Study of Pedestrian Flow Parameters for Urban Signalized Midblock

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Abstract: Walking is one of the most important modes of travel, so pedestrian facilities are currently attracting the interest of various researchers. But, due to rapid urbanisation traffic congestion has become a major problem for safe pedestrian movement. It is necessary to objectively quantify how well roadways accommodate pedestrian movement. Due to more urbanisation and also large distance between the successive intersections people are forced to cross at midblock. This paper aims in understanding pedestrian characteristics which is a fundamental in pedestrian planning process, by developing a model consisting of basic parameters (speed, flow and density) which fits best for the collected data. Pedestrian data required are retrieved using videography technique during morning and evening peak hours of a day at Kukatpally and Nizampet signalised midblocks in Hyderabad city. In this paper, Greenshields's macroscopic stream model is used to find the important parameters like free flow speed (v_f), max flow (Qmax) and jam density (k_j). A statistical model using statistical regression analysis and soft computing Artificial Neural Network (ANN) technique is developed using the basic parameters flow, speed and density. The R square obtained for the model using regression analysis is 0.67 and R value obtained using ANN is 0.91649.

Keywords: Signalised Midblock, Greenshield's Model, R software, Pedestrian crosswalk, ANN

1 Introduction

Generally transportation is the basic source for the transfer of goods and persons from one place to other. Transportation is broadly classified as private, public and walk. Of the entire medium, pedestrians are the most neglected mode of transportation in terms of safety, at intersections as well as midblocks. Generally, pedestrians in view of safety are allowed to cross near the intersections where the vehicles approaching intersections must stop, giving way for the pedestrians. Due to controlled conditions at the intersections the probability of occurring hazardous situations between vehicle and the pedestrian is less. These days people started crossing at different midblock locations because of the large distance between the successive intersections, to save their crossing time. At these locations, pedestrians are responsible for their own safety.

In India, according to the accidents that are recorded in the year of 2014, number of people expired was about 141,573 and 488,730 people have been wounded. Statistics show about 37 per cent of road accident victims in the city, are pedestrians. As per police records around 272 pedestrians were either killed or critically injured on the outskirts of Hyderabad city, most of them are due to pedestrians, crossing the road. According to the data released by the Cyberabad police in 2015, at least three pedestrians were hit everyday and the number of deaths of pedestrians is three times higher than deaths among any other category of road users. It is revealed that Hyderabad, Mumbai and New Delhi has worst pedestrian infrastructure.

This paper studies the basic parameters like flow (q), density (k) and speed (v) of the pedestrians at signalised midblock using Greenshield's macroscopic stream model and develops a new model that best suits the collected pedestrian data. Generally, Greenshield's model is used for the calibration of traffic flow but in this paper it is used for the modelling of pedestrian flow. The data required for the analysis (flow, speed and density) are retrieved manually from the videos and the data obtained is put in the Greenshield's macroscopic formulae to calculate jam density (K_j), max flow (Q_{max}) and free flow speed (V_f), their respective graphs are plotted.

The main aim is to develop a facile, fundamental model consisting of the basic parameters, which is used in the design of signalised pedestrian midblocks. The data obtained is put in R software (programming language in which statistical simulation is done) and mat lab in which analysis is done, from which a model is developed using the best fit distribution in terms of independent variables speed and density.

2. Literature:

Several studies were made by many researchers regarding the pedestrian flow modelling at intersections and midblock as shown 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.

Helbing (1992) developed a fluid dynamic model for pedestrian crowds using Boltzmann-like gas-kinetic model observing the pedestrian footprints.

Lyons et.al. (2000) explained signalised midblock pedestrian crossing is a general method of resolving conflicts between pedestrian and vehicular traffic. ANN models are developed to enhance the operation of signalised midblock pedestrian crossings. This research has proposed a high performance pedestrian gap acceptance model for pedestrian crossing opportunities implemented with the ANN software simulation.

Hamed (2001) presented methodology for studying the behaviour of pedestrians at midblock crossings in Jordan city using survival models and Poisson regression model. This paper concluded that pedestrians behave differently from one side of the street to refuge and from refuge to other side.

Hoogendoorn et.al. (2005) proposed a new approach to estimate basic model parameters for microscopic pedestrian models using individual trajectory data. The implications of these findings in the microscopic description of pedestrian flows are considered by studying the predicted flow operations at a narrow bottleneck.

Daamen et.al. (2004) applied the obtained pedestrian data in the macroscopic stream model equations and the free flow speed, maximum flow and jam density are determined and the fundamental diagrams are derived from the cumulative flow plots

Rastogi et.al. (2011) explained pedestrian speeds at midblock crossings. Videography technique is used to collect the pedestrian data and the percentile speeds were calculated from cumulative S shaped curve. It was observed that as age increases, speed of the pedestrian decreases and females cross at low speed compared to males.

Kormanova (2013) this paper provided several approaches to pedestrian modelling. A hydrodynamic model was developed based on its similarity with the fluids and gases using conservation equations.

3. Objectives

The objectives of the study are as follows:

- To apply Greenshield's macroscopic model for pedestrian modelling.
- To develop a pedestrian flow model using statistical regression analysis.
- To develop a pedestrian flow model using soft computing - Artificial Neural Network (ANN)

4. Methodological approach

The methodology adopted for modelling pedestrian flow is shown below in figure1.

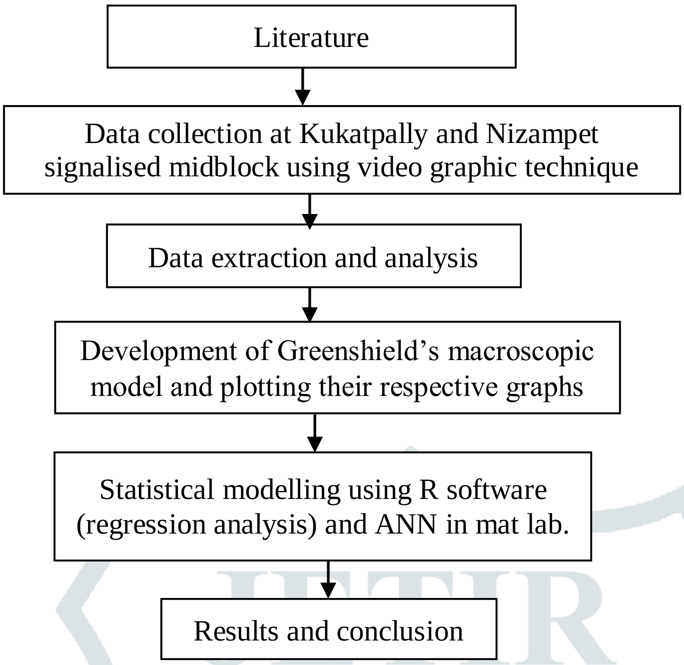

Figure1: Flow chart showing methodology adopted in the study

5. Study location

Two signalized midblock locations were considered for this study which includes location1 Kukatpally and location 2 Nizampet which are having a high pedestrian volume. Kukatpally is a place in Hyderabad, Telangana state situated at latitude of 17.4948^{0}N and a longitude of 78.3996^{0}E. Nizampet is an active Municipality situated in Bachupally Mandal, Medchal District of Telangana State, India at 17.5197^{0}N latitude and 78.3779^{0}E longitude.

The average green time provided for the pedestrians at the two locations is 32s and the red time provided for the pedestrians is 125s.

Figure 2: Kukatpally signalised midblock

Figure 3: Nizampet signalised midblock

Two types of pedestrian crossing patterns are observed at the study locations i.e., one step and two step crossing. One step crossing is the pattern where pedestrian crosses the road without waiting at the refuge island and in two step crossing pattern pedestrian has to wait at the island in order to cross the next half portion of the road.

6. Data collection and analysis

A 2 hour's pedestrian data is collected at two locations having a carriage way of 21m wide each. The data was collected from 9am to 11am in the morning and 4pm to 6pm in the evening using videography technique, Mounted at an elevated position so as to obtain the overall view of location and the data required i.e., flow, speed and crossing time are extracted manually for every 5min interval. The study location and data collection timings are shown in the below table1:

Table1: Study location and Data collection

S.No	Site identity	Location	Time	Flow (pedestrians/hour)
1	KM	Kukatpally	9AM to 11AM	3671
2	KE	Kukatpally	4PM to 6PM	4868
3	NM	Nizampet	9AM to 11AM	2263
4	NE	Nizampet	4PM to 6PM	2768

KM = Kukatpally morning, KE = Kukatpally evening,

NM = Nizampet morning, NE = Nizampet evening

Pedestrian crossing speed (v) is calculated as the time taken for the pedestrians to cross the midblock divided by the length of cross walks.

7. Results and discussion:

7.1 Calibration of Greenshield's macroscopic model:

Macroscopic models are used to determine the dependency of the basic traffic parameters (flow, speed and density) on one another. 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:

$$v = v_f - [v_f / k_j].k \text{ .... } (1)$$

A parabolic relation is developed between flow (q) and density (k), shown in equation 2:

$$q = v_f.k - [v_f / k_j].k^2 \text{ .... } (2)$$

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

$$q = k_j.v - [k_j / v_f].v^2 \text{ .... } (3)$$

Using the pedestrian data, a graph is plotted as shown in figure3, between speed and density from which the basic regression equation is obtained as

$$y = -0.2544x+1.357 \text{ .... } (4)$$

x = density of the pedestrian (independent variable) y = crossing speed of the pedestrian (dependent variable)

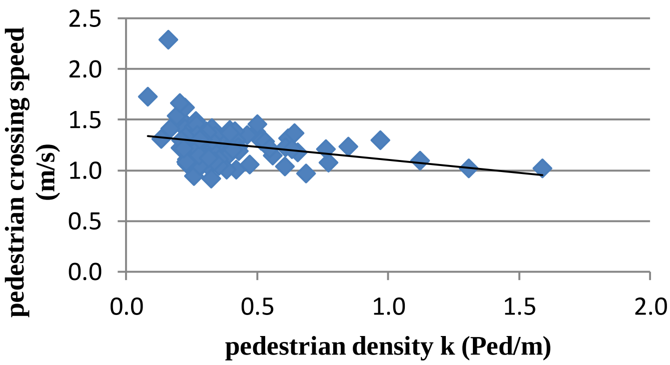

Figure 4: pedestrian crossing speed vs pedestrian density

According to calibration of Greenshield's model, jam density is obtained as 5.33ped/m and free flow speed as 1.36m/s. The respective Greenshield's graphs are plotted as shown below in the figure 4:

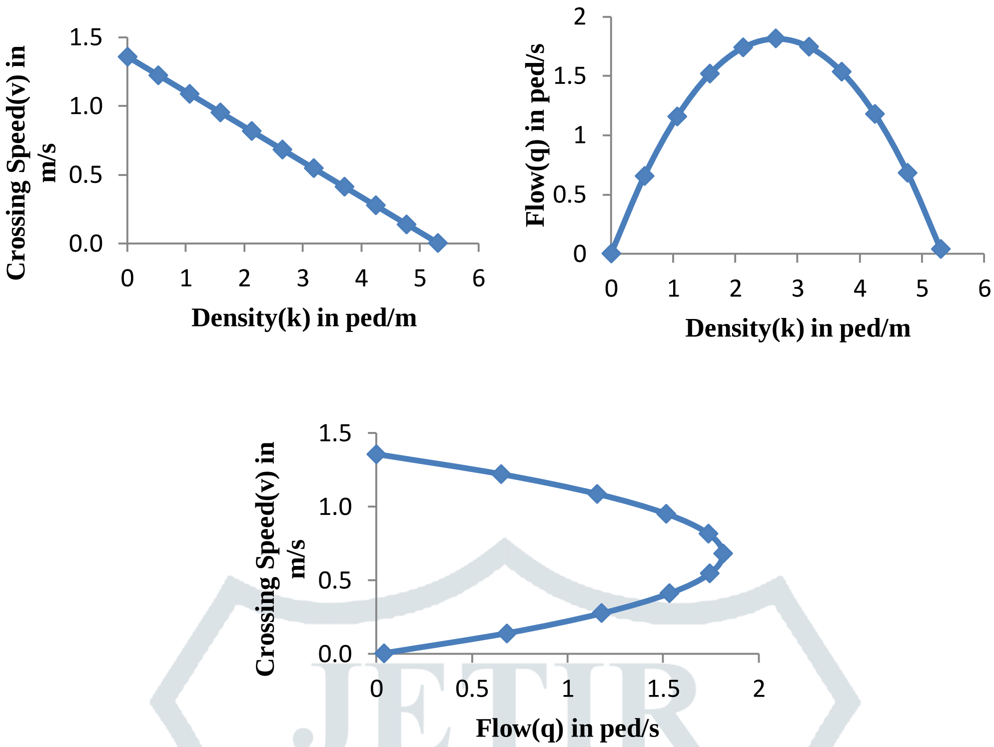

Figure 5: Greenshield's graphs showing relation between basic parameters for the collected pedestrian data.

According 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 1.36 m/sec which is slightly higher than IRC guidelines.

7.2 Calibration of flow model using regression analysis in R software:

From the data collected, 75% data is used to train the model and remaining 25% is used to validate the model. A separate analysis is done for both test and train data and their respective observed, predicted graphs variation is shown.

The 75% of the data obtained is used for the analysis in the R programming software and run for "goodness of fit statistics" i.e., Kolmogorov Smirnov statistic, Cramer von mises statistic, Anderson information criteria, and for "goodness of fit criteria" i.e., Akaikes information criteria, Bayesian information criteria based on normal, log normal, Weibull and Gamma distributions. The values and the histogram developed in the software are shown below:

Table2: Goodness-of-fit statistics

	Normal	Lognormal	Weibull	Gamma
Kolmogorov- Smirnov statistic	0.1842832	**0.09709108**	0.1487354	0.1263592
Cramer - Von Mises statistic	0.5202339	**0.10607810**	0.3674822	0.2030137
Anderson – Darling statistic	3.0132593	**0.66979575**	2.1772533	1.1896710

Table3: Goodness-of-fit criteria

	Normal	Lognormal	Weibull	Gamma
Akaike's Information Criterion	15.94316	**-11.097450**	4.087418	-6.245606
Bayesian Information Criterion	19.92113	**-7.119482**	8.065386	-2.267638

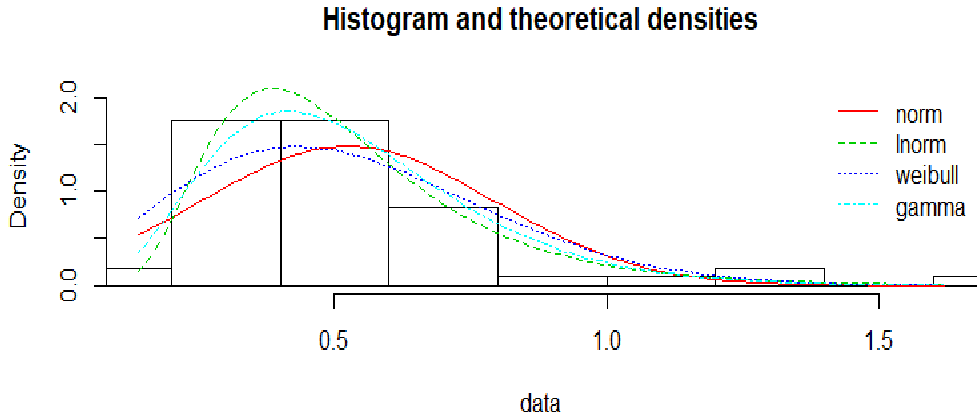

Figure 6: Histogram for the observed flow at the midblock from R software

From the graph shown in figure 6 it is clear that, on developing a model log normal distribution fits best for the collected pedestrian flow data. Lognormal distribution is a continuous distribution of a random variable whose logarithm is distributed normally. For the calibrated model, observed and predicted flow graph is shown as figure 7.

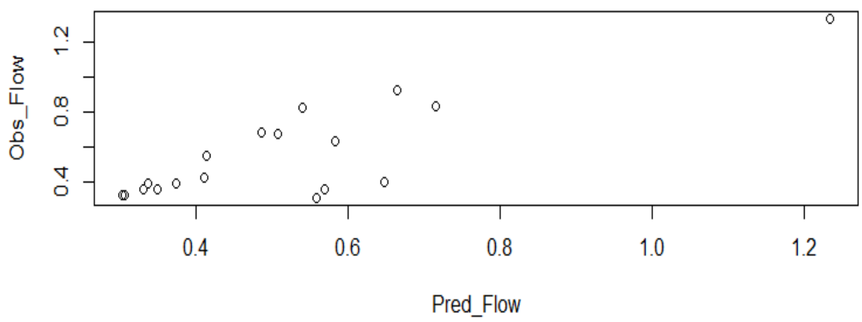

Figure 7: Observed vs predicted flow graph for the calibrated model

The chi square value observed for the calibrated is 0.74 which is very much less than chi critical value of 4.61 for 99% confidence interval. The root mean square value is noted as 0.15. The reliability (R^2) obtained is 0.67 which tells 67% is predicted properly.

The flow equation is obtained for the model considering flow as dependent and speed, density as the independent variables, from the R software using the values from the table below:

Table 4: Model coefficients for the flow equation from lognormal distribution

	Estimate	Std. error	t value	Pr(>| t |)	Significance
Intercept	-0.4058	0.3423	-1.186	0.24146	
Density	1.9199	0.6244	3.075	0.00344	**
Speed	0.4193	0.2552	1.643	0.10669	
Density : speed	0.9754	0.5091	-1.916	0.06125	.

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

From the values flow equation is written as shown in equation 5:

Pedestrian flow, q = -0.4058+1.9199k+0.4193v+0.9754*k*v……………… (5)

v = Crossing speed of pedestrian

k = density of pedestrian

7.3 Validation or testing of developed flow model in R:

The 25% of data is used to carry this analysis to assess the performance of developed model. This data is put in the software and similar analysis is carried out, considering the lognormal distribution which best fitted the data.

The Chi squared value obtained from the Chi-squared test is 0.0004 which is less that Chi-critical for 95% confidence interval. The R-squared value calculated from the observed and predicted values is 0.97, which means 97% of the dataset can be predicted accurately

The Root Mean Square Error (RMSE) calculated is 0.0047, which approximates zero, indicates that the lognormal distribution better fits the dataset. Lognormal distribution is a continuous distribution of a random variable whose logarithm is distributed normally.

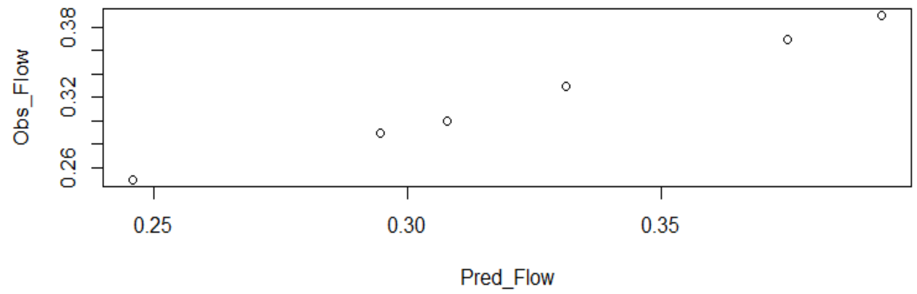

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Figure 8: Observed vs predicted flow for the validation of developed model using regression analysis in R

7.4 Calibration and validation of flow model developed using soft computing ANN:

Artificial Neural Network (ANN) is a computational model which is based on functions and structures of biological neural networks. Generally, the working of a human brain by making the right connections is the idea behind ANNs. This has many applications in the fields of aerospace, military, electronics, medical, speech, telecommunications, transportation and software etc. In this present paper, the technique is used since it is the widely used technique in the recent days and can handle large amount of data sets.

The entire data is put in the mat lab and analysis is done taking x as input data (speed and density) and y as target data (flow). Then the data is trained and simulated from which graphs are obtained as shown in figure 9 below. The chi square value obtained for the model using ANN is 0.2017 which is less than chi critical value of

4.61 For 99% confidence interval.

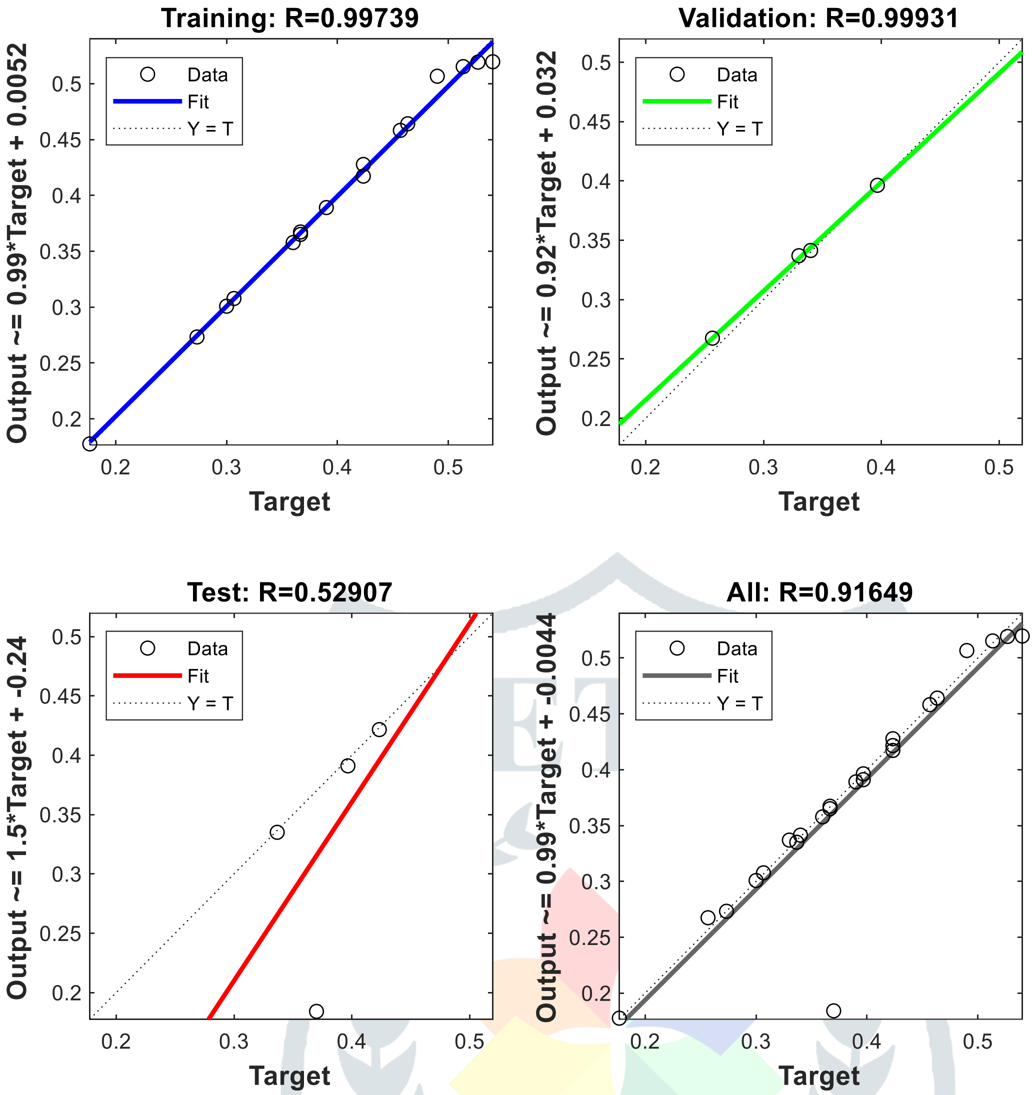

Figure 9: Observed vs predicted flow for the validation of developed model using ANN

8. Conclusion

- Greenshield's model is the most flexible and efficient method for the data analysis. This model is basically used to establish the relation between traffic flow parameters, but in this study it is used for the pedestrian analysis at signalized midblocks.
- The obtained observed pedestrian flow distribution is used for predicting pedestrian flow based on pedestrian crossing speed and density from the equation generated. This study can be further continued to calculate pedestrian LOS at the signalized midblock.
- Chi square value generated for the model developed using statistical regression analysis is more compared to that of ANN method. Therefore ANN is the best suitable method for the collected pedestrian data for the considered locations.

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