Estimation of Pedestrian Level of Service at Signalised Intersections

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Abstract: Pedestrian Level of Service (PLOS) is a qualitative measure used to relate the quality of pedestrian service and it represents quality of given intersection in terms of perceived safety, convenience and comfort in terms of pedestrian perspective. Pedestrian delay was one of the key performance indicators for pedestrian level of service. The main objective of this study is to identify the various factors affecting PLOS at signalized intersections and to develop a PLOS model for signalized intersection crosswalk. Video graphic method was used for collection of field data. Questionnaire survey was conducted to know the perceived level of service of pedestrians. The correlation between PLOS and various factors affecting it were determined by using Pearson correlation in SPSS software. And by using the linear regression a model was created for determining the LOS at intersections. This study concludes that turning vehicles, number of pedestrians and pedestrian delay are the main factors affecting LOS of crosswalks at signalized intersection. The model helps intersection designers to decrease the delay while separating the conflicting vehicles to best accommodate pedestrians comfortably and safely.

Keywords: Pedestrian Level of Service, Pedestrian Delay, Signalized intersection, Crosswalk

I. INTRODUCTION

In Indian urban and suburban areas pedestrians form the largest and most vulnerable road users. Pedestrians consist of any person walking, running or standing in the road. Pedestrian concerns are always neglected in transportation planning, construction and management even though pedestrian's safety is the most important category in the traffic system. The pedestrian related problems mainly arises at intersections since they are losing their space. The chances of accidents and conflicts are more at intersections since the vehicles and pedestrians are using the space at same time and due to the traffic violation behaviour of pedestrians. Level of service is one of the best known criteria to express the condition and performance of a road in terms of traveller's point of view. It gives an idea about the environmental qualities of a pedestrian space and serves as a guide for development of standards for pedestrian facilities. Pedestrian Level of Service (PLOS) is an overall measure of walking conditions on a route, path, or facility and it is influenced by a lot of factors. This paper helps to identify the pedestrian related problems at signalised intersections and to identify the various factors affecting PLOS. Also the correlation between the various factors and PLOS were found using Pearson Correlation analysis. With perceived LOS as dependent variable and significant factors obtained from correlation as independent variables, regression analysis was done to develop the model that fit for urban mixed traffic condition. Thus, the factors which is adversely affecting the safe pedestrian movement can be identified which helps in assessing the safety level of pedestrians crossing.

II. OVERVIEW OF LITERATURE

E. M. Cepolin et al. (2017) conducted a study on PLOS: the impact of social groups on pedestrian flow characteristics. They studied on the behaviour of pedestrian groups. Pedestrian's behavior seems very different in the voluntary group. The study concluded that level of comfort of people is related to the area of space that people can use while they are walking and individuals walking independently exhibit similar speed variations as groups since they are not forced to move in a certain way, as slower or closer to each other to keep the consistency of the group, then this behavior does not depend on the presence of people clusters solely.

Vaibhav Vijayawargiya et al. (2017) researched to identify the factors affecting PLOS of crosswalks at roundabouts. They designated six level of services from A to F which indicates best operating condition to worst operating condition. Factors affecting PLOS of crosswalks at roundabouts were found out. They concluded that Roundabouts have

advantages over conventional signalized and un-controlled intersections such as uninterrupted flow, saving in fuel, time etc. and to improve PLOS of crosswalks, the factors affecting it need to be identified and required measures need to be taken and different factors have significant effect on PLOS.

Rima Sahani, et al. (2017) conducted a study for Defining pedestrian level of service at signalized intersections through modelled parameters and SOM clustering. Among various types of Artificial Neural Network (ANN) algorithms, in this study SOM is used for clustering of PLOS scores because of its inherent capability to learn the pattern of input. They concluded that with increase in pedestrian vehicle interaction time, total delay decrease logarithmically. And intersections having score value less than 2 provide best quality of service with pedestrian delay

Sankaran Marisamynathan, et al. (2016) conducted a study to find a method to determine pedestrian level of service for sidewalks in Indian context. The aim of this study is to propose a method for the evaluation of PLOS at sidewalk, based on quantitative and qualitative data. Pedestrian LOS model was developed by using the stepwise regression techniques and LOS ratings are defined by using Khisty's relationship chart. The developed model and LOS rating are validated with field data and results show a lesser percentage error. Finally, the improvement measures are applied and the results are compared before and after improvements with validation data. The results indicate that the new model can provide more accurate and reliable solutions with less error.

Archana.G, et al. (2013) conducted study on analysis of pedestrian level of service for crosswalk at intersections for urban condition which focus on assessing the factors affecting pedestrian level of service at intersections and thus evaluating a method to determine LOS of pedestrians at intersections and to develop a regression model, this can be used to determine the pedestrian level of service of crosswalks at signalized intersections.

Singh K, et al. (2011) conducted a study on different methods of assessing pedestrian level of service. The study focus on discussing some new concepts which have been proposed by the researchers to evaluate pedestrian environment in a better way. The paper concludes that the majority of these methods and models have been developed by combining models that have been applied to other choice contexts and, as a result, are not suited to universal applications and the currently available methodologies of assessing service levels for pedestrians are unable to analyse the entire spectrum of the walking experience.

T. M. Rengarasu, et al. (2012) researched for the estimation of Pedestrian walking speeds at controlled cross walks in Sri Lanka to develop and test a methodology to extract pedestrian speed data from video footage and to find the pedestrian walking speed of Sri Lankans. Results of this study showed that pedestrians in Sri Lanka walked with a mean speed of 1.3 m/s having standard deviation of 0.183 m/s. From this the 15th percentile data was calculated to be 1.20 m/s.

T. A. Petritsch, et al. (2005) studied about Level-of-Service model for pedestrian at signalized intersections. The model incorporates perceived safety and comfort and operations. The pedestrian LOS model for intersections described in this paper is based on Pearson correlation analyses and stepwise regression modelling. The resulting general model for the pedestrian LOS at intersections is highly reliable, has a high correlation coefficient ($R2=0.73$), and is transferable to the majority of metropolitan areas in the United States.

Abishai Polus, et al. (1983) studied about Pedestrian flow and level of service to analyse properties and characteristics of pedestrian flow on sidewalks. It was found that with the increase in pedestrian density, there was a significant decrease in walking speed. It was further found that male pedestrian speeds were significantly greater than that of females.

R. Nagraj, et al. (2013) conducted a study on modelling pedestrian delay and LOS at signalized intersection crosswalks under mixed traffic conditions. The study attempted to develop a PLOS model for signalized intersection crosswalks. This study concludes that turning vehicles, through vehicles, and pedestrian delay are the main factors affecting LOS of crosswalks at signalized intersection.

III.   METHODOLOGY

The steps required for the study were found out. Accident data were collected from police stations and based on the study areas were selected. Three 3 leg signalised intersections of Thrissur district such as Mundur, Choondal and Akkikkavu intersections were selected. Videography survey was conducted to find the traffic volume, pedestrian volume and pedestrian delay, left and right turning traffic. Questionnaire survey was conducted among 50 pedestrians at each intersection to determine the perceived LOS by considering the rating given to each intersection by the

pedestrians. Different geometric data of road such as presence of crosswalk, crosswalk length, crosswalk width, height and width of median, signal cycle length, green time etc. were collected by manual method. Cross walk length and width is taken by using rodo-meter.

IV.   ANALYSIS OF DATA

Number of pedestrians, pedestrian delay, right and left turning traffic were determined from the videography survey. The data from the questionnaire survey was quantified and the selected intersections were rated for finding the perceived LOS. By using the perceived PLOS obtained from the questionnaire survey, graphs were plotted and correlation were determined between PLOS and various factors affecting the PLOS. The correlation is determined to find out the significance of the factors considered to find the LOS. Correlation is mainly intended to identify the relation between dependent and independent variable is linear, exponential or logarithmic. The correlation between PLOS and various factors is shown in the table below.

   The correlation obtained between average LOS and various factors shows that the factors such as number of pedestrians and pedestrian is highly correlated with average PLOS. Number of pedestrians have 85.3% correlation with PLOS at 99 percent level of significance. Pedestrian delay have 82.4% correlation with PLOS at 99 percent level of significance. Factors such as left turning and right turning vehicle have less correlation as compared to number of pedestrians and pedestrian delay. Left turning vehicle have 55.2% correlation with PLOS at 95 percent level of significance and right turning traffic have 53.5% correlation with PLOS at 95% level of significance. So the main factors affecting the PLOS at intersection are number of pedestrians and pedestrian delay.

Table I Correlation Between PLOS and Various Factors

Factors	PLOS
Number of pedestrians	0.853^{**}
Pedestrian delay	0.824^{**}
Left turning traffic	0.552^{*}
Right turning traffic	0.535^{*}

V.   MODEL FORMULATION

These variables were selected from the Pearson correlation, for model development: left-turning traffic (l), right-turning traffic (r), number of pedestrians crossing in both directions (p), and pedestrian delay (d). With regression analysis using collected samples, the best-fit model was developed on the basis of R-squared and t-statistic values. The model is developed by considering LOS as dependent variable and various factors as independent variable. The predicted model and its coefficients are given as follows:

$$LOS = a1 * p + a2 * d + a3 * l + a4 * r + constant$$

Where,
p = number of pedestrians crossing every 15 min
d= pedestrian delay,
l = left-turning vehicles [passenger car unit (PCU)/15 min],
r = right-turning vehicles (PCU/15 min)
Constant = regression equation constant.

The result obtained after regression analysis is shown in Table II

Table II Regression Analysis Result

Model	B	T	Sig.
(Constant)	3.393	19.923	.000
Pedestrian	.002	.508	.627
Delay	-.230	-.637	.545
Left turn traffic	-.012	-2.454	.044
Right turn traffic	.002	.525	.616

Therefore the predicted model becomes,

LOS=0.002*p-0.230*d-0.012*l +0.002*r+3.393

The coefficients were found to be significant at the 95% confidence interval and with R^2 value 0.628.

VI.   MODEL VALIDATION

The model validation was done by applying this model in another intersection. The predicted LOS for that intersection is 1.4 which is less than obtained LOS for that intersection. This decrease in value may be due to the less R-squared value, insufficiency of data or may be due to the model is not linear.

RESULTS AND CONCLUSIONS

- Significance of various factors affecting PLOS were identified
- Data such as number of pedestrians, pedestrian delay, left turning traffic and right turning vehicle were obtained from the video graphic survey
- Perceived LOS of each intersection was obtained from the questionnaire survey conducted at each intersection
- Correlation between average PLOS and various influencing factors were determined
- Number of pedestrians have 85.3% correlation with average PLOS at 99 percent level of significance
- Pedestrian delay have 82.4% correlation with average PLOS at 99 percent level of significance
- Left turning and right turning vehicles respectively have 55.2% and 53.5% correlation with average PLOS at 95 percent level of significance
- Number of pedestrians and pedestrian delay are highly correlated with average PLOS
- Using the value of pedestrian LOS at crosswalks, roadway designers can determine how well a particular intersection accommodates pedestrian travel.

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