Determination of Pedestrian Level of Service at Signalized Midblock Locations for Mixed Traffic Conditions

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Abstract: walking is considered as one of the most important modes of transportation in India. But it is observed that the facilities for the pedestrians are ignored during design, planning and maintenance stage. But these days due to increase in population in urban areas, traffic congestion has become a major problem for safe pedestrian crossing. It is necessary to objectively quantify how well roadways accommodate pedestrian travel. Estimation of pedestrian level of service (PLOS) is the most common approach to assess quality of operations of pedestrian facilities. Due to more urbanisation and also large distance between the successive intersections people are forced to cross at their respective midblock.

This paper aims in understanding pedestrian characteristics or pedestrian behaviour which is a fundamental in pedestrian planning process and finding the level of service for the pedestrians (PLOS) at selected signalised midblock. Pedestrian data required was collected using video graphic technique during two peak hours in a day at Kukatpally and Nizampet signalised midblocks in Hyderabad city. The factors considered for the calculation of PLOS are their delay, crossing time, speed, density and volume of pedestrians.

Greenshields's macroscopic model was used to resolve important parameters like free speed (v_f) and jam density (k_j) by plotting their respective graphs. Finally, regression analysis is carried in R software to calculate pedestrian LOS using the above factors considered. Clustering technique is used to obtain the LOS scores for the collected pedestrian data. LOS calculated from model outputs is compared with the values in Indo HCM 2017.

Key words: Pedestrian LOS, Signalised Midblock, Greenshield's Model, Indo HCM 2017, R studio.

I. INTRODUCTION

Walking is considered as as one of the most significant modes to commute in Indian situation. It is seen that a large portion of the pedestrian issues are disregarded during design and planning stage. Until the mid-seventies, pedestrian traffic has scarcely been the subject of research where just pedestrian behaviour was seen by watching and inferring simple theories and by inferring models to decide the behaviour of pedestrians.

Recently, where more advancements that are recently increased the technology became available and pedestrian models have been easily developed to understand their behaviours and to measure the quality of services. In spite of these advancements, no legitimate consideration is given to pedestrian facilities. Since no appropriate consideration is given to these facilities, pedestrian mishaps have transcendently expanded.

Pedestrian crossings are broadly classified as, at grade and Grade separated pedestrian crossings.

1. At grade pedestrian crossing, is defined as the place where pedestrians cross the carriage way at the same level as that of the vehicular movement. This includes crossings at intersections and midblocks.
2. Grade separated pedestrian crossing, is defined as the place where pedestrians and vehicles cross the carriage way at different level. Foot over bridges, underpass and overpass comes under this type of pedestrian crossing.

Pedestrians and motorcyclists make up to half of those killed on the roads, highlighting the necessity for these road users give more consideration in road safety programs. Unsurprisingly, thickly populated countries have higher numbers of pedestrian deaths (as per year 2009) which includes China, India, and the Russian Federation. As indicated by The Times of India report, "pedestrians represent 33% street fatalities". In the previous 5 years, 666 people on foot have lost their lives in deadly incidents in Hyderabad police Commissioner-ate restrains alone.

This paper includes the study of pedestrian behaviour at signalised midblocks. Safety, comfort, convenience and minimum delay are the important parameters considered for the pedestrians at midblocks. Therefore it is necessary to evaluate the quality of the crosswalk with these qualitative parameters. Level of service (LOS) is generally used to measure the quality of traffic service, in this paper this is used to measure the quality of pedestrian service at selected signalised midblocks based on their crossing speed and delay. The parameters delay (D), speed (V), density (K) and flow (Q) are retrieved manually from the videos taken, by mounting the camera at certain elevation. Greenshield's model is used for the calibration of pedestrian data. The retrieved data is put in the Greenshield's formulae to calculate jam density (Kj), maximum flow (Qmax), free flow speed (Vmax), volume capacity ratio and their respective graphs are plotted.

The main aim is to determine LOS of the pedestrians using clustering technique based on delay and v/c ratio. Clustering is a statistical technique of partitioning a sample into homogeneous groups to produce an operational classification. LOS scores are determined by developing the number of clusters using K mean clustering analysis.

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The algorithm is run in the R program using sapply() function over the K range, where k is the number of clusters chosen.

II. LITERATURE SURVEY

Several studies have been conducted by the various researchers on pedestrian behaviour and pedestrian level of service in urban areas. Some of them are listed as below:

Axler (1984) suggested more warrants and other considerations for grade separated pedestrian crossings. This included pedestrian hourly volume, vehicle volume, any physical barrier like underpass, overpass and the elevation difference etc.

Lyons et.al. (2000) explained that signalised midblock pedestrian crossing is a general method of resolving the conflicts between pedestrian and vehicular traffic. This paper focuses on developing an alternatives for signalised midblock pedestrian crossing that are more responsive to the needs of pedestrians without causing excess delay to the vehicular traffic. ANN models are developed to enhance the operation of signalised midblock pedestrian crossings.

Xuehaochu et.al. (2002) developed a methodology for pedestrian LOS at midblock locations. The objective was to determine what variables are correlated with pedestrians' perceived quality of service for midblock crossings. Results showed that the levels of crossing difficulty tend to increase with the width of painted medians, signal spacing, and turning movements. The results also indicated that presence of pedestrian signals lowers the crossing difficulty.

Noyce et.al. (2009) used a micro simulation approach for determining the common alternatives for signalising a typical midblock crosswalk with diverged geometrics, aimed to explore how changing geometrics and signalisation schemes affects various measures of effectiveness from both pedestrian and vehicle perspectives.

Kadali et.al. (2014) examined the gap acceptance of a pedestrian using ANN model. Video graphic data was captured with the help of three cameras placed at Worli in Mumbai; one is used for knowing the pedestrian behaviour and the other two for recording vehicular characteristics. From the results it has been found that the pedestrian rolling gap, frequency of attempt, vehicular gap size, pedestrian speed change condition and vehicle speed play an important role in pedestrian gap acceptance.

Lin et.al. (2014) developed an LOS for pedestrians at an unsignalised midblock in China. Data was collected from the pedestrian crossing by questionnaire survey. Pedestrians perception were noted from two respects separately i.e., the convenience and the safety. Regression and Pearson correlation analysis were carried out to develop LOS model and results revealed that Los model developed was reliable with R^2 as 0.8.

Vedagiri et.al (2014) modelled pedestrian midblock crosswalk LOS under mix traffic conditions. The objective of the study is to find out the factors affecting pedestrian LOS at mid-block locations based on pedestrian perceived conditions. A complete 2154 pedestrians were asked to give evaluations of mid-block after they cross the road in the city of Mumbai. From the study it can be concluded that the variables such as age, frequency of using crosswalk, purpose of the trip, safety condition, crossing difficulty and median width have a significant effect on pedestrian LOS at mid-block location under mixed traffic scenario.

Kadali et.al. (2015) explained pedestrian LOS with respect to land use such as shopping, residential and business areas. NLOGIT software package and the ordered probit (OP) model were used for the analysis. Results conclude that land use condition, number of vehicles encountered, median width and number of lanes have significant effect on pedestrian LOS at unsignalised midblock crosswalks.

Asaithambi et.al. (2016) investigated pedestrian road crossing behaviour of an intersection before and after signal installation. Parameters like crossing patterns, waiting time, crossing time, and pedestrian crossing speed, pedestrian gender, age, types of vehicles and flow were retrieved from the video camera survey. From this study, after installing the signal pedestrians chose one-step crossing, as the pedestrians got space to wait to travel across the street at signal red of vehicular traffic.
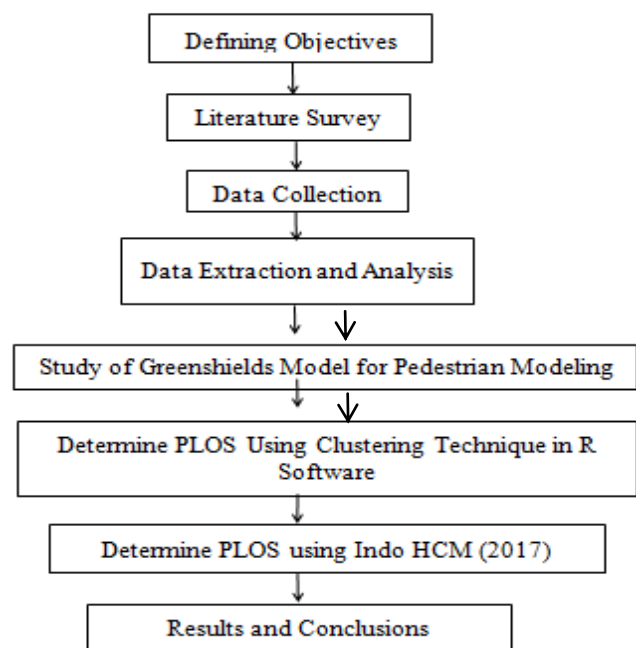
III. OBJECTIVES

The objectives of the study include:

- To study macroscopic stream model for pedestrian midblock crosswalks.
- To evaluate pedestrian Level of Service (PLOS) at selected signalised midblocks.

IV. METHODOLOGY

The methodology adopted for the study is shown below in figure 1:

Fig. 1. Flow chart showing the methodology adopted in the study.

V. STUDY LOCATION AND DATA COLLECTION

Three signalised midblock locations Kukatpally, Dilshuknagar and Nizampet are considered for the study as shown in the figures below. A two hours pedestrian data is collected for two peak hours in a day using videography technique.

The data required for the study (flow, speed and delay) are extracted manually from the video for every 5min interval. The other parameters max speed (Vmax), jam density (Kj) and max flow (Qmax) is determined using Greenshield's formulae and their respective graphs are plotted.

Fig. 2. Kukatpally signalised midblock.

Fig. 3. Nizampet signalised midblock

Fig. 4. Dilshuknagar signalised midblock

The green time provided for the pedestrians at two locations is 30 sec and the green time provided for the vehicles is 125 sec. The flow recorded at the locations is as follows:

- Kukatpally morning (9AM to 11AM) – 3671 pedestrians/hour
- Kukatpally evening (4PM to 6PM) - 4868 pedestrians/hour
- Nizampet morning (9AM to 11AM) - 2263 pedestrians/hour
- Nizampet evening (4PM to 6PM) - 2768 pedestrians/hour
- Dilshuknagar morning (9AM to 11AM) - 3183 pedestrians/hour
- Dilshuknagar evening (4PM to 6PM) - 3104 pedestrians/hour

VI. RESULTS AND DISCUSSION

A. Calibration of Greenshields macroscopic model

Macroscopic models are used to determine the relation between traffic parameters (flow, speed and density). The most important relation among them is speed and density. The simplest relation between them is first proposed by Greenshield. A linear relationship is developed between speed (v) and density (k) using the Equation (1):

$$v = v_f - \left[\frac{v_f}{k_j}\right] * k \qquad (1)$$

The relation between flow (q) and density (k), shown in equation (2):

$$q = v_f * k - \left[\frac{v_f}{k_j}\right] * k^2 \qquad (2)$$

The relation between speed (v) and flow (q) is shown in equation (3):

$$q = k_j * v - \left[\frac{k_j}{v_f}\right] * v^2 \qquad (3)$$

Using the pedestrian data, a graph is plotted as shown in figure3, between speed and density from which the basic equation is obtained as shown in equation (4). Here X is considered as the pedestrian density and Y is crossing speed of the pedestrian.
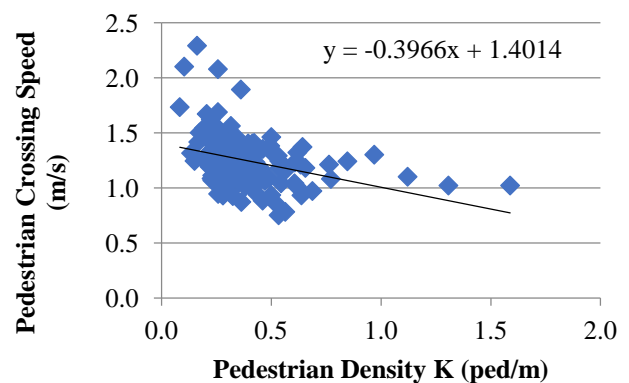
$$y = -0.3966x + 1.4014 \qquad (4)$$

Fig. 4. Pedestrian Crossing Speed Vs Pedestrian Density.

According to calibration of Greenshield's model, jam density is obtained as 3.53ped/m and free flow speed as 1.4m/s. The respective Greenshield's graphs are plotted as shown below in the figure (5):
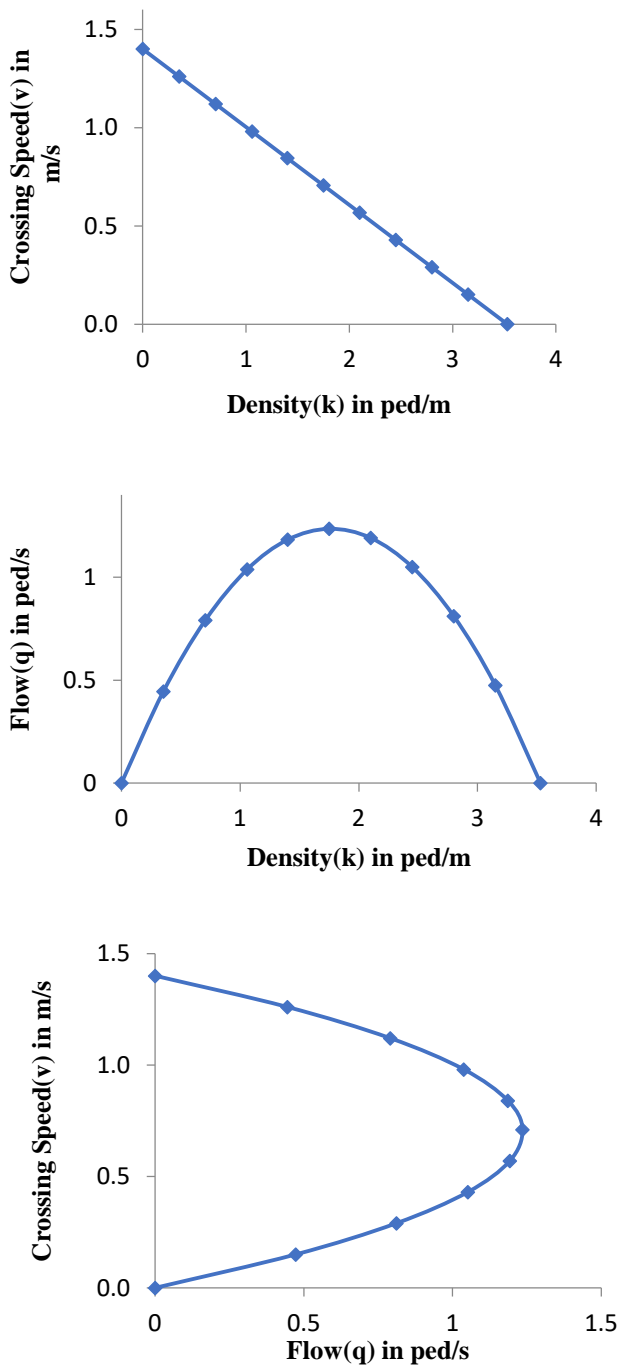
Fig. 5. Greenshield's graphs showing relation between basic parameters for the collected pedestrian data.

sAccording to IRC 103 guidelines max free flow speed is 1.2m/sec. From the study it is revealed that free flow speed for the midblocks is 1.4 m/sec which is slightly higher than IRC guidelines.

B. Development of LOS scores:

To develop Level of Service score clustering technique is adopted using K-mean clustering analysis. Clustering is a technique where the dataset is divided into broad sets for finding subgroups in one set of observation. K-means clustering is the simplest form of clustering technique where the observations are divided into k number of clusters. In order to know how many number of clusters an observation can be divided optimal number of clusters is determined.

Three popular methods are used to determine the optimal number of clusters. They are: 1. Elbow Method
2. Silhouette Method
3. Gap Statistic
In this study Elbow method is used to find the number of clusters using R software. It is a method of interpretation and validation of total within clusters designed to find the appropriate number of clusters in a dataset.
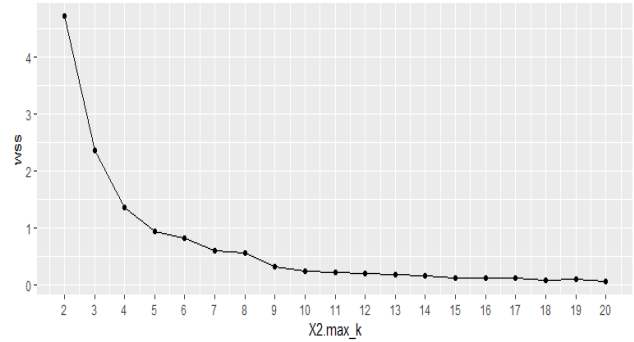

Fig. 6. Validation Measures for Optimal Number of Clusters using Elbow Method.

From the figure 6, it is clear that the number of clusters obtained is six (k=6). Once the optimal k is resolved, the program is re-run with k equivalents to 6 to assess the clusters. Average crossing speed and volume to capacity ratio (v/c ratio) were used as an input to the clustering algorithm in R studio. Using the free flow speeds data the validation parameters are classified into some number of classes to classify the values for signalized midblocks. The validation parameters for the obtained values are shown in below Figure 5.10.
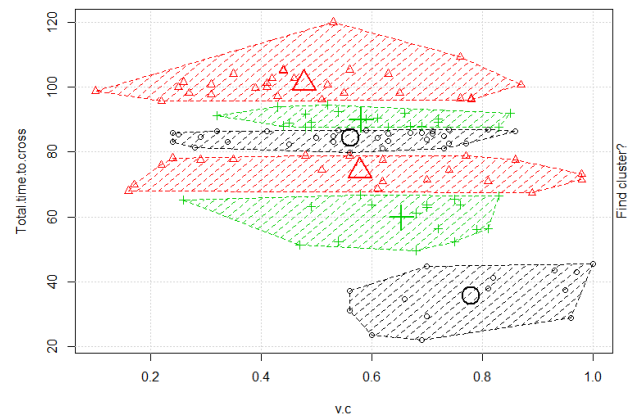

Fig. 7. Pedestrian level of service of signalized midblocks using elbow method.

Clusters formed are used to determine the total time taken by the pedestrian to cross the midblock (waiting time or delay + crossing time) for each LOS. The time ranges are determined from the six clusters formed as shown in table:

Table-I: Proposed Time Ranges for Different PLOS Proposed in Indian Conditions for Signalized Midblocks

PLOS	Total time taken by the pedestrian to cross midblock (s)
A	<52
B	52-64
C	64-82
D	82-90
E	90-98
F	>98

Based on the time ranges LOS is categorised from A to F. In LOS-A sufficient area is provided for pedestrians to select freely their own walking speed and there will be no congestion. In LOS-F pedestrians have extremely restricted walking speed indicating difficulties such as pedestrian vehicle interaction, improper signal timing, and maximum pedestrian volume.

Table - II: Obtained PLOS for the Selected Midblock Locations

Midblock Location	Average time taken by the pedestrians to cross the road (s)	PLOS based on proposed scores	Average Delay for the pedestrians (s)	PLOS according to Indo HCM 2017
Kukatpally	89.04	D	71.4	E
Nizam-pet	87.82	D	68.73	E
Dilshuk nagar	52.44	B	38.45	D

This study provides the measure of midblocks performance. Utilizing PLOS value at midblocks their plan can be comprehended based on the pattern of pedestrian travel which helps in characterizing its condition and furthermore understands the necessities of pedestrians. This study helps in improving pedestrian facilities ensuring safety and comfort. As per the study, LOS for the Kukatpally and Nizampet signalised midblock is D and for Dilshuknagar it is obtained as B which indicates the occurrence of minor pedestrian conflicts.

VII.   CONCLUSION AND FUTURE SCOPE

LOS scores are developed using K-mean clustering analysis for the obtained speeds and are compared with the Indo HCM 2017 methodology. As the present PLOS the LOS scores mostly lie in between B and D, as the demand increases facilities has to be improved to cater to the future pedestrian volumes. Different techniques like Cellular

Autometa can be applied for microscopic analysis of the data. Further analysis can be considered using pedestrian age, gender, with or without baggage, purpose of the walking trip etc. Further research can be extended to develop criteria for PLOS at signalized midblocks for different types of roads.

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