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ANALYSIS OF PEDESTRIAN LEVEL OF SERVICE FOR CROSSWALK AT INTERSECTIONS FOR URBAN CONDITION

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Abstract

It is necessary to objectively quantify how well roadways accommodate pedestrian travel. Estimation of pedestrian level of service (LOS) is the most common approach to assess quality of operations of pedestrian facilities. Intersections, by their very nature, are locations where there is considerable potential for conflict between different traffic streams and different users. At busy intersections motorists, cyclists, and pedestrians often have to deal with complex situations and be aware of the position, movement and intent of other users. Mixed traffic of motor vehicles and pedestrians are common in urban intersections. The demand for the improvement of pedestrian facilities is raised due to the reasons such as difficulties in crossing heavily trafficked intersections, turning vehicles across their paths during the green signal, conflicts among pedestrians and cyclists, physical barriers, low visibility, improper design of handicapped accessible ramps and so on. A method is needed to assess the degree of difficulty a user will experience crossing an intersection. A field survey will be conducted to collect geometric, operational and traffic characteristics of crosswalks. A number of primary independent variables influencing pedestrian LOS should be identified and tested in the stepwise regression analysis Development of pedestrian LOS measure for intersection are intended to indicate the level of difficulty in crossing intersections. This study explains a method for the estimation of pedestrian LOS at intersections and also identifies the factors affecting pedestrian level-of service LOS at intersections.

Key Words: pedestrian facilities, heavily trafficked intersections

1. INTRODUCTION

Since the pedestrian environment is multi-dimensional, the pedestrian in the roadside environment is subjected to a set of several factors significantly affecting his or her perception of safety, comfort, and convenience. Measurement of these factors is necessary to evaluate the pedestrian facilities and evaluation methods are needed to understand how well a particular street accommodates pedestrian travel. In order to appropriately plan for more walkable environments, methods are required that allow planners and decision-makers to effectively identify and assess the elements of the built environment that support or detract from walking. The quality of the pedestrian environment has been measured for many years using the Level-of-Service (LOS) approach. The LOS for pedestrian facilities is influenced by a lot of factors and different pedestrians have different perceptions on the LOS.

The pedestrian movement through an intersection, hence the intersection level of service to the pedestrian, can be described by the conflicts, exposure and delay experienced by the pedestrian. As the pedestrian walks along the primary facility and travels through an intersection, he experiences conflicts with various motor vehicle turning movements, the number, volume, and speed of which is believed to affect the pedestrian perception of safety and comfort. Likewise, the pedestrian exposure to conflicts with motor vehicle traffic is believed to affect his level of service. The intersection crossing delay experienced by the pedestrian is considered a principal aspect of the intersection level of service to the pedestrian. This study mainly focus on assessing the factors affecting pedestrian level of service at intersections and thus evaluating a method to determine LOS of pedestrians at intersections.

2. OBJECTIVES

This research was carried out ultimately to develop a pedestrian level of service (P-LOS) model which takes into account the factors which influence pedestrians' perception of safety and comfort and thus help provide higher LOS for pedestrian crosswalks at signalized intersections. In order to develop the P-LOS model, a statistical method called multiple linear regression analysis was used..

The main objectives of this study are:

- To identify factors which influence the level of service of crosswalks at signalized intersections
- To develop a regression model, this can be used to determine the pedestrian level of service of crosswalks at signalized intersections.

3. LITERATURE REVIEW

3.1 GENERAL

To represent an integrated picture of facilities for pedestrians, it is important to review, compile, and organize the current state of researches that assess level-of service (LOS). The literature review is focused on the review of earlier studies regarding pedestrian level of service at intersections.

3.2 EXISTING PEDESTRIAN LOS METHODOLOGIES

A pedestrian LOS criterion for signalized/ unsignalized intersection is defined in terms of time delay in the Highway Capacity Manual 2000 (HCM, 2000). Although HCM describes LOS criteria for pedestrian at intersections based on pedestrian delay, it does not include the other factors such as crossing facilities, turning vehicles, and pedestrian-bicycle interactions at crosswalks, etc. In HCM, sophisticated models are provided to estimate vehicle delays at signalized intersections, but the provided pedestrian delay model is quite simple. This might because at signalized intersections vehicle delays are usually regarded as more important than pedestrian delays. Another reason might be the difficulty of estimating pedestrian delays accurately due to the flexibility and diversity of pedestrians.

IRC-103-1988 specifies the provision of pedestrian crosswalks at all important intersections and at locations where substantial conflict exist between vehicular and pedestrian movements. It describes that wherever possible; crosswalks should be at right angles to the carriageway and properly marked so that pedestrians are subjected to minimum inconvenience. Also, crosswalks should not increase walk distance of pedestrians. Adequate visibility, freedom from obstructions, and sufficient space for waiting are other important requirements provided in IRC for the location of crosswalks.

Dixon (1996) proposed a pedestrian LOS evaluation criterion which involves the provision of basic facilities, conflicts, amenities, motor vehicle LOS, maintenance, and travel demand management, and multimodal provisions. There was no qualitative environmental assessment relating to walkability. This seems to be best suited to footpath assessments, applicability to intersections was uncertain.

A mathematical model was proposed by Landis et al., (2001) based on five variables: lateral separation of pedestrians from motor vehicle traffic, presence of physical barriers and buffers, outside lane traffic volume, motor vehicle speed, and vehicle mix. Although this mathematical model evaluates a roadway segment, it does not include intersections. However, they believe that intersection conditions have a significant bearing on pedestrians and a measure must be developed that includes conditions at intersections.

Gallin (2001) developed a simple model for determining how well paths and roads cater to the needs of pedestrians. The process involved the formulation of a method for assigning a LOS grade to pedestrian facilities that was based on the interpretation of factors affecting pedestrian LOS and the degree to which these factors are provided (or absent) on selected path segments.

Muraleetharan et al., (2004) used conjoint technique to combine the factors affecting pedestrian LOS. Total utility from the conjoint analysis represents an overall value, which specifies how much a user puts on a product or service. Even though this study proposed a method to determine overall LOS, it does not include all the factors affecting pedestrian LOS.

Muraleetharan et al., (2005) identified the factors affecting pedestrian level-of service at intersections and proposed a method for the estimation of pedestrian LOS at intersections. The study revealed that the factor turning vehicle has greater influence on pedestrian LOS than other factors. Furthermore, the factors delays at signals and pedestrian-bicycle interaction were also found to be significant factors in determining pedestrian LOS at intersections.

Hubbard et al., (2009) did a statistical analysis using a binary logit model that provides new insights into the factors that affect the likelihood that a pedestrian is compromised ,delayed, altered their travel path, or altered their travel speed, in response to traffic turning right on green during concurrent vehicle/pedestrian signal timing. Application of a binary logit model of pedestrian compromises shows that the probability of a pedestrian compromise increases with increasing right-turn vehicle flow rate, and is higher for crosswalks outside the CBD compared to crosswalks in the CBD for the same right-turn flow rate.

Based on literature review, much of the works dealing with pedestrian is limited to pedestrian facilities on uninterrupted sidewalks. On the other hand, there are a few studies dealing with pedestrian facility issues at intersections. This indicates that a reliable measure is needed to describe the pedestrian environment at intersections. Development of pedestrian LOS measure for intersection is therefore intended to indicate the level of difficulty in crossing intersections.

4. METHODOLOGY

4.1 FACTORS INFLUENCING PEDESTRIAN LEVEL OF SERVICE AT SIGNALIZED INTERSECTIONS

The various factors that can be considered in the development of the model can be grouped into three main categories, as follows

1. Pedestrian Factors
   - Pedestrian Flow
   - Pedestrian Crossing Time
   - Pedestrian Delay
   - Pedestrian Sight Distance
2. Crosswalk Factors
   - Pedestrian Holding Area
   - Crosswalk Width
   - Crosswalk Surface Condition
   - Crosswalk Marking
3. Roadway Factors
   - Number of Lanes
   - Roadway Width
   - Exclusive Left-Turn Lanes

The various factors considered in the development of the present P-LOS model are as follows:

- Pedestrian Flow
- Pedestrian Crossing Time
- Pedestrian Delay Time
- Crosswalk Surface Condition
- Crosswalk width
- Crosswalk Marking
- Roadway width
- Number of lanes.

4.2 METHODOLOGY FOR DEVELOPMENT OF P-LOS MODEL:

The development of the P-LOS model involved

- The collection of data by visual surveys and field surveys,
- A statistical analysis of the collected data using multiple linear regressions
- A model validation process using several statistical tests.

For statistical analysis software **SPSS** is used. Originally it is called as "Statistical Package for Social Scientists" but now stands for "Statistical Product and Service Solutions", one of the most popular statistical packages which can perform highly complex data manipulation and analysis with simple instructions.

4.2.1 DATA FOR THE DEPENDENT AND INDEPENDENT VARIABLES:

The P-LOS model consisted of a dependent variable and seven independent variables. The dependent variable was the P-LOS Score obtained through interviews and questionnaires. Pedestrians were asked to rate the crosswalks in terms of safety and comfort. The average rating of the pedestrians for each crosswalk is mentioned in Appendix 1

The independent variables were the factors as identified in section 2. Pedestrian flow (ped/hr), pedestrian crossing time (sec), pedestrian delay (sec), crosswalk surface condition (0- poor, 1 - moderate, 2 - good), crosswalk marking (0 - not visible, 1-slightly visible, 2 - highly visible), crosswalk width, and roadway width (m) were measured at the study locations. These data formed the input for the analysis as shown in Appendix 2.

4.2.2 DATA ANALYSIS

The following are the assumptions made, prior to the development of the model using the multiple regression analysis method.

(1) For each value of the independent variables (X), there is an array of possible values for the dependent variables (Y) which is normally distributed about the regression line.

(2) The mean of the distribution of possible Y values is on the regression line, that is, the expected value of the error term is zero.

(3) The standard deviation of the distribution of the possible Y values is constant regardless of the X values.

(4) The error terms are statistically independent of each other, that is, there is no serial correlation.

(5) The error terms are statistically independent of X values

4.2.3 VALIDATION OF THE MODEL

Based on the summary output from the regression analysis, as shown in Appendix 3, a series of statistical tests were done to validate the model.

Coefficient of Determination (R-Square)

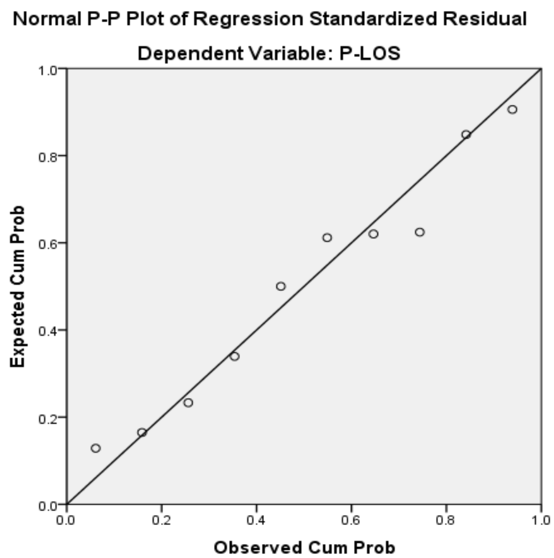
From the multiple regression analysis performed, the coefficient of determination or R-square value was 0.949, (refer to Appendix 3), which indicates that 94.9% of the variation in the predicted P-LOS Score has been explained by the explanatory variables, or in other words, the regression line. The R-square value obtained is exceptionally high and it indicates that the model is almost a perfect fit (an R-square value of 1 is a perfect fit).

T-Test

The T value, which is the square root of ratio between the Mean Square Regression (MSR) and the Mean Square Error or Residual (MSE), or square root of F (=37.199) in Appendix 3. With the significance level (a) and degree of freedom (d.f.) being 0.05 and 9 respectively, the critical-t value is 2.262 and the T value for the model is 6.099. Since T is greater than critical-t, therefore it can be concluded that the relationship is significant and the model can be used to calculate the P-LOS Score.

Comparison

The comparison between the predicted and observed P-LOS Scores is shown in Figure 1. The graph indicates that the P-LOS model which was developed through this study yielded results which are close to the observed values. Thus, it can be used to predict the P-LOS Scores.



Outcome from the Validation Tests

Since the P-LOS model which was developed through this study has passed the validation tests (R-square value& T-test), therefore it can be summed up that this model is valid and can be used to determine the P-LOS Score.

5. RESULTS

From the analysis, the regression equation to determine the P-LOS Score took the form of:

P- LOS =7.443 - 0.002PFH -0.061PCT + 0.679CSR

Where, CSR = crosswalk surface condition rating. (0 - poor, 1 - moderate, 2 - good)

PCT = pedestrian crossing time (sec)

PFH = pedestrian flow (ped/hr)

To aid in the determination of the P-LOS of the crosswalk, a LOS table, as shown in Table below, was developed as a basis for stratifying the model's numerical result into a level of service category.

Pedestrian level of service (P-Los)	P-Los score
A	8.5 < x < 10.0
B	7.0 < x < 8.5
C	6.0< x < 7.0
D	5.0 <x < 6.0
E	4.0 <x < 5.0
F	x <4.0

6. CONCLUSIONS AND RECOMMENDATIONS

From this study, it was found that the following factors had a greater influence on the level of service of crosswalks at signalized intersections for the selected study site.

a) Pedestrian Flow

b) Pedestrian Crossing Time

c) Crosswalk Surface Condition

This study also produced a P-LOS Model which can be used to determine the level of service of crosswalks at signalized intersections. The model is in the form of the following equation:

$$P\text{-}LOS = 7.443 - 0.002PFH - 0.061PCT + 0.679CSR$$

Where, CSR = crosswalk surface condition rating. (0 - poor, 1 - moderate, 2 - good)

PCT = pedestrian crossing time (sec)

PFH = pedestrian flow (ped/hr)

Significance of P-LOS models.

- Pedestrian LOS model for crosswalk provides a measure of a crosswalk's performance with respect to pedestrians' safety and comfort.
- Using the value of pedestrian LOS at crosswalk, roadway designers can determine how well a particular intersection accommodates pedestrian travel. In other words, pedestrian LOS measures can provide an easy understanding about the condition of a crosswalk. Such a measure would help in evaluating and prioritizing the needs for pedestrians on existing intersections.
- Pedestrian LOS at crosswalk can be used to develop a minimum LOS standard which could prescribe the minimum acceptable LOS for the adequate accommodation of pedestrians. Crosswalks at urban intersections should be targeted to maintain a minimum pedestrian LOS in order to provide a minimum level of accommodation for pedestrians.
- Pedestrian LOS models could also be used to support the development of pedestrian facility improvements.
- Roadway designers can use the pedestrian LOS model to test alternative intersection designs by iteratively changing the independent variables to find the best combination of factors to achieve the desired LOS

From the model and the observations made, it can be recommended that in order to achieve high levels of service of crosswalks at signalized intersections, the following can be practiced in the planning and design of crosswalks at signalized intersections:

- Shorten pedestrian crossing time by reducing crosswalk length and increasing crosswalk width.
- Increase pedestrian flow by providing a longer pedestrian green time and providing larger walking space.
- Reduce pedestrian delay by shortening cycle length of the traffic signal system.
- Improve the condition of crosswalk surface through routine checks and maintenance.
- Make sure that crosswalk markings at intersections are visible both day and night through routine checks and maintenance.
- Provide adequate space for holding or accommodating pedestrians while waiting to cross.
- Provide minimum required roadway width at the intersections in order to shorten crossing distance and time.

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APPENDIX 1

P- LOS USERS SCORE			
LOCATION	CROSSWALK	NUMBER OF PARTICIPANTS	AVERAGE USERS SCORE
Banashnkari junction	1	25	6.00
	2	25	6.50
	3	25	6.00
	4	25	6.00
	5	25	7.00
	6	25	6.00
Btm layout petrol bunk junction	1	25	8.00
	2	25	7.50
	3	25	8.00
	4	25	7.00

LOCATION	CROSSWALK	CROSS MARK (VC)	CROSSWAK SURFACE CONDITION (CSR)	LANES	ROADWAY WIDTH (RW)	CROSSWALK WIDTH(CW)	PEDESTRIAN CROSSING TIME(PCT)	DELAY (D)
1	1	1	2	2	21.30	3.4	7	120
	2	1	2	2	22.00	2.7	12	120
	3	1	2	2	36.70	3.05	9	120
	4	1	1	2	36.70	2.8	17	120
	5	1	2	2	25.00	3.7	14	180
	6	1	2	2	37.00	3	12	180
2	1	2	2	2	21.20	2.94	6	69
	2	1	2	3	31.50	3	8	58
	3	1	2	2	13.50	2.52	7	60
	4	2	2	2	31.50	3.02	8	58

APPENDIX 2

P-LOS	VC	CSR	LANES	RW	CW	PCT	D	PFH
6.00	1	2	2.00	21.30	3.4	7	120	1392
6.50	1	2	2.00	22.00	2.7	12	120	840
6.00	1	2	2.00	36.70	3.05	18	120	1222
6.00	1	1	2.00	36.70	2.8	14	120	800
7.00	1	2	2.00	25.00	3.7	10	180	940
6.00	1	2	2.00	37.00	3	15	180	1130
8.00	2	2	2.00	21.20	2.94	6	69	320
7.50	1	2	3.00	31.50	3	12	58	400
8.00	1	2	2.00	13.50	2.52	7	60	280
7.00	2	2	2.00	31.50	3.02	14	58	435