclists, this behavior leads to severe accidents, serious injuries, and death. Hence, awareness of potential hazards and adherence to driving safety are significant. This research aims to study the risk perceptions and explain the psychological factors associated with rider's RLR behavior. The questionnaires (N=250), approved by the ethics committee for human research (No. HE613041), will be utilized to gather data on rider behaviors in Khon Kaen City. Psychological factors related to RLR behavior will be explained through the Theory of Reasoned Action (TRA) and Human Error (HE) by utilizing the Structural Equation Model (SEM). The results indicated that the overall model could explain about 36% of the variance of rider's behavior at a 95% confidence level. The outcomes can serve as an initial guideline for defining necessary traffic safety strategies to reduce serious injuries of motorcyclists in Khon Kaen City.*

Keywords:

driver behavior, road safety, severe accident, unsafe action

1. Introduction

Motorcycles are the most popular vehicles used for travel and daily activities in ASEAN countries, making them the most vulnerable group on the road. High death rates and declining helmet-wearing rates continue to be a significant problem, especially in developing countries. This was also confirmed by the percentage of deaths related to motorized 2-3 wheelers, as reported in the Road Traffic Injury Prevention Global Status Report on Road Safety in 2015 [1], as shown in Figure 1. In Thailand, the death rate from 2-3-wheeler accidents is the highest amongst ASEAN countries at 72.8% [1]. RLR is one of the primary causes of these deaths and a significant road safety problem faced by many countries. It is considered risky and dangerous behavior at signalized intersections [2], [3]-[5].

RLR is caused either by acts of non-compliance or complete disobedience at signalized intersections. In cases of urgency, some drivers accelerate to cross the intersection when a red light appears or during the transition to a red traffic light. This action carries a high risk of severe accidents, injuries, and fatalities, particularly when motorcyclists are involved. Although such accidents have a low probability of occurring, there is still a chance, and they result in significant losses. The cost of accidents caused by RLR is approximately a million baht every year. This highlights the urgent need to find ways to prevent these incidents and study the factors related to this risky behavior.

In Thailand, studies on RLR behavior involve both observational surveys (external factors) and questionnaires (internal factors) [3], [4]-[6]. However, RLR behavior is complex due to the intricacies of the decision-making process, which can change depending upon various influencing factors. Previous studies have categorized RLR behaviors based upon behavioral characteristics into risk-taking, opportunistic, and traffic-following categories [3], [4], [7], [8]. RLR can occur both intentionally and unintentionally, sometimes because of human error (HE). Studies focusing on RLR behavior caused by human error are not yet widespread, with most research concentrating on the Theory of Planned Behavior (TPB) [6]. Therefore, this study aims to examine RLR behavior by incorporating human error (HE) and the Theory of Reasoned Action (TRA) to better understand and explain this risky behavior. Ultimately, the goal is to prevent and reduce the occurrence of risky behavior in a sustainable manner.

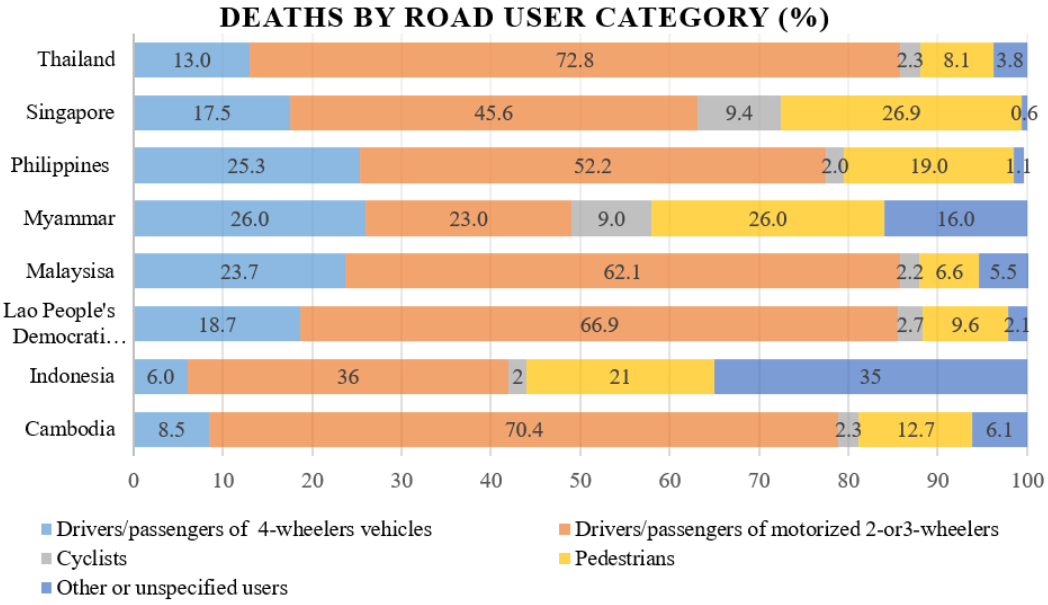


Fig. 1 Deaths by road user category of ASEAN countries [1].

1.1 Human Error (HE)

Human behavior can result from both intentional and unintentional actions, with both types being susceptible to basic human errors. In previous studies, HE was applied to investigate road users and driving behaviors in urban areas in the form of the Driver Behavior Questionnaire (DBQ) [9], [10]. Further research improved upon this approach, leading to the development of the Motorcycle Rider Behavior Questionnaire (MRBQ) for studying the driving behavior of motorcyclists [11], [12], [13]. In addition, Reason [9] classified basic human errors into three groups: slips, lapses, and mistakes.

Slip and Lapse (SL) are characteristics of unintentional HE behavior, while Mistake (M) is characteristic of intentional HE behavior. There is also a human action known as a risky behavior resulting from intentional actions, namely Violation (V).

RLR by Slip (S) involves a lack of awareness, such as using a phone, talking to a travel companion, or being lost in thought, causing the driver to cross an intersection without noticing the traffic light.

RLR by Lapse (L) involves following the vehicles in front without noticing the traffic light, resulting in the driver crossing the intersection.

RLR by Mistake (M) occurs when a driver misunderstands their right-of-way or traffic light signal when crossing an intersection.

RLR by Violation (V) is a risky action that can lead to severe accidents. This action involves crossing an intersection at high speed when a red light is displayed or when the light turns red.

Among the abovementioned groups (S, L, or M), if any of them occur simultaneously with RLR by violation from opposite directions, it can lead to severe accidents, injuries, and fatalities. The majority of RLR studies tend to focus on external factors and the evaluation of implemented measures. Studies examining internal factors, especially those that combine HE with RLR, are relatively scarce. Thus, the present study attempts to address this research gap by employing HE as an explanatory framework for RLR behavior and integrating it with the TRA through the application of Structural Equation Modelling.

1.2 The Theory of Reasoned Action (TRA)

The Theory of Reasoned Action (TRA) was developed by Ajzen and Fishbein [14]. This theory offers a framework for examining attitudes toward behaviors, as illustrated in Figure 2. The intention to engage in specific behaviors is influenced by two factors: attitude toward the behavior (ATT) and subjective norm (SN).

ATT is determined by behavioral beliefs, reflecting an individual's general sentiment towards the behavior in question.

SN is determined by normative beliefs, which encompass a person's perception of whether influential individuals, such as parents and friends, believe they should or should not engage in the behavior.

Subsequently, Fishbein and Ajzen [15]. extended the TRA to the Theory of Planned Behavior (TPB), which expands the factors influencing behavioral intentions from two to three by introducing the concept of Perceived Behavioral Control (PBC). Additionally,

TPB further refines the concept of SN, dividing it into two distinct components: Injunctive Norm (ISN) and Descriptive Norm (DSN), as outlined by Fishbein and Ajzen [15]. It is worth noting that these three factors (ATT, SN, and PBC) are interrelated and mutually influence one another.

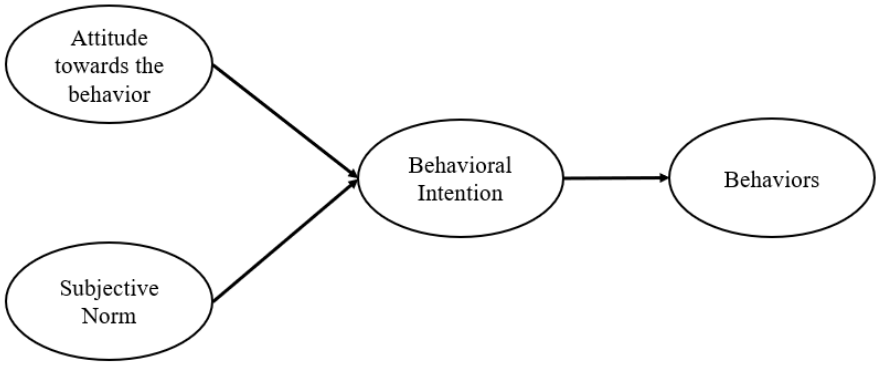


Fig. 2 The Theory of Reasoned Action (TRA) [14].

2. Methodology

2.1 Participants

The study involved 250 motorcyclists from Khon Kaen City (KKC), Thailand. These participants were randomly selected for individual interviews and completed questionnaire surveys addressing their risk perception and RLR behavior. It is important to note that the questionnaire used in this study has been reviewed and approved by the ethics committee for human research (No. HE613041).

2.2 Measurements

2.2.1 TRA measurements

This study utilized the three criteria: Action, Target, and Context [14], [15]. The design of driving scenarios was adapted from a previous study by Palat and Delhomme [2], which serves as a reference for participants when responding to the questionnaire items related to the TRA. The TRA continues to be widely employed for the explanation and analysis of various behaviors.

RLR: participants were measured using one item. This reports how likely they are to RLR under the specified scenario conditions with the scale level from 1 to 5 as shown in Table 1.

ATT: participants were categorized into two groups: Cognitive Attitude and Affective Attitude. Cognitive Attitude is quantified as Positive Attitude (PA), while Affective Attitude is assessed as Negative Attitude (NA). These measurements will be taken under specified scenario conditions, employing a 1 to 5 scale, as shown in Table 1.

SN: A pilot study was carried out to identify suitable reference groups that influence the target population's perceived social pressure regarding RLR behavior. Participants will be categorized into two groups: Injunctive Norm (ISN) and Descriptive Norm (DSN). Each category consists of six items, and these measurements will be conducted under specified scenario conditions using a 1 to 5 scale, as shown in Table 1.

Table 1 The specified scenario conditions

Item	Scoring	M	SD
Attitude (ATT)			
Positive Attitude (PA)			
PA1: RLR, it would be to destination faster.	1 = disagree : 5 = agree	2.70	1.44
PA2: RLR, it would be not waiting a long.	1 = disagree : 5 = agree	2.73	1.48
PA3: RLR, it would be not heat.	1 = disagree : 5 = agree	2.57	1.46
PA4: RLR, it would be not wet.	1 = disagree : 5 = agree	2.53	1.43
Negative Attitude (NA)			
NA1: RLR, it would be increasing a risk of accident.	1 = disagree : 5 = agree	4.19	1.42
NA2: RLR, it would be caught.	1 = disagree : 5 = agree	4.27	1.20
NA3: RLR, it would be receiving a ticket.	1 = disagree : 5 = agree	4.24	1.22

Item	Scoring	M	SD
NA4: RLR, it would be causing trouble for others.	1 = disagree : 5 = agree	4.30	1.16
Injunctive Norm (ISN)			
ISN1: I think people who are important to me (Parent) would think I need….	1 = disagree : 5 = agree	1.18	0.65
ISN2: I think people who are important to me (suitor) would think I should…	1 = disagree : 5 = agree	1.26	0.73
ISN3: I think people who are important to me (police) would think I support …..	1 = disagree : 5 = agree	1.30	0.88
ISN4: I think people who are important to me (pedestrian) would think I support …..	1 = disagree : 5 = agree	1.28	0.86
Descriptive Norm (DSN)			
DSN1: Most of my friend perform RLR when driving...	1 = disagree : 5 = agree	2.17	1.17
DSN2: Most people perform RLR when driving....	1 = disagree : 5 = agree	2.65	1.26
Behavioral (B)			
Frequency:			
B1: Last 1 month, how often you perform RLR when driving...	1 = Never : 5 = Always	1.31	0.69
Human Error (HE)			
Violation (V)			
V1: I drive through the intersection with speed while the red-light appeared.	1 = Never : 5 = Always	1.88	0.96
V2: I drive through the intersection following a traffic ahead (low speed) while the red light appeared.	1 = Never : 5 = Always	1.95	0.97
Slip & Lapse (SL)			
SL1: RLR because talking with a conversationalist.	1 = Never : 5 = Always	1.61	0.93
SL2: RLR because thinking about something.	1 = Never : 5 = Always	1.63	0.92
SL3: RLR because forgeting to look a traffic signal.	1 = Never : 5 = Always	1.73	0.96
Intention (IN)			
IN1: Next 1 month, I will perform RLR when driving...	1 = disagree : 5 = agree	1.52	0.94
IN2: Next 1 month, I want to perform RLR when driving...	1 = disagree : 5 = agree	1.29	0.79
IN3: Next 1 month, I intent to perform RLR when driving...	1 = disagree : 5 = agree	1.24	0.75

2.2.2 Hypothesizes and Conceptual Framework

TRA and HE were applied to explain the RLR behavior. Therefore, this study has the following hypothesizes:

H1: PA is positively related to the intention of RLR.

H2: NA is negatively related to the intention of RLR.

H3: ISN is positively related to the intention of RLR.

H4: DSN is positively related to the intention of RLR.

H5: Intention is positively related to RLR.

H6: Violation is positively related to the intention of RLR.

H7: Slip & lapse is positively related to the violation.

H8: Violation is positively related to RLR.

H9: Slip & lapse is positively related to RLR.

Based on these hypotheses, a conceptual framework of this study is designed as shown in Figure 3.

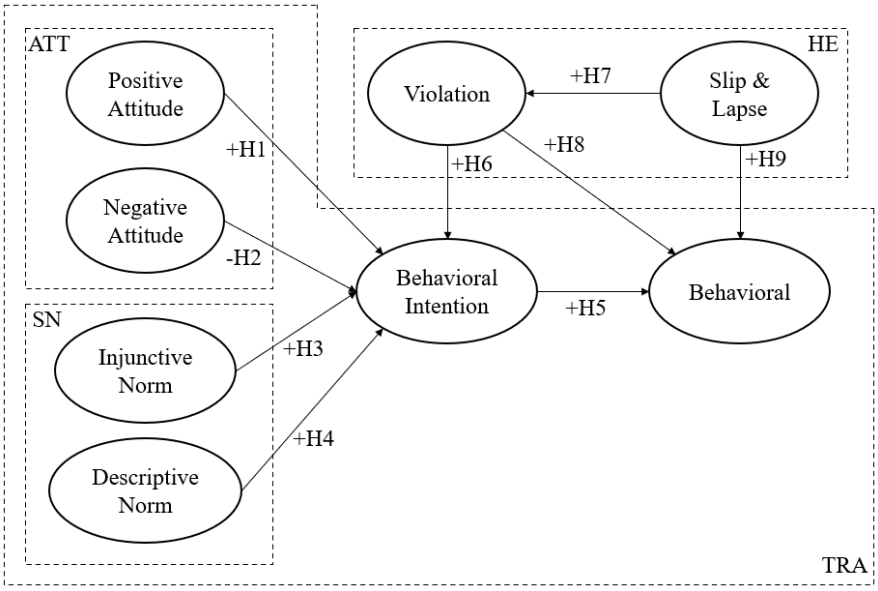


Fig. 3 Conceptual Framework

2.3 Data Analysis

2.3.1 Risk perception

Data sets will be analyzed with the descriptive statistics to present trends or frequencies. Associated variables were assessed by Pearson Chi-square test and p-value at 0.05 level was considered as statistically significant variables [3], [4].

2.3.2 RLR behavior model

First, the structure of model was examined using the exploratory factor analysis (EFA). Then, the confirmatory factor analysis (CFA) was conducted to ascertain the fit with this structure [16].

Second, model and hypotheses (H1 to H9) will be assessed and examined using the structural equation modeling (SEM). The hierarchical regression modeling was then used to explore the relationships between HE factors and RLR behavior.

Lastly, the overall model fit will be evaluated against recommended fit statistics and indices, in accordance with the guidelines outlined by the previous studies [16]-[19].

3. Results and Discussion

3.1 Proportion of sample demographic

Out of the 250 participants, 61% were male, and 39% were female. The majority of participants fell within the age range of 21 to 25 years (50%). Notably, 62% of the participants reported no prior experience with road accidents, and 80% indicated having less than 25 years of riding experience. The summary of demographic proportions within the sample is provided in Table 2.

3.2 Questionnaire survey

The results of the self-reported driver behavior survey are presented in Table 1, displaying the means and standard deviations for various items. Notably, the intention to engage in Red Light Running (RLR) in the next 1 month and the frequency of RLR in the past 1 month were reported to be relatively infrequent.

In the context of Attitude (ATT) toward RLR, especially Negative Attitude (NA), it is observed to be significantly high. This suggests that participants are aware of the potential negative effects and consequences associated with RLR behaviors.

Regarding Subjective Norm (SN) and its influence on RLR, it appears that the important individuals and those in close proximity to the participants do not support or engage in RLR. This lack of support from influential people may contribute to the reduction or absence of RLR acts among the participants.

Red Light Running by V1 and V2 occur with similar frequency, although these actions differ in terms of speed and crossing characteristics. RLR by V1 involves crossing the intersection either alone or as the lead vehicle in a group, whereas RLR by V2 involves crossing the intersection following the traffic ahead or as the second or subsequent vehicle in a group.

Similarly, RLR by Slip (SL) is reported with comparable frequency, especially SL1 and SL2. This finding aligns with previous studies conducted by Reason [20]. However, the influence of Human Error (HE) on

RLR appears to have a limited impact within this group of participants.

3.3 Risk Perception

The overall survey results, presented in Table 3, reveal that approximately half of the participants are adult males who consistently wear helmets while riding their motorcycles. This finding aligns with previous studies conducted in Thailand and elsewhere.

85.2% of participants report a high-level perception of risk. Within this group, a significant majority (66.2%) consistently wear helmets, with 22.1% wearing them very often and 44.1% always wearing them while riding.

On the other hand, 14.0% of participants perceive a medium level of risk. In this group, a majority occasionally wear helmets while riding. However, the participants' self-reported driver behavior indicates a generally high perceived risk.

An analysis of the relationship between helmet-wearing and the level of risk perception reveals a statistically significant relationship at the 0.05 significance level.

Table 2 The summary of demographic proportions within samples

Variables	Categories	Frequency	Percentage
Gender	Male	152	61
	Female	98	39
Age (year)	≤ 20	74	30
	21-25	126	50
	26-50	47	18
	≥ 51	3	2
Road accident experience	Yes	95	38
	No	155	62
Riding experience (year)	≤ 20	74	30
	21-25	126	50
	26-50	47	19
	> 50	3	1

Table 3 Risk perception from the evaluation of a helmet wearing of participants

Items	Level of risk perception			*p*-value
	High	Medium	Low	
How often do you wear the helmet for riding?				
Never	7	1	0	0.001**
Rarely	20	7	2	
Sometimes	45	13	0	
Very often	47	8	0	
Always	94	6	0	

3.4 Model Analysis

3.4.1 Model Validity

The results of reliability and validation estimation are presented in Table 4. These results demonstrate that all reliability and validation values adhere to the principles of strong internal consistency and standard guidelines.

Adequate convergence is suggested, with Cronbach's α indicating consistent responses from identical sets of questions within the respondents (e.g., items for Positive Attitude (PA), Negative Attitude (NA), and Injunctive Norm (ISN)). The values obtained are all at or above the acceptable threshold of 0.7, as recommended by Hair [17]. This confirms that the latent variables within the model represent reliable measures for explaining the model.

The correlation coefficients for all latent variables are provided in Table 5. Those ISN, SL, V, and PA variables exhibit significant correlations with the IN variable at a significance level of 0.05. In particular, the

ISN variable demonstrates the highest correlation coefficient. Furthermore, when comparing all variables, the factors V and SL exhibit the most substantial and significant correlation coefficients.

Table 4 Reliability scales of model

Variable	Items	Factor loadings	Cronbach's α
PA	PA1	0.790	0.896
	PA2	0.867	
	PA3	0.913	
	PA4	0.849	
NA	NA1	0.828	0.915
	NA 2	0.940	
	NA 3	0.947	
	NA 4	0.847	
ISN	ISN1	0.878	0.852
	ISN2	0.863	
	ISN3	0.709	
	ISN4	0.844	
DSN	DSN1	0.794	0.637
	DSN2	0.858	
V	V1	0.790	0.659
	V2	0.794	
SL	SL2	0.836	0.899
	SL3	0.900	
	SL4	0.871	
IN	IN1	0.841	0.902
	IN2	0.823	
	IN3	0.893	

Remark: Factor loadings > 0.7; α > 0.7; (KMO = 0.751, p < 0.001)

Table 5 Correlation matrix model

Factors	SL	V	PA	NA	IN	ISN	DSN
SL	1						
V	0.608***	1					
PA	0.257***	0.232**	1				
NA	-0.064	0.002	0.146**	1			
IN	0.286***	0.263**	0.237***	0.012	1		
ISN	0.175**	0.200**	0.060	-0.153**	0.389***	1	
DSN	0.320***	0.362**	0.305**	0.106	0.054	0.093	1

Remark: *** Significant at 0.01 level, ** Significant at 0.05 level

3.4.2 Structural Equation Model (SEM)

The results of the SEM model analysis, as displayed in Table 6, indicate that the model's values align with recommended statistics and fit indices, in accordance with the guidelines by Hair [17]. This suggests that the model effectively captures the relationships between the theoretical constructs and observational constructs. Therefore, the results demonstrate that the model provides an adequate fit to the data.

Figure 4 shows the results of SEM while considering the tested hypotheses. The standardized path coefficients reveal that several factors, as hypothesized, exhibit statistical significance at the 0.05 level. These include SL-V, IN-B, ISN-IN, SL-B, V-IN, and PA-IN.

In summary, the model demonstrates the ability to explain 36% of the variance in RLR behavior. It accounts for 38% of the variance between V and SL with respect to RLR behavior and 21% of the variance in RLR intention.

The hypotheses (H1 to H9) are partially supported, including H1 (PA-IN), H3 (ISN-IN), and H5 (IN-B) for TRA, and H6 (V-IN), H7 (SL-V), and H9 (SL-B) for HE.

For the TRA hypotheses, specifically H1 (PA-IN), it is evident that Positive Attitude has a positive relationship with the intention to engage in RLR. Motorcyclists may be inclined to perform RLR to reach

their destination more quickly, avoid extended waiting times, or prevent discomfort due to heat or rain. These perceived benefits contribute to the intention to engage in RLR behavior. This outcome aligns with previous studies that have identified Attitude as a prominent influencing factor for risk behaviors, such as yellow light running (YLR), as observed by Palat and Delhomme [2]. When these actions become habitual, they increase the risk of serious accidents, injuries, and fatalities. The results also indicate a positive relationship between PA and Negative Attitude (NA) (reflecting the perception of consequences) and suggest that PA has a greater influence on the intention to engage in RLR than NA. Moreover, PA is positively related to Descriptive Norm (DSN) (representing friends or imitating behavior). Therefore, raising awareness about the risky or hazardous nature of these behaviors and developing riders' attitudes to perceive these risks as outweighing the benefits is crucial. In the long term, this shift in attitude can lead to a reduced chance of accidents and their associated consequences.

H3 (ISN-IN): Injunctive Subjective Norm exhibits a positive relationship with the intention to engage in RLR. This suggests that individuals who hold importance for motorcyclists, such as parents, partners, pedestrians, and law enforcement officers, influence riders' driving intentions. When riders perceive that these individuals do not condone RLR, it affects their attitude toward such behavior. If these influential individuals are significant in the lives of riders, the likelihood of engaging in risky behavior decreases. The results demonstrate a positive relationship between ISN and PA. When riders consider the consequences of RLR outweighing its benefits and these influential individuals hold significance in their lives, the likelihood of engaging in RLR diminishes. Similarly, ISN and DSN exhibit a positive relationship. If people in the rider's social sphere do not engage in RLR, especially those influential individuals who impact the rider's decisions, the likelihood of RLR diminishes.

Hence, the cultivation of positive attitudes and the values upheld by the individuals in the rider's social domain are pivotal in reducing RLR and ensuring the sustainability of safe driving behavior in the long term. This aligns with previous studies that establish a significant relationship between subjective norm and driver intention to engage in RLR, as per the Theory of Planned Behavior (TPB) [6]. This highlights the importance of raising awareness while emphasizing the role of the family institution, which is the closest social unit, ultimately leading to safer driving behavior and the sustained reduction of risky behavior in the future.

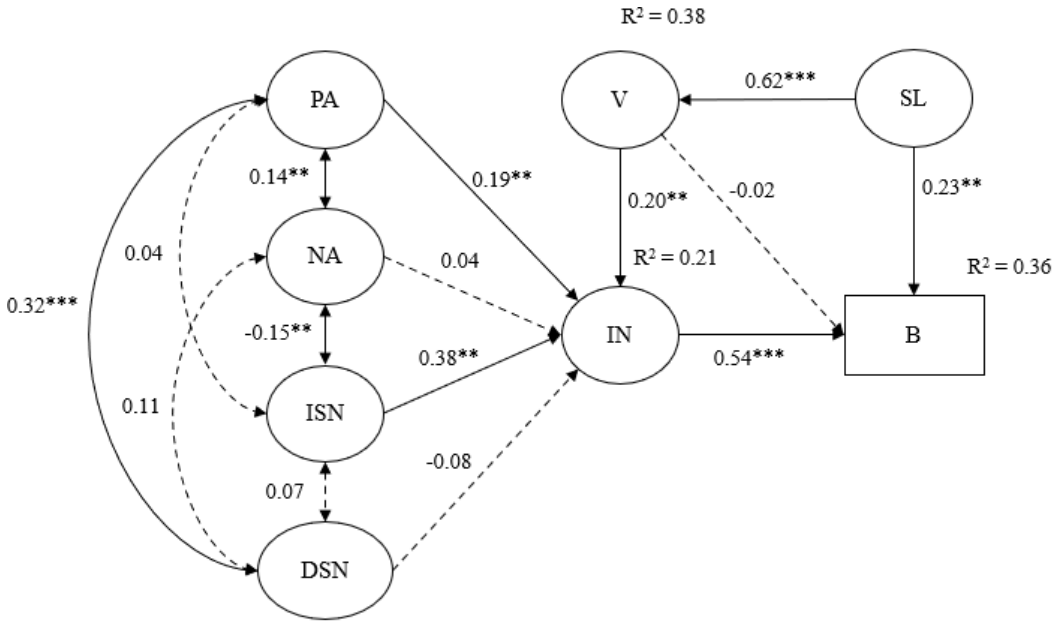
HE hypotheses: H6 (V-IN): Violation is positively related to the intention of engaging in RLR. H7 (SL-V): Slip and lapse are positively related to the violation of RLR. H9 (SL-B): Slip and lapse are positively related to RLR behavior. These findings indicate that variables related to HE, specifically those related to basic HE, have an impact on RLR. RLR can occur as the result of both intentional and unintentional actions. Slip is particularly noteworthy as a variable related to unintentional RLR, where individuals may forget to observe a traffic signal due to distractions like thinking about something or engaging in conversation. These scenarios can lead to RLR actions occurring unconsciously, with the most significant danger arising when riders from opposing directions enter the intersection simultaneously, increasing the risk of severe accidents.

To address these issues, the design of traffic signals could include measures such as additional poles to display warning signals before riders enter the intersection. Additionally, road surface symbols, including rumble strips, speed bars, traffic light indicators, and the use of red-colored paint, can serve as warnings to riders prior to entering intersections. However, it is essential to consider noise pollution concerns in the case of rumble strips, and their implementation should be limited to areas away from residential communities. Another widely adopted measure in many countries involves the use of automatic detection cameras for law enforcement.

While these measures offer solutions to the issue at hand, fostering a culture of awareness and safety promotion in driving is of paramount importance. An effective approach is to compare the road to one's home and road users to members of the household. Just as one prioritizes the safety of household members, they should prioritize safe driving with the guiding principle "You Safe, Everyone Safe". Ultimately, these efforts contribute to the reduction of sustained risky behavior in the long term and the future.

Table 6 Explanatory power and fit index of models

Model fit	Recommended value	Model
χ^2		323.282
df		192
Chi-square/df	< 3.0	1.68
GFI	> 0.90	0.903
CFI	> 0.90	0.967
RMSEA	< 0.08	0.052



Note: $\chi 2/df$ = 1.68; RMSEA=0.052; $^{***}p<0.001$, $^{**}p<0.05$, $^{*}p<0.10$

Fig. 4 Structural model

4. Conclusion and Recommendation

This study aims to investigate the Red Light Running (RLR) behavior of motorcyclists in Khon Kaen City using Structural Equation Modeling (SEM) based on the Theory of Reasoned Action (TRA) and Human Error (HE) frameworks. The study involved 250 participants who were interviewed using a questionnaire that had received ethical approval from the relevant committee for human research.

The findings indicate that Positive Attitude (PA) and Injunctive Subjective Norm (ISN), both based on the TRA, significantly correlate with the intention to engage in RLR. Moreover, Slip (SL) and Violation (V), elements related to HE, exhibit significant relationships with RLR behavior and behavioral intention, respectively. SL also shows a significant correlation with V. Collectively, the model explains approximately 36% of the variance in RLR behavior.

These results address that RLR behavior is contingent on riders perceiving benefits from engaging in RLR and the influence of significant individuals in their social sphere (PA and ISN, respectively). Additionally, HE demonstrates that RLR can result from both intentional and unintentional actions (V and SL, respectively).

The implications of these findings lead to measures for the sustainable reduction of risky behavior in the long term. Fostering awareness about safe driving and instilling attitudes that prioritize safety by emphasizing the importance of individuals in the rider's social network is essential. An effective approach is to liken the road to one's home and road users to members of the household, following the guiding principle "You Safe, Everyone Safe". These measures represent a form of soft power that gradually fosters behavioral change among riders, ultimately contributing to the reduction of risky behavior and the cultivation of sustainable safe driving practices in the future.

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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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