MODELLING OF PEDESTRIAN GAP ACCEPTANCE BEHAVIOUR AT UNCONTROLLED INTERSECTIONS

Subina S[1], Archana S[2]

[1]Subina S, PG Scholar, Dept of Civil Engineering, Jyothi Engineering College, Kerala, India
[2]Archana S, Assistant Professor, Dept of Civil Engineering, Jyothi Engineering College, Kerala, India

---***---

Abstract - *One way of studying pedestrian crossing behaviour is to estimate critical gap, using accepted or rejected gaps by the pedestrians which may be indicative of safety levels at pedestrian facilities. Gap acceptance theory is widely used to evaluate the safety and operational performance of minor road at uncontrolled intersection and uncontrolled pedestrian crossings. The pedestrian's decision to cross the road illegally depends on many factors including the pedestrian characteristics and the traffic flow. Generally, a pedestrian observes the approaching vehicles in the travel lanes analyses them, then selects a particular gap to cross. the gap acceptance behaviour and the pedestrians speed are important for a safe crossing. the number of crossing lanes has a major effect on the pedestrian vehicle conflicts. As the pedestrians cross a higher number of lanes, the number of conflicts and speeds increase accordingly. So critical gap study or gap acceptance study is important in the pedestrian accident risk analysis. In this study multiple linear regression model for safe gap acceptance for the pedestrians 'crossing is to be modelled using the variables such as carriage way width, traffic volume, vehicle speed, pedestrian speed, waiting time of pedestrians, length of accepted gap, length of rejected gap, vehicle type, presence of medians, presence of crosswalk.*

***Key Words*: Gap acceptance theory, Critical gap, Linear regression model, Fuzzy logic model, Gap, Pedestrian vehicle conflicts**

1. INTRODUCTION

The use of the road network by pedestrians and their conduct when crossing it have traditionally been recognized as contributing to pedestrian accidents. The smallest distance a pedestrian will accept when crossing a road is known as a critical gap. In metropolitan areas, there are many crossings that lack signalization. Pedestrians must wait for a safe opening to cross the road at these sites. In the current transportation system pedestrian crossing is a complicated problem particularly in metropolitan areas where there is no control for pedestrian road crossing. Depending on the geometry of the road, the behaviour of crossing cars and pedestrians and other factors, pedestrians choose gaps in the traffic stream. Pedestrians are occasionally forced to cross the road because to faulty road geometry and a lack of marked crossing places.

Based on the speed of the nearby vehicle and the minimum distance in terms of corresponding time the pedestrian gap acceptability is calculated. The probability of an accident for the pedestrian increases with decreasing spacing. One of the most crucial factors in the gap- acceptance process is the critical gap, which has an impact on both determining pedestrian safety and researching accident risk analysis. A method of analyzing the behaviour of pedestrians crossing the street involves estimating the critical gap using the accepted or rejected gaps by the pedestrians which may also be a sign of the level of safety present at pedestrian facilities. Because greater gaps in traffic streams are extremely uncommon pedestrian behaviour changes when there are smaller gaps available as they attempt to cross.

1.1 Objectives

- To analyze the pedestrian road crossing behaviour.
- To model safe acceptance gap for pedestrians' crossing using multiple linear regression model.

2. BACKGROUND OF THE RESEARCH

Inorder to carry out the study, more information regarding the pedestrians and their gap acceptance behaviour were required. For these different journals were information gathered was used for the study.

Wafaa Shoukry Saleh and Maha M A Lahsin [1] examined the critical gaps and pedestrian crossing behaviour at a two way midblock crossing. The smallest distance a pedestrian will tolerate when crossing a road is known as a crucial gap. The fuzzy logic system was employed for the analysis. Due to its straightforward and practical construction, the fuzzy logic systems adopted membership function has a triangle shape. The number and length of rejected gaps as well as the length of accepted gaps at the crossing point serve as the input variables for the analysis. The crucial gaps are the output variables. The findings demonstrate that estimating the crucial gap for pedestrians crossing using fuzzy logic is feasible and yields accurate results that are equivalent to those published in the literature.

Vinayaraj VS et al. [2] studied pedestrian crossing behaviour is to estimate critical gap, using accepted/rejected gaps by the pedestrians, which may be indicative of safety levels at pedestrian facilities. This study aims to determine critical gaps using different methods like Raff's method, Maximum Likelihood Method (MLM), Root Mean Square (RMS) Method, Probability Equilibrium Method (PEM), and Logit method. These methods are then compared to single out the most appropriate one. The study results also conclude that logit method is the most appropriate one for estimating critical gap, as it considers the effect of pedestrian- behavior as well as vehicular characteristics concurrently. There would be a significant difference in estimated critical gap values with and without considering pedestrian behavioral characteristics.

Khaled Shaaban et al. [3] determined the illegal crossing behaviour of pedestrians at unmarked mid-block sections is unsafe, risky, and increase the potential of severe conflicts and crashes, especially in the case of multilane roads. This paper investigates pedestrian gap acceptance while crossing the road illegally at unmarked midblock section of six lane divided urban road. MLM was developed to estimate size of accepted gap as a function of demographic crossing behaviour, traffic related characteristics.

B Raghuram Kadali, P Vedagiri [4] explained to investigate the pedestrian roadcrossing behaviour at the uncontrolled midblock location in India under mixed traffic condition. Pedestrian road crossing behaviour at uncontrolled midblock has been modeled by the size of vehicular gaps accepted by pedestrian using multiple linear regression (MLR) technique. Also, choice model has been developed to capture the decision making process of pedestrian i.e., accepted or rejected vehicular gaps based on the discrete choice theory.

Madhumita Paul and Pabitra Rajbonshi [5] explained pedestrians traffic gap acceptance for unsignalized road in urban areas. Pedestrian crossing is a complex issue in present transportation system, especially in urban areas there is no control for pedestrian road crossing. Pedestrians select gaps in vehicular stream depending on roadway geometry, behavioural characteristic of crossing vehicles and pedestrian etc. Due to improper road geometry and insufficient designated crossing points on road, pedestrians are sometimes forced to cross the road and they create confusion and risk to themselves, as well as to the drivers. For road users the choice of where, when and how to cross unsignalized roads are more or less depend on available gaps in vehicular stream.

3. STUDY AREA

Four stretches were taken for the study based on the high pedestrian and traffic flow. They are KSRTC road, Municipal office road (MO road), Kuruppam road and Mahatma Gandhi Road (MG road) at Thrissur which are uncontrolled intersections.

4.METHODOLOGY

Based on the high pedestrian and traffic flow identified the study stretches. Then the data collection proceeds which includes geometric data and traffic volume data. Geometric data includes carriage way width and from videographic survey the traffic volume, spot speed, pedestrian speed, pedestrian volume, waiting time of pedestrians, length of accepted and number of rejected gaps, presence of crosswalks, presence of medians and vehicle type based on the area which is taken were extracted and next step to input the values to get a Multiple linear regression model for safe gap acceptance for pedestrians' crossing where, dependent variable is length of accepted gap and independent variables are traffic count, pedestrian volume, spot speed, no of rejected gaps, pedestrian speed and waiting time, presence of medians and crosswalk.

5.DATA COLLECTION

Primary data is collected for the four stretches which includes the geometric data collections of the Four road stretches and Videographic survey is conducted to extract pedestrian attributes while crossing. Then traffic volume data, spot speed data, pedestrian volume, pedestrian crossing speed, waiting time of pedestrians, length of accepted gap and number of rejected gaps, presence of crosswalks, presence of medians of all study stretches were extracted from the playback videos. For the data collection for pedestrian study video recording taken of the pedestrian during morning and evening peak period of 3 hours from (7 to 10 am) and (3 to 6pm). The geometric data were collected from the field.

6.DATA ANALYSIS

6.1 pedestrian volume

Table -1: Pedestrian Volume

Name of the road	Male	Female
KSRTC road	41%	59%
Municipal Office Road (MO road)	62%	38%
Kuruppam road	47%	43%
Mahatma Gandhi road (MG road)	29%	71%

6.2 Pedestrian Crossing pattern

Table -2: Pedestrian Crossing pattern

Name of the road	Straight	Rolling
KSRTC road	14%	86%
Municipal Office Road	21%	79%
Kuruppam road	17%	83%
M G road	34%	66%

6.2 Pedestrian Crossing speed

Average pedestrian crossing speed based on the gender were analyzed during morning and evening periods and there are significant variations in the crossing speed of pedestrians for both gender class during peak hours. The crossing speed of the pedestrians were varied based on the gender.

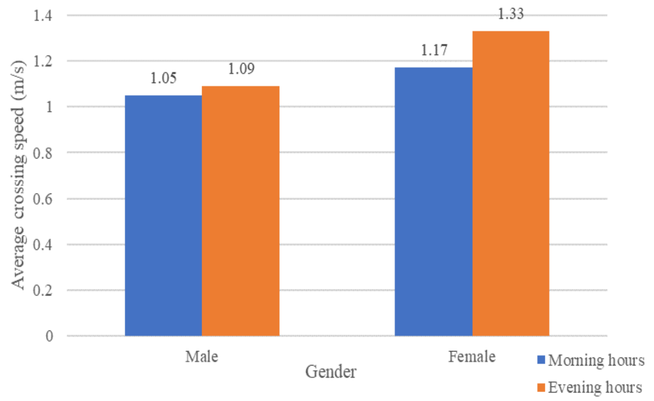

Chart -1: Average crossing speed of pedestrians at KSRTC road

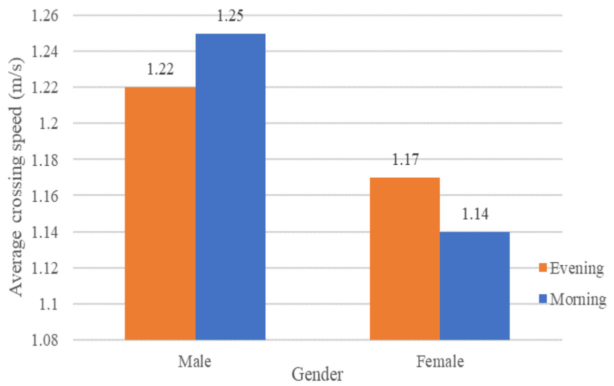

Chart -2: Average crossing speed of pedestrians at MO road

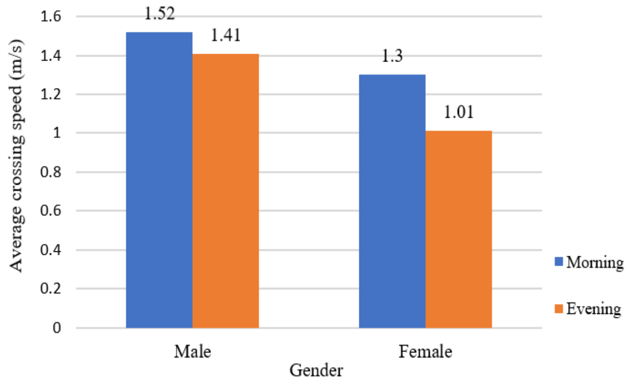

Chart -3: Average crossing speed of pedestrians at Kuruppam road

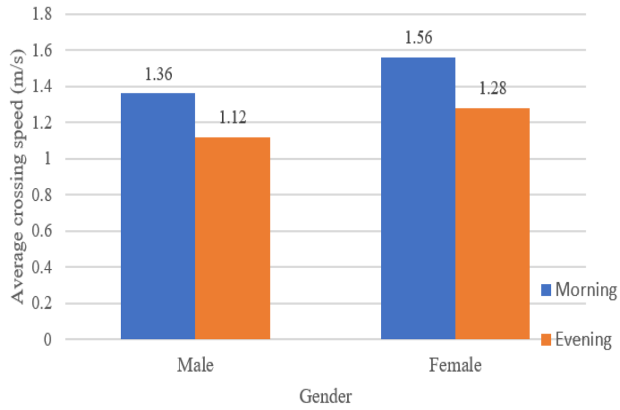

Chart -4: Average crossing speed of pedestrians at M G road

7.MODEL DEVELOPMENT USING SPSS

Multiple linear regression model was developed using SPSS 25.0 software. The dependent variable is length of accepted gap and the independent variables used for the model development were mentioned in Table 3. The test was performed at 95% confidence interval and the variables have a strong link according to Pearson's bivariate analysis ($r = .959$ with $p < 0.001$). Correlation is a bivariate study that assesses the degree of association and the nature of the relationship between two variables.

Table -3: Independent variables used in the model development

Variables	Description	Unit
Tv	Traffic volume	pcu/h
Vs	Vehicle speed	(m/s)
Cw	Carriageway width	m
C	Presence of crosswalk	_

Tov	Type of vehicle	_
Pv	Pedestrian volume	Ped/min
Ps	Pedestrian speed	m/s
Wt	Waiting time	s
Lr	No of rejected gaps	_

The obtained coefficient or correlation matrix which denotes the numerical summary of model and strength of linear relationship between the two variables were explained and ANOVA were explained in Table 4 and Table 5

Table -4: ANOVA table

Model		Sum of squares	df	Mean square	F	Remarks
1	Regression	155.433	9	17.270	126.418	Significant
	Residual	331.014	2423	0.137		
	Total	486.447	2432			

Table -5: Coefficient matrix

Model	Coefficients	Remarks
Constant	0.570	Significant
Traffic volume (pcu/h)	0.023	Significant
Vehicle speed (m/s)	-0.008	Significant
Carriageway width (m)	0.029	Significant
Presence of crosswalk	0.265	Significant
Type of vehicle	-0.136	Significant
Pedestrian Volume (Ped/min)	0.201	Significant
Pedestrian speed (m/s)	0.322	Significant
Waiting time (s)	0.025	Significant
No of rejected gaps	-0.033	Significant

Hence the Pedestrian gap acceptance model is developed using multiple linear regression. The developed gap acceptance model for pedestrian crossing is,

$$La = 0.570 + (0.023 \times Tv) - (0.008 \times Vs) + (0.029 \times Cw) + (0.265 \times C) - (0.136 \times Tov) + (0.201 \times Pv) + (0.322 \times Ps) + (0.025 \times Wt) - (0.033 \times Lr)$$

Where La is the length of accepted gap which is the dependent variable

7.1 Validation of Model

Data validation in which 1/3 of the data is used. Scatter plot diagram shown in chart 5 in which X axis represents estimated value and Y axis represents observed value. From the graph it is clear that the model developed shows an overestimated result with root mean square value or RMSE (Root mean square value) of 0.323. RMSE values between 0.2 and 0.5 shows that model can predict data accurately and the model is validated with RMSE error 0.323

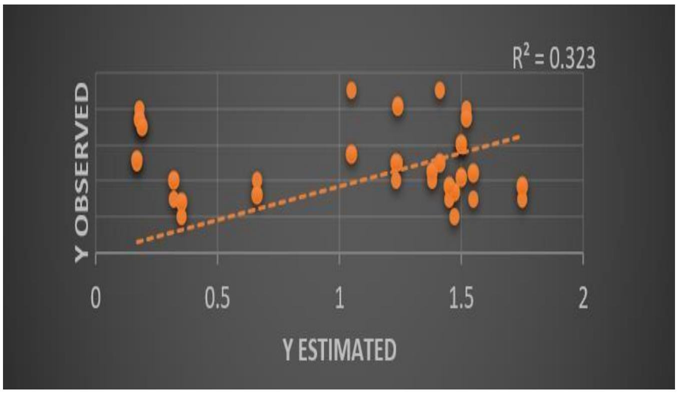

Chart-5: Validation chart for model development

8.RESULTS AND DISCUSSIONS

Pedestrian gap acceptance model is estimated using multiple linear regression analysis by using data from 2433 data points. The final estimated gap acceptance model is

$$La = 0.570 + (0.023 \times Tv) - (0.008 \times Vs) + (0.029 \times Cw) + (0.265 \times C) - (0.136 \times Tov) + (0.201 \times Pv) + (0.322 \times Ps) + (0.025 \times Wt) - (0.033 \times Lr)$$

Where La is the Length of accepted gap (s) which is the dependent variable. Here vehicle speed, type of vehicle, no of rejected gaps shows a negative relationship with length of accepted gap which indicates that when these independent variables increase length of accepted gap decrease. Model is validated with root mean square error value of 0.323. RMSE values between 0.2 and 0.5 shows that model can predict data accurately.

9. CONCLUSIONS

Critical gap estimation is necessary in accident risk analysis of pedestrians. In the study gap acceptance behaviour of pedestrians were modelled and subject to examine the pedestrian gap acceptance behaviour. Mathematical modelling that is, Multiple linear regression model for the safe acceptance gap is modelled using SPSS software where the variables used were carriage way width, traffic volume, vehicle speed, pedestrian speed, pedestrian volume, waiting time, length of accepted and rejected gap, vehicle type, presence of crosswalks, presence of medians. By using these parameters, the best model is modelled. The results show that using correlation and regression via SPSS is useful for the novice researchers. R^2 value obtained for the model was 0.825 which is good for fit. R is the correlation between predicted value and observed value. Vehicle speed, type of vehicle, no of rejected gaps shows a negative relationship with length of accepted gap which indicates that when these independent variables increase length of accepted gap decrease. Model is validated with overestimated result of root mean square value of 0.323. RMSE values between 0.2 and 0.5 shows that model can predict data accurately. The outcomes also showed that correlation and regression are only used with quantitative data.

ACKNOWLEDGEMENT

I am thankful to teaching staffs and Department of Civil Engineering, Jyothi Engineering College, for great support throughout this project. I am deeply indebted to Police station, Thrissur city who helped me to collect the videographic data for the completion of my project.

REFERENCES

[1] Wafaa Shoukry Saleh and Maha M A Lashin, "Investigation of Critical Gap for Pedestrian Crossing Using Fuzzy Logic System", Applied sciences,2021.

[2] Chuanyao Li, Shikun Liu, Xuekai Cen, "Safety and efficiency impact of pedestrian–vehicle conflicts at non signalized midblock crosswalks based on fuzzy cellular automata", Physica A,2021, 572 (125871).

[3] Vinayaraj VS, Shriniwas Arkatkarb , Gaurang Joshi ,ManoranjanParida , " Examining Pedestrian Critical Gap Analysis at Un-Signalized Midblock Crosswalk Sections in India" , Transportation Research Procedia 48,2019 pp. (2230–2250).

[4] Khaled Shaaban, Deepti Muley & Abdulla Mohammed," Modelling pedestrian gap acceptance behavior at a six-lane urban road", Journal of Transportation Safety & Security, 2019, ISSN: 1943-9962 (Print) 1943-9970.

[5] Digvijay S. Pawar, Gopal R. Patil, "Critical gap estimation for pedestrians at uncontrolled mid-block crossings on high-speed arterials ", Safety Science 86 ,2015,(295–303).

[6] Madhumita Paul, Pabitra Rajbonshi," A Comprehensive Review on Pedestrian Gap Acceptance at Unsignalized Road", International Journal of Engineering Research & Technology (IJERT), Vol 03 Issue 11, 2014, ISSN 2278-0181.

[7] Li Dana , Xiaofa Shi "Estimates of pedestrian crossing delay based on multiple linear regression and application ",13th COTA International Conference of Transportation Professionals,2013

[8] B Raghuram Kadali, P Vedagiri "Modelling pedestrian road crossing behaviour under mixed traffic condition", European Transport,2013, ISSN:1825-3997