Factors Affecting Red-Light Running of Pedestrians at Signalized Intersections

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ABSTRACT

Hundreds of pedestrians have died and many have been injured in the past decades as a result of Red Light Running (RLR) infractions. According to the United States Department of Transportation, 846 pedestrians have died and 143,000 have been injured in 2019 due to RLR violations. The majority of previous studies have focused on pedestrian behavior at an intersection, whereas only a few have looked into pedestrian RLR violations. The main objectives of this research are to find the pedestrians' RLR rate in Sri Lanka and to find ways to reduce the RLR rate of pedestrians at the signalized crossing. Video observation surveys were conducted to collect data at three signalized intersections within Kandy city limits during weekdays for two hours per site. Pedestrian demographic variables such as gender and age; crossing characteristics such as crossing type, direction, crossing speed etc; and site characteristics such as crossing length, pedestrian green time, etc. were recorded. Chi-square and binary logistic regression tests were done. Results showed that out of 178 females, 130 had compliance with signal phases and out of 386 males, only 215 had compliance with RLR of a pedestrian. Furthermore, other independent variables such as age, crossing type, direction etc. were also associated with compliance RLR of pedestrians under Chi-square results. Based on the results of binary logistic regression, the variables such as gender, crossing type, number of traffic lanes, and pedestrian speed are significant when decreasing the log of probability -0.658, -3.040, -1.022 and -2.556 of compliance for RLR respectively. Variables that crosswalk utilization are also significant when increasing the log of probability of RLR 1.406 of compliance for RLR. The results would help develop safer pedestrian infrastructures and engineering countermeasures as well as assist the researchers and practitioners in better understanding pedestrian crossing behavior at signalized intersections.

KEYWORDS: *Pedestrian's violation, Road safety, Signalized crosswalk, Red-light running.*

1 INTRODUCTION

Globally, about 1.24 million lives are lost annually due to road traffic accidents (WHO, 2018). According to the United States (US) National Highway Traffic Safety Administration's (NHTSA), Fatality Analysis Reporting System (FARS), the number of pedestrian fatalities in the US has increased by 53%, from 4,109 in 2009 to 6,283 deaths in 2018 and compared with other traffic fatalities which had only increased by +2% during that period as shown in Table 1(Retting, 2019). According to the National Police Agency (NPA) examination of data from traffic accidents in multiple nations between 2016 and 2018, pedestrians account for around 36% of fatalities in Japan (Sasaki et al, 2019). In the same year, the number of pedestrian fatalities in the United Kingdom is around 25% (IIHS, 2020), and in the US and France are both around 16% (Retting, 2019). In addition, based on World Health Organization (WHO) statistics, road traffic fatalities in Sri Lanka reached 3,590 or 2.82% of total fatalities and ranked 96th in the world in 2018 (WHO, 2018).

It is very important to investigate pedestrians' RLR violations at signalized intersections. In this research, pedestrian crossing behavior is investigated using a video observation survey with the objectives of (a) quantifying the RLR rate at the selected signalized intersections; (b) suggesting recommendations which can be used to develop education programmes about the safety of pedestrians for school children and it will help them to be safe on road as pedestrians; (c) giving some recommendations which can be used to reduce the RLR.

Table 1: Pedestrian fatalities and percentage out of total fatalities in the US: 2009-2018

Year	Pedestrian Fatalities	All other traffic fatalities (Excluding pedestrian fatalities)	Total traffic fatalities	
			Number	Percentage
2009	4,109	29,774	33,883	12%
2010	4,302	28,697	32,999	13%
2011	4,457	28,022	32,479	14%
2012	4,818	28,964	33,782	14%
2013	4,779	28,114	32,893	15%
2014	4,910	27,834	32,744	15%
2015	5,494	29,990	35,484	15%
2016	6,080	31,726	37,806	16%
2017	6,075	31,398	37,473	16%
2018	6,283	30,277	36,560	17%
% change from 2009 to 2018	+53%	+2%	+8%	

Source: (Retting, 2019)

Motorized vehicles, non-motorized vehicles, and pedestrians should refrain from driving or walking in front of red traffic lights, according to the traffic safety law of Sri Lanka (Amarasingha and Ilhaam, 2019). Thus, all traffic that passes the red traffic light can be defined as RLR violations. It is not considered a violation, if the traffic passes the traffic light before it turns red. Pedestrian signal phases/colors have been categorized into three: green, amber, and red. When the 'green' light is pedestrians can cross the road, while the 'flash green/ amber light is on, pedestrians can cross but they cannot start to cross. Also, when the 'red' light is on, pedestrians cannot cross the road. Besides, pedestrian cycle length has also been defined using signal phases. It starts from green then amber and ends with red. In addition, RLR violators should be considered as one of the main contributing factors for pedestrian crashes (Johnson, 2011). Pedestrian RLR violators are of two types: 'opportunists' and 'risk takers'. Opportunist pedestrians cross the road even if the red signal is on if there is no vehicle in sight, risk takers cross the road when the color is amber (Amarasingha and Ilhaam, 2019).

According to Sri Lankan police-reported crash data, over time pedestrian crashes have increased in Sri Lanka even though it is still a developing country in the world. Some pedestrians on Sri Lankan roads seem to be aggressive while not obeying the rules and regulations (Jayasinghe and Amarasingha, 2019). The majority of Sri Lankans do not have their own vehicles when compared with people who live in developed countries. Therefore, most Sri Lankans travel by foot. Due to the high number of pedestrians, there is a high probability of accidents. In Japan, people generally use public transportation for travelling as they do not like to use their own vehicles for inefficient travel (Yudhistira et al, 2015). Japanese pedestrians obey traffic rules. Even when there are no cars on the road, pedestrians remain in the proper place at the edge of the sidewalk and wait the traffic light to turn green.

Road injuries have a major impact on a country's public health. Unfortunately, only about one-third of countries have a government-endorsed national road safety strategy that includes specific objectives, as well as funds allocated for its implementation (WHO, 2018). In addition, due to the increase in the number of road collisions, lives and property damages have also increased and it negatively affects society as well as the economy. Pavement qualities, road characteristics, geometric features, traffic characteristics, vehicle design, driver characteristics, road user behavior, and environmental features are some sub factors that contribute to the probability of road pedestrian accidents occurrence. It is difficult to identify pedestrian crossing behavior due to the complexity of multiple parameters such as personal, environmental and traffic attributes at signalized intersections (Marisamynathan et al, 2014). Because of the noncompliance behavior of pedestrians with traffic signals, vehicular-pedestrian interactions may occur at signalized intersections, and it is also highly likely for pedestrians to be injured in traffic accidents as a group at high risk of traveling on the road. Over time, signal lights have been developed to control the interaction between vehicles and pedestrians at

crosswalks. But accidents occur every day. One main reason for this issue may be pedestrians' violation of traffic regulations.

2 LITERATURE REVIEW

Wang et al. (2019) investigated RLR infringement of pedestrians in Hong Kong. According to that pedestrians were accountable for 62% of road fatalities in 2017(Transport Department, 2018). The purpose of this study was to investigate the factors that impact pedestrian red-light infractions and the severity of pedestrian injuries at signalized intersections. A significant non-compliance with traffic laws, especially among walkers, was found. The data used in this study's statistical analysis is from the Transport Department's Traffic Accident Database System (TRADS) and the Hong Kong Police Force. A binary logit model was applied to investigate the elements to find the severity of accident injuries and pre-crash violation behavior. The data was separated according to whether violated (N=1364) or not (N=388). The percentage of fatal/serious injuries that were caused that happened as a result of pedestrian RLR violations (28.39 %) did not vary from that of serious injuries that did not occur as a result of pedestrian RLR violations (25.29 %). Consequently, several models based on the random parameter probit approach were used to study pedestrian red-light infractions and injury severity.

Dommes et al. (2015) investigated RLR violation by adult pedestrians and other safety-related behaviors at signalized crosswalks. According to the Organization for Economic Cooperation and Development (OECD), over 20,000 pedestrian deaths occurred in its member nations in 2011 and ranged from 8% to 37% of all road fatalities. According to national figures, 30% of traffic collision has occurred on signalized crosswalks in France. An observation grid, location of observation, and questionnaires were used to collect data. Observational data with questionnaires administered among the 680 observed pedestrians, answered by 422 pedestrians (221 women and 201 men) of French adult pedestrians were observed. The functions of certain contextual, demographical, and mobility-related variables were investigated and a total of 13 observed behavioral indicators were extracted (twelve before, while crossing, and red-light violation). Subsequently, they were able to find, the distribution of participants' age groups: very elderly pedestrians (>75 years), elderly pedestrians (65- 74 years), mature pedestrians (50-64 years), middle-aged pedestrians (30-49 years), young pedestrians (18-29 years) who make up 19% , 24%, 17%, 23%, and 17% of the sample, respectively, with nearly equal proportions of males and females in each age group, with the exception of the 18-29-year-old group (more women). The findings of logistic regression analysis conducted on each of the twelve behavioral variables that were observed prior to and during crossing revealed that gender had no significant effect, but that age did, with older pedestrians exhibiting more conservative behaviors. The results can help develop pedestrian safety as well as infrastructures.

Besides, Guo et al. (2011) did a study to identify the RLR of pedestrian activities at signalized crosswalks. In 2006, pedestrian deaths were nearly 26% of all traffic fatalities in China (23,285 pedestrians) and pedestrian injuries reported as 19% of all traffic injuries (82,391 pedestrians) as reported by the Ministry of Public Security of People's Republic of China (MPSPRC, 2007). The hazards-based duration model approach and video observation method were used for analysis. The assessment was carried out at seven crosswalks in Beijing, China. Video cameras were placed in each area to collect data. Peak hours (from 8:00 a.m. to 9:00 a.m. or from 5:00 p.m. to 6:00 p.m.) and off-peak hours (from 2:00 p.m. to 4:00 p.m.) data were included in the survey. Guo et al. (2011) were able to find that, of 1497 pedestrian observations, pedestrians had violated traffic laws in 597 cases (39.88 percent of 100). Per sample, there was an average waiting time of 17.1 seconds, with a standard deviation of 9.2 seconds. The violating crossing had an average waiting time of 15.9 seconds, whereas the normal crossing had an average waiting time of 18.2 seconds.

Marisamynathan et al. (2014) examined pedestrian crossing behavior in mixed traffic conditions such as the crossing speed, signal compliance, and pedestrian-vehicle contact and found contributing factors using statistical tests while designing signalized intersections. Pedestrian crossing speed was a considerable parameter under that study. According to the Indian Road Congress (IRC), the walking speed of pedestrians was estimated as 1.2 m/s at crosswalks. All possible parameters which influence pedestrian crossing behavior at crosswalks were identified using SPSS 16.0 software. Noncompliance logistic model was developed using 775 completed samples. Only 434 pedestrians were in noncompliance with traffic lights and signals. There were 141 pedestrians, who interacted with vehicles directly. Males had higher odds of non-compliance rate and interaction with vehicles than female pedestrians. Old pedestrians and children had much higher odds of interaction than adult pedestrians (8.074).

Xie et al, (2017) explored pedestrian jaywalking at signalized crosswalks. The most prevalent type of intersection in Hong Kong was signalized intersections. Pedestrian vehicle collisions at signalized intersections had decreased by 35% in the last 5 years, although 387 pedestrian-vehicle collisions were recorded, accounting for approximately 25% of all accidents at signalized intersections. The following methods were used to analyze collected data: Basic binary logit model, Random parameter binary logit model, Random effect binary logit model and Goodness-of-fit. Observational surveys were conducted at seven crosswalks in Hong Kong, and pedestrian data and site condition data were integrated into a database. The modified pseudo R^2 value was in the range of 0.26 - 0.29, three models were produced, and an acceptable overall fit was obtained. The AIC values of the random parameter and random effect binary logit models were lower than the basic binary logit model and Mac Fadden's modified Pseudo R^2 values were higher.

Gong et al, (2019) conducted a study which characterized pedestrian violation crossing behavior of the Anning District of Lanzhou City. Pedestrian road deaths accounted for nearly 25 percent of all deaths, as 10 percent in Beijing and 19 percent in Chengdu happened at intersections. Several characteristics that potentially impact the violation rate were determined from the video observation method and field records using questionnaires. A total of 617 violations were involved at random from a total of 2852 legitimate pedestrian crossing samples at signalized junctions. The findings revealed that the rate of infraction crossing among older pedestrians was higher among other age groups with males slightly higher than that of females. The percentage of violations was 21.6 percent. Finally, age, headway, crosswalk length, the time it took to cross the road, gender, countdown display, red light duration, and companions were found as factors causing infractions. It has been found that pedestrians' walking speed, gender, traffic flow, the condition of the crosswalk, and the location of road significantly affect the probability of jaywalking.

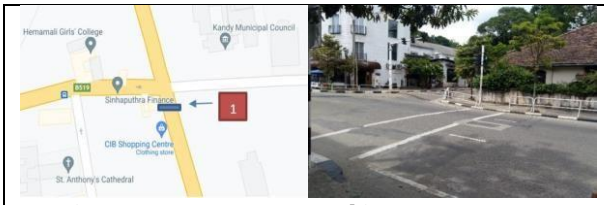
Based on literature reviews, the number of pedestrian crash proportion is high. Therefore, countermeasures should be taken to increase traffic safety. Unfortunately, available studies have been done using information concerning pedestrian crossing behavior (Dommes et al, 2015; Wang et al, 2017; Xie et al, 2017, Jayasinghe and Amarasingha, 2019, Egodawatta, and Amarasingha, 2019), road and traffic characteristics (Sisiopiku et al, 2003; Wang et al, 2011) and vehicle interaction (Avineri et al, 2012). Many authors have identified both internal human factors as well as external environment's effects such as weather to understand RLR violation in pedestrian crossing, only a few research studies have been done on pedestrians' crossing behavior at signalized intersections in the world, while very few studies in Sri Lanka (Jayasinghe and Amarasingha, 2019) and they do not focus on RLR violations. This study investigates all possible variables and parameters that influence the crossing behavior of pedestrians at crosswalks in Kandy, Sri Lanka with a particular focus on the impact of gender on RLR violations.

However, most of the past safety research has been focused on vehicles rather than pedestrians. Transportation engineers and planners should be concerned about the behavior of pedestrians to improve their walking ability and reduce the interaction between vehicles and pedestrians under mixed traffic conditions at signalized intersections. This research attempts to identify the RLR violation rate of pedestrians in Sri Lanka. This would be helpful in taking measures to reduce pedestrian traffic fatalities.

3 METHODOLOGY

3.1 Study Area

To identify the pedestrian RLR violation, quantitative data were collected through video observation at three crosswalks which are located near 4-way junctions in the Kandy city area as shown in Figure 1 near the sub-post office Crosswalk (SPOC), in front of café 210, and Bowatte Beheth Shalawa Crosswalk (BBSC).



a) Map b) Street view

Site 1: Near sub-post office Crosswalk (SPOC)

b) Map b) Street view

Site 2: In front of café 210 Crosswalk

a) Map b) Street view

Site 3: Kandy,Bowatte Beheth Shalawa Crosswalk (BBSC)

Figure 1: Maps and the street views of the study sites

3.2 Data collection

The main characteristics of the selected sites are shown in Table 2. The video camera was set up at selected crosswalks for 1-hour in the morning peak hours (from 7 am to 8am) and 1 hour in the evening peak hours (from 4pm to 5 pm). In other words, data collection was done for 2 hours per site.

Table 2: Characteristics of crosswalks in the study

Site Information	**Site 1**	**Site 2**	**Site 3**
Crosswalk Location	Sub post office, Kandy/ Kandy Jaffna Hwy A9(SPOC)	Sub post office, Kandy/ Kandy Jaffna Hwy A9 (café 210 crosswalk)	4-way junction/ Bowatte- Beheth-Shalawa/ Yatinuwara-Street (BBSC)
Pedestrian waiting time (For one cycle)	1 min and 55 secs	1 min and 55 secs	1 min and 8 secs
Pedestrian green time	20 secs	20 secs	25 secs
Crossing length	Approximately 8m	Approximately 10m	Approximately 8m
Vehicle flow rate	1675 Veh/hr	2420 Veh/hr	1120 Veh/hr
Number of traffic lanes	One-way road - three lanes	Two-way road	One-way road - three lanes
Date of data collection	14/06 & 15/06/2021	15/06 & 16/06/2021	16/06 & 17/06/2021

Even though the site characteristics are different, pedestrian demographic data can be considered together. Information about pedestrian crossing behavior such as running or walking, alone or accompanied by a companion or group; pedestrians' demographics details such as mainly gender and age; other factors such as pedestrian crossing time, the crossing location (whether crosswalk is used or not), phase time pedestrian (crossing in non-green or green phase), traffic flow rate, number of lanes, and vehicle-pedestrian interaction at crosswalk were considered during the survey. To avoid lighting, visibility, and weather condition considerations, daytime during sunny days was chosen to get the video recording.

3.3 Data analysis

Video recordings were observed, and the variables needed for the study were manually recorded. Data collected using the video observations along with the variable definition are shown in Table 3. The total

number of pedestrians observed was 564. Out of the 186 (32.98%) were in SPOC crossing and 277 (49.11%) were in café 210 and 101 (17.91%) were in BBSC.

Table 3: Variable Definitions and Collected Data

Variable	**Definition**	**Observations**
Gender	If the pedestrian is female, Gender= 0	178
	If the pedestrian is male, Gender= 1	386
Age	If the pedestrian's age is <20 years, Age= 0	72
	If the pedestrian's age is 20-60 years, Age= 1	316
	If the pedestrian's age is > 60 years, Age= 2	176
Crossing type	Crossing the road running = 0	67
	Crossing the road walking = 1	497
Accompanying pedestrians	If the pedestrian is alone, Accom. ped. =0	374
	If the pedestrian with one companion, Accom. ped. =1	43
	If it is a group of pedestrians, Accom. ped. =2	147
Carrying an item	If the pedestrian crosses with baggage, Item= 0	284
	If the pedestrian crosses with an umbrella, Item= 1	11
	If the pedestrian crosses with a heavy item, Item= 2	5
	If the pedestrian crosses without any item, Item= 3	264
Direction	If the pedestrian crosses upstream traffic and then downstream =0	244
	If the pedestrian crosses downstream traffic and then upstream =1	320
Crosswalk utilization	If the pedestrian crosses on the marked crosswalk =0	440
	If the pedestrian does not cross on the marked crosswalk =0	124
Crossing pattern	If the pedestrian crosses the road walking diagonally =0	431
	If the pedestrian crosses the road walking straight =1	86
	If the pedestrian crosses the road walking within the marked crosswalk lines =2	47
Compliance	Non-compliance with the signal phase =0	222
	Compliance with the signal phase =1	342
Mobile phone use while crossing	If the pedestrian uses a mobile phone while crossing =0	28
	If the pedestrian does not use a mobile phone while crossing =1	536

In addition to the categorical data collected for variables in Table 2, waiting endurance time and the crossing speed (the time pedestrians waited to cross during non-green phases) for each pedestrian were collected. The mean values were 18.3 seconds and 0.71 m/s respectively.

Chi-square test and binary logistic regression are utilized in this research. The Chi-Square Test is a statistical approach for determining whether an observed distribution is likely to have arisen randomly. It looks at how well the observed data distribution matches the anticipated distribution if the variables were independent (Heiberger et al, 2015). The Chi-square test is often known as the 'Goodness of Fit' test because of this. As a result, the Chi-square test does not operate with continuous or parametric data. A Chi-square test's null hypothesis usually states that no statistical difference exists between observed and predicted counts of a particular variable in the population. By comparing with the observed and predicted counts at each level of category variable, Chi-square statistic for the Goodness of fit testing can be obtained. The decision can be made on whether to reject the null hypothesis at a predefined significance level. If the prediction is satisfied, the null hypothesis should be rejected. Otherwise, it will not be rejected. As an example, compliance varies with gender, assuming the following,

- Gender and compliance are independent, Null Hypothesis (H0)
- Gender and compliance are not independent, Alternative Hypothesis (H1)

Reject H_0 if P value < α level. Since P value is less than 5%, so H_0 can be rejected at a 5% level of significance (Heiberger et al, 2015).

Logistic regression is a classification approach that aids in predicting the likelihood of an event result (Heiberger et al, 2015). When the dependent variable is binary, binary logistic regression is utilized (Amarsingha, 2021). Given a set of predictors, logistic regression can help estimate the likelihood of falling into a specific level of categorical response. The likelihood of RLR violation equation of the binary logistic regression model is shown in Equation 1, when k number of predictors exists (Amarasingha, 2021).

$$\pi(X) = \frac{\exp(\beta 0 + \beta 1\, X1 + \ldots.. + \beta k\, Xk)}{(1+\exp(\beta 0 + \beta 1\, X1 + \cdots. + \beta k\, Xk)} \quad (1)$$

where: $\pi(X)$: the probability of RLR violation under the influence of *k* number of predictors,
xi : the influencing predictors for RLR violations, and
βi : regression coefficients (Amarasingha, 2021).

The regression coefficients of this model were estimated using the maximum likelihood method with the help of SPSS software, which uses a numerical analysis involving successive approximations.

4 RESULTS

4.1 Descriptive Data

Table 4 shows the number and percentage of compliance and non-compliance of both male and female pedestrians. The overall RLR violation rate of the pedestrians was 38.83%. The RLR violation rates of males and females are 44.30% and 26.97% respectively.

Table 4: Kandy pedestrians' signal phase compliance versus gender

Variable	Level	Non-Compliance with signal phases (RLR violations)	Non-Compliance Percentage (RLR violations %)	Compliance with signal phases	Compliance Percentage	Total
Gender	Female	48	26.97	130	73.03	178
	Male	171	44.30	215	55.70	386
	Total	219	38.83	345	61.17	564

4.2 Chi-Square Tests

In Chi-square analysis, the dependent variable 'RLR violations (non-compliance with signal phases)' was taken and the way it associated with other variables was analyzed. Table 5 gives the observed numbers and expected numbers of pedestrians in both compliance and non-compliance with signal phases for each significant variable. Variables such as gender, age, crossing type, carrying an Item, crosswalk utilization, and crossing pattern showed significant differences in RLR violations. Accompanying pedestrians or crossing direction did not show any association with the RLR violations. When investigating the variable 'gender', it showed that females were less likely to violate RLR while males were more likely to violate RLR. Pedestrians whose age is below 20 years were more likely, those aged between 20-60 years less likely, and those aged above 60 years more likely to be RLR violators. Pedestrians who were running across the crosswalk or who crossed out of the marked crosswalk lines were more likely to be RLR violators.

4.3 Binary Logistic Regression

Before developing the binary logistics regression model, the six model assumptions were checked (Leung, 2021; Amarasingha, 2021).

Assumption #1: The response variable is binary:

The dependent variable, the "RLR violations", was assigned the value of '1' for pedestrians of non-compliance with signal phases while the value of '0'was assigned for pedestrians' compliance with signal phases. As the dependent variable is RLR violation with 2 responses, the assumption is satisfied.

Assumption #2: The Observations are independent:

As shown in Figure 2, observation order versus standardized Pearson residual graph does not have a clear pattern. Therefore, it can be concluded that observations are independent.

Table 5: Compliance varies with independent variables

Variable	**Level**	**Observed/ Expected**	**Non-Compliance with signal phases**	**Compliance with signal phases**	**Asymptotic Significance (P)**
Gender	Female	Observed	53	134	0.000
		Expected	74	113	
	Male	Observed	169	208	
		Expected	148	229	
Age (years)	< 20	Observed	35	37	0.003
		Expected	28	44	
	20-60	Observed	105	211	
		Expected	124	192	
	60>	Observed	82	94	
		Expected	69	107	
Crossing Type	Walk	Observed	179	318	0.000
		Expected	196	301	
	Run	Observed	43	24	
		Expected	26	41	
Carrying an Item	Baggage	Observed	99	185	0.000
		Expected	112	172	
	Umbrella	Observed	0	11	
		Expected	4	7	
	Heavy Item	Observed	5	0	
		Expected	2	3	
	None	Observed	118	146	
		Expected	104	160	
Crosswalk Utilization	No	Observed	71	53	0.000
		Expected	49	75	
	Yes	Observed	151	289	
		Expected	173	267	
Crossing pattern	Within crosswalk lines	Observed	30	17	0.000
		Expected	19	29	
	Straight outside the marked lines	Observed	44	42	
		Expected	34	52	
	Diagonal outside the marked lines	Observed	148	283	
		Expected	170	261	

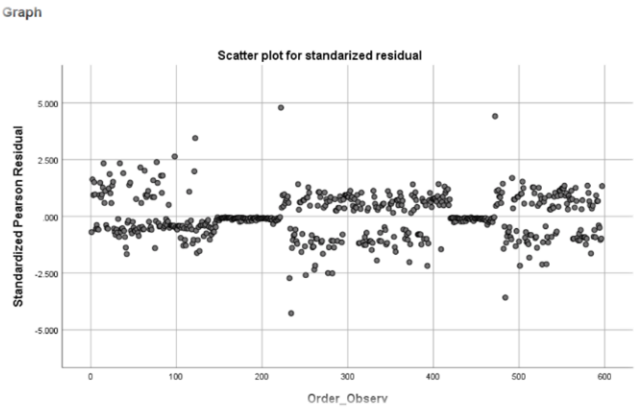


Figure 2: Scatter plot for standardized residual

Assumption #3: There is no multicollinearity among independent variables:

Initially, correlated matrix was prepared with 15 independent variables and highly correlated variables were noted. The highly correlated variable pairs were 'number of traffic lanes', 'pedestrian green time'; 'vehicle flow rate', 'crossing length', 'crossing beyond the line' and 'crosswalk utilization'. Then taking one variable out of the pair of highly correlated variables at a time, the binary logistics regression model was developed, and R-square value was checked. The variable within the lower R-square value was excluded for the rest of the analysis. Accordingly, the 'number of traffic lanes', 'crossing length', and 'crosswalk utilization' were the other three variables that were excluded.

Assumption #4: There are no extreme outliers:

Some outliers were noticed in the dataset as the threshold (= 4/ [sample size - number of parameters including the intercept) is smaller than the Cook distance. Therefore, outliers were removed from observations, and data were refitted to get the best model.

Assumption #5: There is a linear relationship between independent variables and the logit of the dependent variable:

The scatter plot between each independent variable and the logit values was visually observed and the logit linearity was ensured.

Assumption #6: The sample size is sufficiently large:

An adequate number of observations for each independent variable in the data is needed to avoid overfitting the model. The sample size of this study was 564 which could be considered as sufficient.

As all assumptions are satisfied, a binary logistic model was developed of with the Likelihood Ratio Chi-Square statistic of 248.780 with a P-value < 0.001. According to the obtained coefficient estimates in Table 6, five variables out of twelve are statistically significant which is less than 0.05 at a 5% level of significance towards RLR violation of pedestrians.

Table 6: Pedestrian RLR compliance at signalized intersections

Variable (type)	**Description**	**B**	**Sig (P)**
Intercept	-	76.849	0.997
Gender (categorical)	If the pedestrian is female, Gender= 0	-0.658	0.034
	If the pedestrian is male, Gender= 1	0.000	
Age (categorical)	If the pedestrian's age is <20 years, Age= 0	0.309	0.112
	If the pedestrian's age is 20-60 years, Age= 1	-0.385	
	If the pedestrian's age is > 60 years, Age= 2	0.000	
Crossing Type (categorical)	If pedestrians walk, Crossing Type= 0	-3.040	0.000
	If pedestrians run, Crossing Type= 1	0.000	

Accompanying pedestrians (categorical)	If the pedestrian is alone, Accom. ped. =0	0.124	0.872
	If the pedestrian is with one companion, Accom. ped. =1	0.229	
	If it is a group of pedestrians, Accom. ped. =2	0.000	
Crossing with baggage/ Umbrella/ Heavy item (categorical)	If the pedestrian crosses with baggage, Item= 0	-0.036	0.999
	If the pedestrian crosses with an umbrella, Item= 1	-20.092	
	If the pedestrian crosses with a heavy item, Item= 2	22.076	
	If the pedestrian crosses without any item, Item= 3	0.000	
Direction (categorical)	If the pedestrian crosses upstream traffic and then downstream =0	-0.044	0.861
	the pedestrian crosses downstream traffic and then upstream =1	0.000	
Crosswalk Utilization (categorical)	the pedestrian crosses on the marked crosswalk =0	1.406	0.000
	If the pedestrian does not cross on the marked crosswalk =1	0.000	
Mobile Phone Use (categorical)	If the pedestrian uses a mobile phone while crossing =0	21.799	0.999
	If the pedestrian does not use a mobile phone while crossing =1	0.000	
Waiting endurance time (Continuous)	-	-0.003	0.602
Crossing length (Conti...)	-	-11.405	0.997
Number of traffic lane (nominal)	If the number of lanes is two, Lane =2	-1.022	0.000
	If the number of lanes is three, Lane =3	0.000	
Pedestrian Speed (Conti...)	-	-2.556	0.000

The significant variables were gender, crossing type, crosswalk utilization, number of traffic lanes, and pedestrian speed. The variable 'Gender' is significant where the decreasing log of probability -0.658 of compliance for RLR among females was seen compared to that of males. 'Crossing type' is another significant variable which includes walking on the crossing decreases compliance of RLR with the log of probability 3.040 compared to running at the pedestrian crossing. The variable 'Crosswalk Utilization' is also significant when increasing the log of probability 1.406 of compliance with RLR among users of crosswalk compared to that of non- users of crosswalks. Another significant variable is the 'Number of traffic lanes' and log of the probability -1.022 which decreases compliance with RLR. 'Pedestrian speed' is also a significant variable where the log of probability -2.556 which decreases the compliance of the pedestrian's RLR.

5 DISCUSSION

According to the study done by Marisamynathan et al. (2014), pedestrian compliance with traffic signals in India was identified as 44%. But in Sri Lanka, it has gone up to 61.17%. By comparing these two outputs, India's pedestrian compliance is less than Sri Lanka. In other words, pedestrian violation rate at signalized intersections in India is higher than Sri Lanka. In another study, a total of 617 illegal violation samples were chosen at random from a total of 2852 valid pedestrian crossing samples at signalized intersections in Anning District of Lanzhou (Gong et al, 2019). They have identified that the violation rate of pedestrians was 21.6% which is less than Sri Lanka's 38.83%. By comparing these results, Sri Lankan pedestrian violation rate is higher than Lanzhou, China. Besides, Gong et al (2019) compared their result with other cities in China. In comparison to other cities, the violation rate in Lanzhou is higher than in Beijing, China (10%) and lower than in Izmir, Turkey (40%). Even though the violation rate in Lanzhou's Anning District is still quite high, it is not as high as the Sri Lanka's rate of 38.83 %. In addition, Wang et al. (2020) found the pedestrian redlight violations in Beijing, China as 22.1% with 388 cases. It is also lesser than Sri

Lanka's RLR violation rate. Guo et al. (2011) found pedestrian violation in Beijing, China at 39.88 % which is nearly equal to the Sri Lankan value of 38.83 %. According to these results, Sri Lankan RLR violation rate is less than India's but not China's.

As a European country, a study was done on pedestrian behavior at signalized crosswalks in France (Dommes et al, 2015). They found that approximately two-thirds of the observed pedestrians (68%) obeyed the pedestrian red light which is greater than 61.17% of Sri Lanka's. Based on this result, Sri Lankan RLR violation rate is higher than France's. The RLR violation of pedestrians' percentages in Sri Lanka shows that male pedestrians are less patient and more likely to crosswalk than female pedestrians, which is consistent with most previous research (Tiwari et al., 2007; Rosenbloom, 2009; and Brosseau et al., 2013). As the obtained result, there are some associations with compliance RLR of pedestrians with age, crossing type, the number of pedestrian crossing, crossing with baggage/umbrella/heavy item, direction, crosswalk utilization, and crossing beyond the line.

According to this study, the variables: gender, crossing type, crosswalk utilization, number of traffic lanes, and pedestrian speed are significant in RLR violations of pedestrian in Sri Lanka. Gender of the pedestrian had a significant impact on pedestrian compliance behavior in India (Marisamynathan et al, 2014). The gender of the pedestrian and their walking speed have been found to have a significant impact on the likelihood of pedestrian jaywalking in Hong Kong (Wang et al, 2017). Dommes et al, (2015) found that, age was not a direct significant predictor of RLR violation which is one result of our model with Sri Lankan data. In addition, Zhu et al. (2020) found age, gender, the presence of a companion, and traffic volume as significant variables in Hong Kong. But only gender was significant in our model. However, according to Ren et al. (2011) gender did not emerge as an important factor in crossing behaviors in results, except for these two: waiting on the roadway (more often observed in women) and running (rarely observed in men). These findings are slightly different from previous research, which found significant gender differences in pedestrian behavior, both as reported by pedestrians and as directly observed in real-world situations (Rosenbloom, 2009; Tom & Granié, 2011; Yagil, 2000). In addition, there are some considerable associations with particular pedestrian crossing behavior and significant variables.

6 CONCLUSIONS

This study finds the RLR violation rates of pedestrian's as 38.83%. Out of 564 pedestrians 219 violated the rules, as found in video observation surveys at the signalized crosswalk in Kandy city, Sri Lanka. It shows that RLR violation rate of males is higher than females. When the pedestrian violation rate in Sri Lanka is compared with India (54%), Sri Lakas' is lower. But not low as in China (21.6%) and France (32%). Usually, the RLR violation rate in developing countries such as Sri Lanka, India etc is higher than in developed countries such as France, China etc. According to the binary logistic regression model, 'gender', 'crossing type', 'crosswalk utilization', 'number of traffic lanes', and 'pedestrian speed' were statistically significant variables for influencing the RLR violations. These findings help improve the effectiveness of pedestrian management and control at signalized intersections by providing a better understanding of illegal crossings and their impact factors. With a more comprehensive dataset, other environmental factors such as weather, noise, temperature, and land use type would be well worth investigating. Analyzing pedestrian crossing behavior, including pedestrian arrival patterns and influencing parameters, would improve the work's future potential and pedestrian safety. Under this study, some recommendations can be briefly listed as follows: introduce a new fine system for pedestrians who do not obey the traffic rules and regulations, increase existing fines and imprisonment for drivers charged with RLR violations., pedestrians should be informed by government and non-government organization, pedestrians who obey red light would be awarded and appreciated, introduce new subjects to school system such as 'Traffic Safety' and children should be trained to obey traffic rules and regulations. Future researchers will be able to develop a better model by following these suggestions: an automated camera system would be developed rather than manual data collection which takes more time to exact data, sample size should be increased to get very accurate results, and the number of locations should be increased, data only collected during regular days, not holiday and Poya days etc., latest cameras would be placed to capture the large view as well as a video of high quality.

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