



A Cost Effective Methodology for Pedestrian Road Crossing for Developing Countries

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For more than forty years, Dr. Fazil T. Najafi has worked in government, industry and education. He earned a BSCE in 1963 from the American College of Engineering, in his place of birth, Kabul, Afghanistan, and since then came to the United States with a Fulbright scholarship earning his MS in civil engineering in 1972 and a Ph.D. degree in transportation in 1977. His experience in industry includes work as a highway, structural, mechanical, and consultant engineer and construction manager for government groups and private companies. Najafi went on to teaching, first becoming an assistant professor at Villanova University, Pennsylvania in 1977, a visiting professor at George Mason University, and then to the University of Florida, Department of Civil Engineering, where he advanced to associate professor in 1991 and then full professor in 2000 in the Department of Civil and Coastal Engineering. He has received numerous awards including a scholarship award (Fulbright), teaching awards, best paper awards, community service awards, and admission as an Eminent Engineer into Tau Beta Pi. His research on passive radon-resistant new residential building construction was adapted in HB1647 building code of Florida Legislature. Najafi is a member of numerous professional societies and has served on many committees and programs, and continuously attends and presents refereed papers at international, national, and local professional meetings and conferences. Lastly, Najafi attends courses, seminars and workshops, and has developed courses, videos and software packages during his career. His areas of specialization include transportation planning and management, legal aspects, construction contract administration, and public works.

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Abstract:

The objective of this paper is to present a low-cost methodology for the selection of proper pedestrian crossing facility by anticipating pedestrian delays at interrupted and uninterrupted flow and to correlate the pedestrian delays with level of service based on 6 levels which are ranked using the human's perceptions of comfort, safety and psychological limitation as well as acceptable delay. This paper focuses on the application of statistical distributions to model traffic and pedestrian flows. A Monte Carlo technique used to simulate traffic and pedestrians, and discusses how to create a tool in order to quantitatively rank which pedestrian facility is appropriate for particular situation. Initially pedestrian delay can anticipate at an unsignalized intersection. If the pedestrian delay is found to be more in uninterrupted flow, then signalized facility will be simulated. Later, the effect on vehicle delay at signalized intersection will be simulated. Finally delay simulation outputs will be used for the selection of pedestrian facility either unsignalized crosswalk, signalized crosswalk or grade separated pedestrian facility. Thus, the simulation results gained in this study should be useful for enhancing the current assessment of facility. It is also hoped that the developed model could be used as a reference source for other Asian cities with similar pedestrian and traffic flow characteristics.

Keywords:

Monte Carlo Simulation, Traffic Flow Modeling, Level of Service, signalized and unsignalized

Introduction:

Recent infrastructure development and rapid growth of traffic in Karachi, Pakistan from the past few years raises issues regarding pedestrian safety and accidents. For a transport planner, it is necessary to assure the safety of pedestrians while facilitating vehicular platoon. When pedestrians move in vehicular platoon chances of casualties increase due to improper interaction between pedestrian and vehicle, therefore, a crosswalk is required to reduce the conflicts. This Crosswalk can be at-grade or grade separated. At-grade crosswalks affect the level of serviceability of vehicular flow whereas grade-separated crosswalk requires a large financial investment.

Governments around the world are spending money for construction of pedestrian facilities. Currently a large investment is done by the City District Government of Karachi (CDGK) to facilitate pedestrians by constructing pedestrian flyover bridges at newly constructed road corridors. Karachi is the largest metropolitan city of Pakistan, with a population around twenty million. This paper covers the analysis procedure of vehicular and pedestrian delay, to decide which type of pedestrian facility is suitable for the prevailing situations.

Analysis of pedestrians and vehicles flow before implementation of facility is necessary for better results. The implementation of a policy without pedestrian analysis might lead to a

very costly trial and error due to the implementation cost (i.e. user cost, construction time and cost, etc.)^[6]. Better planning for pedestrians helps provide better linkage among various transport modes, enhance land use activities, improve pedestrian circulation, quality of and walking environments, and minimize conflict between pedestrians and vehicles. Therefore, understanding pedestrian walking behavior and pedestrian needs is a priority in the study of planning and design of the pedestrian facilities.^[4] Since the interaction of pedestrians cannot be well addressed using a macroscopic level of analysis, we will look at a microscopic level of analysis. Pedestrian microscopic models are an important tool in assessing the efficiency and safety of pedestrian facilities and urban spaces and form an integral part in the planning and design of modern cities and the structures within. Pedestrian simulation models can be used to assess the interactions between people and traffic in urban areas focusing on safety.^[7]

Delay is an important measure of effectiveness in traffic studies. Much research has been conducted on vehicles delays, but not enough research has been focused on pedestrian delay. However, the most commonly used delay estimation methods are derived from the Highway Capacity Manual (HCM) and are relatively simple, without enough attention on the effect of platoon.^[2]

Through Monte Carlo simulation, pedestrian delay can first be anticipated at an unsignalized intersection and then at a signalized intersection. If the pedestrian delay is found to be more in uninterrupted flow, then signalized facility will be simulated. After this, effect on vehicle delay at signalized intersection will also be simulated. Finally on the basis of delay simulation output, LOS of pedestrian and traffic flow is identified which ultimately helps for the selection of facility and should be useful for enhancing the current assessment of providing pedestrian bridges.

Methodology:

The general methodology is represented through a flowchart in Figure-1.

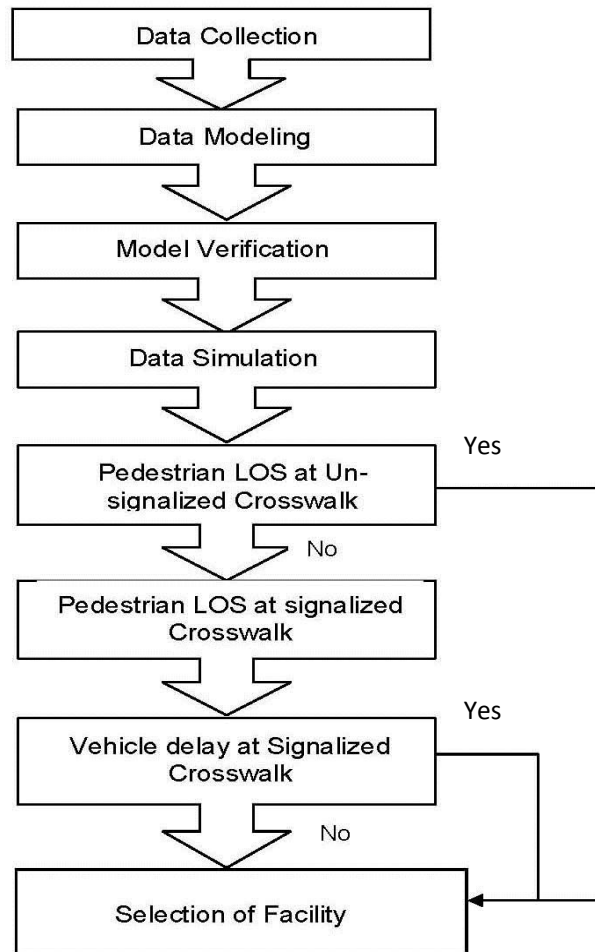


FIGURE 1 Flow diagram for facility selection procedure

Data Collection:

Pedestrian and vehicle flow models are the most integral part of this project. Therefore, data collection for flow modeling is critical. Microscopic flow is modeled by the use of time headways.

- **Pedestrian Data Collection**

Pedestrian data is collected for peak hour to analyze the situation for most critical condition. Two types of data sets are collected during pedestrian data collection; time headways between pedestrians arriving at unsignalized pedestrian cross walk and the waiting time of pedestrian at cross walk.

- **Vehicular data collection**

Vehicular time headways are measured along with their classifications as if they followed lane behavior i.e. all vehicular headways are measured that completely or partially lie in the specific lane under observation. At places where lane markings are present, the methodology is straight forward. Roadways where lane markings are absent, a 10 foot lane width was assumed.

Due to inadequacy of existing traffic data, data collection is an integral part of this exercise. As quite a few parameters are to be observed per vehicle, manual data collection was concluded inefficient. Also, the data collection methodology needed to be cost effective, efficient and non-altering to the vehicular flow behavior i.e. cheap non-intrusive methodologies need to be applied. A simple solution was devised to cater to these issues. A camcorder was used to shoot videos at data collection sites which were then analyzed on a computer later. 16 hours of video survey was performed per day for four days per site to have a representative sample size. The camera was mounted on a heavy duty tripod at locations and angles to ensure optimal view of the road length under study. These videos were then imported to a computer and analyzed for time headway. An on-computer stopwatch was used in order to measure time headways. Headway measurements are made for almost every vehicle regardless of their classification. Measurement errors of distance and time were also incorporated to improve data quality ^[5]. After data extraction from videos, the headway data were arranged in groups. Time headways were grouped in intervals of 5 seconds.

Data Modeling & Verification:

The time headway between vehicles or pedestrians is an important flow characteristic that affects safety. The distribution of time headway determines the requirements and the opportunity for passing, merging and crossing ^[1]. Through statistical distribution models, prediction for crossing opportunity with minimal amount of information is possible. Therefore, statistical distributions with a certain degree of randomness have been used to model traffic and pedestrian flow effectively.

Vehicles and pedestrians flowing in platoon both have almost same microscopic characteristics. These flows can be classified in random headway state, intermediate headway state, or uniform headway state. Modeling for every state requires a different distribution, namely the negative exponential distribution, Pearson type III distribution, normal

distribution for traffic flow with random headway, intermediate headway and uniform headway respectively. Integration of all the aforementioned distributions towards modeling traffic flow for simulation is complex. Fortunately the Pearson type III distribution accommodates both negative and normal distributions as well, thus simplifying the difficulty.

Pearson type III distribution is of particular use as it accommodates negative exponential distribution, Erlang distribution, gamma distribution, and normal distribution along with their shifted counterparts. The probability density function for Pearson type III distribution is given by Equation (1)

$$f(t) = \frac{\lambda}{\Gamma(K)} [\lambda(t - \alpha)]^{K-1} e^{-\lambda(t-\alpha)} \quad \text{Equation (1)}$$

Where $f(t)$ = probability density function

λ = parameter that is a function of the mean time headway and the two user specified parameters, K and α

K = (shape parameter) user-selected parameter between 0 and ∞ that affects the shape of the distribution (seconds)

α = (shift parameter) user-selected parameter greater than or equal to zero that affects the shift of the distribution (seconds)

t = time headway being investigated (seconds)

e = constant parameter, 2.71828

$\Gamma(K)$ = gamma function, equivalent to $(K - 1)!$

It is the values of K , α , and λ which dictate the type of headway distribution being followed. This can be represented graphically in Figure 2.

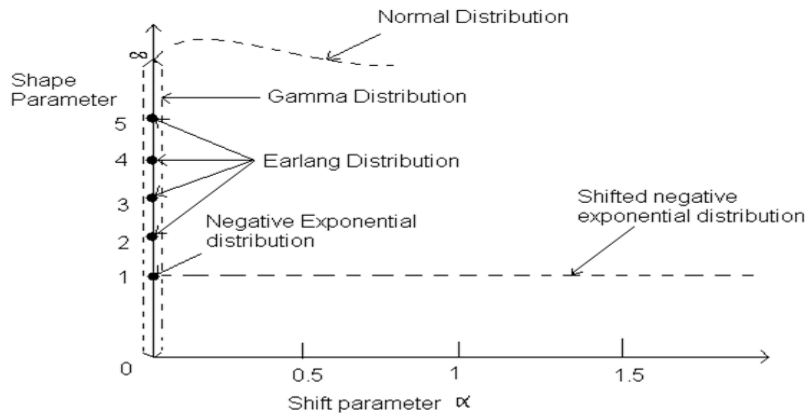


FIGURE 2 Pearson type III distribution, for different values of K and α . [6]

Modeling for Traffic Flow

Traffic flow data is modeled for each lane using Pearson Type III distribution. The collected field data is then classified into different groups based on the volume in 5 second intervals to analyze the effect of the different volume levels on the headway distribution.

The analyses were performed from two aspects: the goodness of fit test and the suitable shifted value. For the goodness of fit test, the headway data was tested on Pearson type III. The test was made based on Chi-square test at 0.05 level of significance for more accuracy, with different values of K and α to pass the goodness of fit test.

The summary results of the Chi-square tests are shown in Figure 3. It is observed that Pearson type III is the best distribution. Here, $P(t)$ is the probability of time headways of vehicles on y-axis and vehicles arrival time in seconds on x-axis.

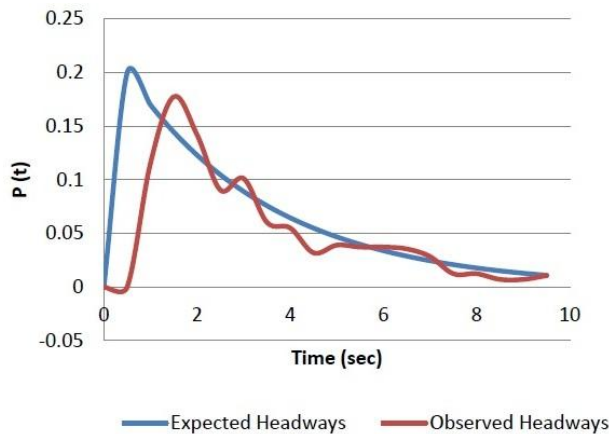


FIGURE 3 Graph of observed and estimated values of headway for vehicles

Modeling for Pedestrian Arrival

A model for the arrival of pedestrians at cross walk facility is formed using Pearson Type III distribution; it is assumed that each pedestrian is moving with an average speed of common man in that area. Based on the findings, it is recommended that Draft Accessible Guidelines and the MUTCD use a 3.5 fps (1.1 m/s) minimum walking speed across the street itself (curb-to-curb) for determining the Pedestrian Clearance interval, and a 3.0 fps (0.9 m/s) walking speed across the total crossing distance (top of ramp to far curb) for the entire WALK plus Pedestrian Clearance signal phasing. In any case, the minimum WALK signal indication should still be 4 seconds for single lane one direction road. ^[5]

The collected field data of pedestrian arrival were then classified into different groups based on the arrival volume in 5 second intervals to analyze the effect of different arrival volume levels on the pedestrian headway distribution.

The analyses were performed similarly for vehicular data. The headway data was tested on Pearson type III. The test was made based on Chi-square test at 0.05 level of significance for more accuracy, with different values of K and α , to pass the goodness of fit test.

The summary results of the Chi-square tests are shown in Figure 4. Here, $P(t)$ is the probability of time headways of pedestrians on y-axis and pedestrian arrival time in seconds on x-axis.

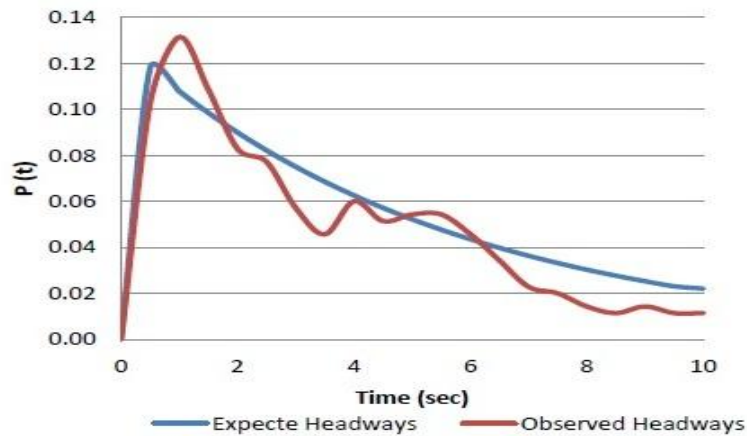


FIGURE 4 Graph of observed and estimated values of headway for pedestrians

This result may be attributed to the fact that the pedestrian arrival volume was low. It has been shown by a number of researchers that Negative Exponential (NE) provides a good fit for data under low volume conditions (i.e. random). It should be noted that NE are also a specific form of Pearson type III. ^[1]

Data simulation:

The study of complex systems that cannot be sufficiently simplified to be amenable to analytical solution requires alternative methods; the use of simulation is one possibility ^[3]. One of the greatest advantages of simulation, as opposed to observation of actual traffic streams is the ability to control all the conditions related to the traffic streams ^[9]. Once the results from the modeling exercise are verified, they are used to simulate flows. In this paper a Monte Carlo technique has been used. The term "Monte Carlo Method" is a stochastic technique, meaning that it is based on using random numbers and probability to investigate problems. Basically, Monte Carlo Simulation technique converts uncertainties in input variables of a model into probability distributions. By combining the distributions and randomly selecting values from them, it recalculates the simulated model many times and brings out the probability of the output.

Simulation Methodology

Monte Carlo technique has been applied for both data sets; pedestrian as well as vehicular data and categorized into two parts.

1. Pedestrian Delay simulation
2. Vehicular Delay simulation

The simulation of pedestrians and vehicles flow is dependent on the time headway distribution. With the determination of the internal parameters of the Pearson type III distribution, our flow models for simulation are complete. Using the principles of Monte Carlo method, random numbers are generated on a MS Excel spreadsheet which acts as the probabilities for the cumulative probability function of the calibrated Pearson type III distribution. This results in the expression to become a univariate function, where the variable

is the time headway. The successive results to the equation for unbiased random numbers simulate headways to following pedestrians and vehicles, thus simulating flow condition.

Monte Carlo method was used to simulate pedestrian flow in correspondence with the flow simulation for vehicles.

It is to be noted that different random numbers were generated for pedestrian and vehicles simulation to prevent bias simulation results. Once simulation is complete, the output results are tabulated such that each pedestrian and vehicle simulated is marked with its time headway. Alongside, the occurrence of each pedestrian and vehicle scale is tabulated on an absolute time, depicting the time of occurrence for the vehicle and pedestrian once the simulation has started.

1. Pedestrian Delay simulation

Pedestrian delay correlates with vehicular performance and also depends upon the gap acceptance factor. While the time between two following automobiles is enough in the stream of vehicular platoon, it gives the pedestrian a gap to pass through road width by crosswalk successfully and safely^[2]. Such a gap t_0 has a minimum value, namely, acceptable gap, below which a pedestrian will not attempt to do the crosswalk and this critical threshold is the minimum headway among vehicle flow in essence that it guarantees a pedestrian passes through the road width safely. Let's neglect the pedestrian's own influences^[10], we reach the acceptable gap t_0 united the pedestrian need to make crosswalk safely given by the relation:

$$\tau_0 = \frac{d}{v} + t_R + t_0$$

Equation (2)

Where,

τ_0 - Time gap required to cross street

d - The average width of roadway in m;

v - The walking speed of pedestrian in m/s and here we consider $v = 1.2\text{m/s}$;

t_R - The waiting time for pedestrian to decide whether to cross, and here we consider $t_R = 2\text{s}$;

t_0 - the passing time of vehicle, and here we choose $t_0 = 0.72\text{s}$ for standard car.

If the time headway (“ t ”) of simulated vehicles for each lane is greater than “ τ_0 ” at same time interval, simulated pedestrians will be allowed to pass the cross walk. While on contrary, when “ t ” is less than “ τ_0 ” pedestrians will remain waiting in the standing area of cross walk. Delay time for pedestrian at cross walk is calculated using the excel spreadsheet created for simulation of time headways.

Delay time calculated here is then compare with the average delay time specified in HCM for pedestrian facility grading shown in Table 1.If the LOS calculated from the tables is between A to C, it means that current provided pedestrian facility i.e. unsignalized pedestrian crosswalk is functioning effectively. If LOS calculated comes in between D to F, it means that cross walk facility has failed to serve efficiently in unsignalized condition.

Table 2: LOS criteria for Signalized intersection ^[11]

Average delay / s		LOS	Description
Signalized	Unsignalized		
<10	<5	A	very small delay, none crossing irregularity
10~20	5~10	B	Small delay, almost no one crossing irregularity
20~30	10~20	C	Small delay, very few pedestrian crossing irregularity
30~40	20~30	D	Big delay, someone start crossing irregularity
40~60	30~45	E	Very big delay, many pedestrians crossing irregularity
>60	>45	F	Very big delay, almost every waiting pedestrians crossing irregularity

2. Vehicle Delay and Queue Simulation (at Signalized cross walk)

In case of the unsignalized pedestrian crosswalk facility failing to serve effectively, same calibrated models of pedestrian and vehicle flow are used for simulating signalized pedestrian crosswalk facility conditions. Here vehicles delay time and queue lengths are calculated which accumulated during signal red and amber times. Vehicles delay time calculated from the excel spreadsheet is then compared with the average delay time of vehicle specified in HCM for signal controlled intersection. If the LOS calculated from the Table 2 is between A to C, it means that current provided pedestrian facility i.e. signalized pedestrian crosswalk is functioning effectively. If LOS calculated comes in between D to F, it means that pedestrian signal is affecting the vehicular flow drastically. If this is the situation we need to provide the grade separated pedestrian cross walk facility in order to ensure better vehicular flow conditions.

Table 3: LOS criteria for Pedestrian at Signalized intersection ^[11]

LOS	Control Delay per Vehicle (s/veh)
A	≤ 10
B	> 10–20
C	> 20–35
D	> 35–55
E	> 55–80
F	> 80

Concluding Remarks:

This paper attempts to provide cost effective methodology for selection of pedestrian facility by anticipating delay simulation of both traffic and pedestrians at unsignalized crosswalk and signalized intersection. Thus, the simulation results gained in this study should be useful for enhancing the current assessment of facility. It is also hoped that the developed model could be used as a reference source for other Asian cities with similar pedestrian and traffic flow characteristics.

References:

- [1] Adolf D. May, Traffic Flow Fundamentals, 1990, Prentice Hall.
- [2] Chen Kuan-min, Luo Xiao-qiang, Ji Hai and Zhao Yang-dong, "Towards the pedestrian delay estimation at intersections under vehicular platoon caused conflicts". Scientific Research and Essays Vol. 5(9), pp. 941-947, 4 May, 2010.
- [3] C.S. Papacostas, P.D. Prevedouros, Transportation Engineering and Planning, Prentice Hall, Third Edition.
- [4] Jodie Y. S. LEE, William H. K. LAM and Mei Lam TAM, "Calibration of pedestrian simulation model for signalized crosswalk in Hong Kong" Proceedings of the Eastern Asia Society for Transportation Studies, Vol. 5, pp. 1337 - 1351, 2005.
- [5] John LaPlante, PE, PTOE Thomas P. Kaeser, PE, PTOE, "A history of pedestrian signal walking speed assumptions" 3rd Urban Street Symposium June 24-27, 2007 Seattle, Washington.
- [6] Kardi TEKONOMO, Yasushi TAKEYAMA and Hajime INAMURA, "Microscopic pedestrian simulation model to evaluate "lane-like segregation" of pedestrian crossing", Proceedings of Infrastructure Planning Conference Vol. 24, Kouchi, Japan, Nov 2001.
- [7] Pedestrian Simulation "Urban Analytics Framework"
<http://www.pedestriansimulation.com/pedestrian-modelling.php> Accessed March 01 2012
- [8] Nan Vou & Jianwei Wang, A Video Based Method for Evaluating Traffic Data.
- [9] McLeans, J.R., Two Lane Highway traffic Operations – theory and practice, Gordon and Breach Science Publishers, New York, 1989.
- [10] Zhang LW, Chen Y, Hu JX, Liu SY (2006). Characteristic analysis of pedestrian crossing unsignalized crosswalks at urban arteries. J. Dalian Maritime University 32(2): 79-81.
- [11] Highway Capacity Manual, Transportation Research Board, Washington D.C., 2009.