

Effect of Pedestrian Characteristics at Signalized Intersection

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Abstract—Signalized intersections are provided in traffic networks to improve the safety and efficiency of vehicular and pedestrian movement. In case of India, traffic heterogeneity and lack of discipline make the transferability of models developed in other countries infeasible. Pedestrian crossing behavior is a complex phenomenon for traffic engineers to analyze as they differ from person to person and also they tend to violate the green phase (when vehicles are moving) in order to reduce their delay keeping themselves at risk. The present study is an attempt to analyze the pedestrian crossing behavior according to the demographic characteristics like age, gender and crossing patterns at a signalized intersection at Pattom Junction, Trivandrum, Kerala. Analysis of field data yielded some notable observations as pedestrians adjust their crossing speed based on signal timing and length of crosswalk. Pedestrian walking speed at a crossing has been found to be varying from the assumed constant value 1.2 m/s recommended by Indian Road Congress (1985). Analysis of pedestrian walking speed on gender and age groups leads to an observation as average walking speed of a male is more than that of a female and adult is more than that of an old one. As the concept of pedestrian safety is drawing attention worldwide, the study also focuses on the need of enhancing traffic measures and implementing traffic management for the pedestrian safety.

Keywords— *Signalized intersection; Walking Speed; Pedestrian safety ; Crosswalk.*

I. INTRODUCTION

The performance of intersections is crucial to a road network in terms of efficiency and safety, as vehicles, pedestrians, and other roadway users interact with each other intensively at these locations. Intersections are also always bottlenecks in the operation of a road network due to delays in compromising the right-of-way. For this reason, plenty of studies were performed in the past to evaluate the performance of signalized intersections, and to explore potential improvements that can be implemented.

Walking is one of the main and sustainable traffic modes in urban transportation, particularly in India because of the flexibility and mobility involved in it. Pedestrians are considered as the most vulnerable road user involved in large number of accidents due to the complexity in evaluating their behaviors under different conditions. Traffic heterogeneity and reckless walking behavior of pedestrians made them prone to severe conflicts and fatalities. According to the National Crime Records Bureau 12,385 pedestrian deaths were reported for the year 2013 in India [1]. The precise number of pedestrians

injured and killed is difficult to estimate and could be approximately more than 40,000 deaths annually in India. More than half of injured and killed pedestrians were young men in the age group of 16-45. Probable causes of pedestrian accidents at intersections; inadequate protection provided for pedestrians, unwarranted signals, restricted sight distance, inadequate signal phasing and large turning volumes.

Commonly, pedestrians are prohibited to enter cross walk during flashing red and red phases. But in India, traffic condition and pedestrian signal system differ and is complex with pedestrians attempting to enter crosswalk during non-green phases to avoid delay. In many cases no pedestrian green phase is provided for them to cross. Pedestrian usually cross in impractical manner with over-optimistic estimate of motorist's ability to stop or avoid conflicts. Pedestrian violation depends on an acceptable gap level (Critical acceptable gaps are smaller with higher walking speeds) and who disobey the rules are considered as violators. Similar case causing serious pedestrian safety problem in China due to patterns of violation and compliance with law were examined in a research paper in 2011 [2].

Main reasons of pedestrian violation are low quality traffic management, no person specially assigned to manage pedestrians, very less traffic safety awareness and longer cycle time (more than 100 seconds). Pedestrian crossing speed has been found to be varying largely from the existing manual Indian Road Congress (IRC) estimated walking speeds at crosswalks of 1.2m/s (IRC 1985). Major reasons for the variation in walking speed includes pedestrian non-compliance to rules of mixed traffic conditions, non-lane discipline, low quality traffic management and no strict traffic enforcement. The findings of the study emphasize on the need for designing pedestrian facilities and also for devising traffic management measures for pedestrian safety.

II. REVIEW OF LITERATURE

Review of existing literature suggests that a lot of attention has been paid to research on pedestrian delay models for developed countries in recent years, but very little has been done on the pedestrian delay models based on developing countries traffic condition and pedestrian behavior under mixed traffic condition. Pedestrian behavior at signalized crosswalks were analyzed and developed

model for pedestrian walking time and flow relationship, then studied the effect of bidirectional flow [3].

Many studies showed that age and gender significantly affect the pedestrian behaviour and found that males walk faster while crossing than females due to less waiting time. Many analyzed pedestrian delay modeling at signalized intersection crosswalks under mixed traffic conditions. The literature indicates that there is a need for a pedestrian delay model that incorporates pedestrian crossing behavior and vehicular interaction [4]. Some attempted to analyze the crossing behaviour of pedestrians like crossing speed, compliance with signal, and pedestrian-vehicular interaction under mixed traffic conditions and to identify the influencing factors based on statistical tests [5]. Comparison of pedestrian's road crossing behaviour before and after installation of a fixed time signal at an uncontrolled intersection under mixed traffic and non-lane discipline conditions was made [6].

Few attempts were made to analyze pedestrian flow characteristics in pedestrian walkways under mixed traffic conditions in India and present experimental research to study microscopic and macroscopic pedestrian flow characteristics namely free-speed, walking direction, density, and the effect of bottlenecks [7, 8]. In Sri Lanka, a study aimed to develop and test a methodology to extract pedestrian speed data from video footage and to find the pedestrian walking speed and found that Sri Lankans walked with a mean speed of 1.3 m/s and having a standard deviation of 0.183 m/s [9].

III. DATA COLLECTION AND ANALYSIS

In the present study, a video graphic technique was adopted for data collection. Since the signal and timer indication and the corresponding traffic movement are spatially separated, two video cameras were used for the data collection. Cameras were used for capturing the entire intersection. Because, the data on delay and headway are in the range of a few seconds, it was important to make sure that the two cameras were synchronized. The captured videos were played in the laboratory manually later to extract the required data, which included headway discharge and the pedestrian crosswalk behavior. The data were collected from the selected intersection in Trivandrum, Kerala, and are used for the analysis. Data were collected from both peak and non-peak hour (9 am. to 11 am).

The selected intersection was a four-legged one. The through movements and turning movements was selected for the present study. A pre-timed signal control was implemented at the study site with a constant cycle time of 121 s. It had 88 s red, 30 s green, and 3s amber during the data collection period. A suitable vantage point was selected at the intersection from where the signal indication and traffic flow at the stop line could be simultaneously captured. Two cameras were used and time synchronization is done. The data extraction was carried out manually. The volume count is done in both peak and off peak hour condition. A total of 3,442 two wheelers, 952 auto rickshaws (motorized three wheelers), 228 buses, and 1,464 cars were observed with a peak rate flow of 1572

vehicles per hour. The classified vehicle volume in the intersection is given below in the figure 2.



Fig 1: View of the selected intersection at Pattom Jn, Trivandrum

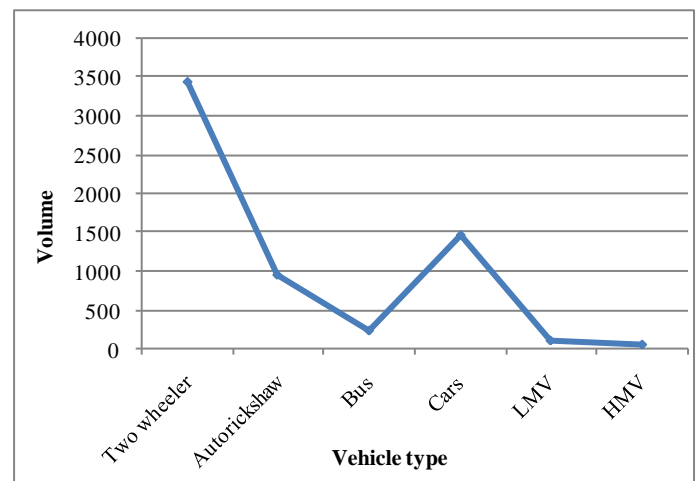


Fig 2: Classified vehicles volume in the intersection

TABLE I PEAK RATE FLOW

Time	Rate of flow (vph)	Peak rate of flow (vph)
9.00-9.15	1527	1572
9.15-9.30	1572	
9.30-9.45	1569	
9.45-10.00	1433	

The present study aims to analyze and compare the crossing behavior of pedestrians like crossing speed with respect to age, gender and crossing patterns under mixed traffic conditions.

A. Pedestrian Behaviour Analysis

Most of previous studies are based on pedestrian flow characteristics and walking time in sidewalks and walkways. Very few studies have focused on pedestrian crossing behaviors in signalized intersections under mixed traffic conditions. They have been developed only for pedestrian safety aspects and analyzed only for pedestrian crossing with walking speed variations. Data extracted from the one hour video survey has given information on the following parameters: arrival pattern of pedestrians, average walking speed and pedestrian-vehicle interaction. An attempt has been made in this study to analyze pedestrian demographic characteristics like walking speed, crossing patterns like one step crossing, two step crossing and zigzag crossing (mostly combination of both one step and zigzag) and pedestrian-vehicle interaction on two crosswalks considered: one is in direction from Pattom to National Transportation Planning and Research Centre (NATPAC) and the other is in direction from Pattom to Murinjapalam from the selected intersection of Trivandrum. The general observations from the field is also given below.

TABLE II OBSERVATIONS FROM THE FIELD

Pedestrian Characteristics	Values
Total number of samples	717
Crosswalk length (Pattom – Murinjapalam)	23m
Crosswalk length (Pattom - NATPAC)	20 m
One step crossing	348
Two step crossing	127
Combined one step and zigzag	123
Not using	119

B. Walking Speed

In India, the present design practice in signalized intersections is to assume the pedestrian walking speed to be a constant value of 1.2m/sec. From field study conducted in Trivandrum, the crossing behavior of pedestrians has been found to be largely varying from the assumed constant value. The major reasons for walking speed variation have been found to be of the following: (i) Very less pedestrian green phase, (ii) Violating behavior of pedestrians, and (iii) Directional crossing effect. So during design of signalized intersections in developing countries like India, there arises a need to consider all possible pedestrian crossing behavior and other influence factors. According to the analyzed field data from two crosswalks at signalized intersection in Pattom, Trivandrum under mixed traffic conditions and the calculated pedestrian walking speed are with necessary classifications such as pedestrian gender, age group, crossing effect for two road stretches.

Average crossing speed is varying between 1.91 m/s to 1.58m/s. The field average crossing speed of pedestrians (1.34 m/s) matches well with field value of

1.33 m/s measured in China [10]. The crossing speed variation is defined as the difference between the 85th and 15th percentile speed. A new factor termed as crossing speed deviation factor (CSDF) is established and defined as the ratio of the crossing speed variation and average crossing speed [11].

$$CSDF = (V_{85} - V_{15}) / V_{50}$$

CSDF is used for getting a clear idea about pedestrian crossing speed variations and the effect of pedestrian volume to pedestrian crossing speed. Two hour video graphic data is also used to analyze the variations in the walking speed of pedestrians. Information regarding the selected study site and pedestrian crossing speeds are tabulated in table III. Pedestrian walking speed based on traffic and pedestrian characteristics on two crosswalks considered is also tabulated to get an idea about the scenario.

TABLE III INFORMATION OF THE SELECTED STUDY SITES AND PEDESTRIAN CROSSING SPEEDS

Location		1	
Intersection		Pattom Junction, Trivandrum	
Time of Survey		9.00 am -11 am	
Crosswalks considered		2	
1) Crosswalk Pattom- NATPAC		2) Crosswalk Pattom-Murinjapalam	
Length	20m	Length	23m
Direction	2	Direction	2
No. of samples	444	No. of samples	239
Mean speed (m/s)	1.55	Mean speed (m/s)	1.56
Std deviation	2.28	Std deviation	1.62
V ₁₅ (m/s)	1.06	V ₁₅ (m/s)	1.125
V ₅₀ (m/s)	1.31	V ₅₀ (m/s)	1.5
V ₈₅ (m/s)	1.63	V ₈₅ (m/s)	2
CSDF	0.4351	CSDF	0.5833

TABLE IV PEDESTRIAN WALKING SPEED BASED ON TRAFFIC AND PEDESTRIAN CHARACTERISTICS AT A SELECTED INTERSECTION

Road stretch	Length of crosswalk	Average Pedestrian walking speed (m/s) based on characteristics			
		Gender		Age group	
		Male	Female	Adult	Old
Pattom - NATPAC	20m	1.58	1.44	1.5	1.19
Pattom-Murinjapalam	23m	1.56	1.49	1.48	1.2

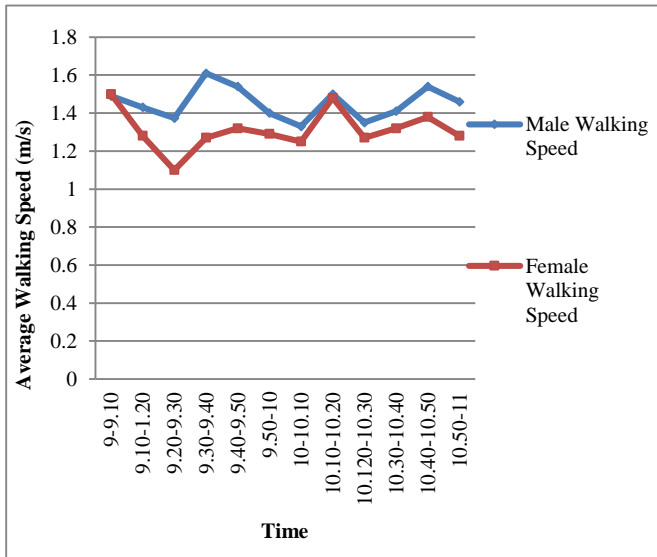


Fig 3: Pedestrian Walking Speed based on Gender on Pattom -NATPAC Stretch

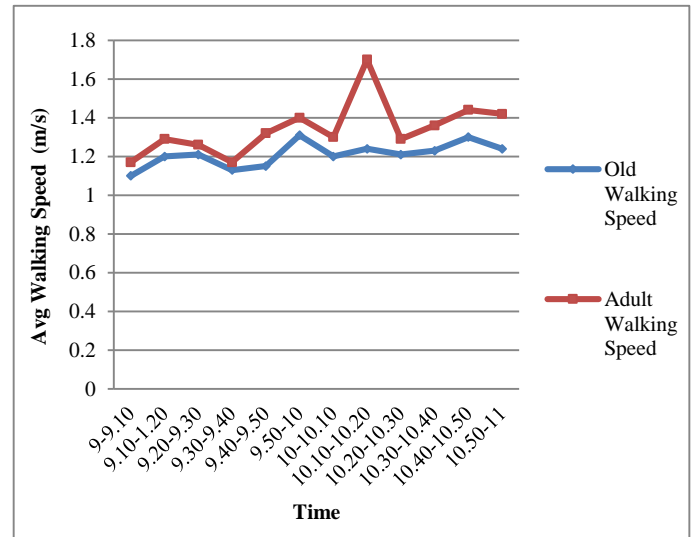


Fig 6: Pedestrian Walking Speed based on Pedestrian Age group at Pattom - Murinjapalam Stretch

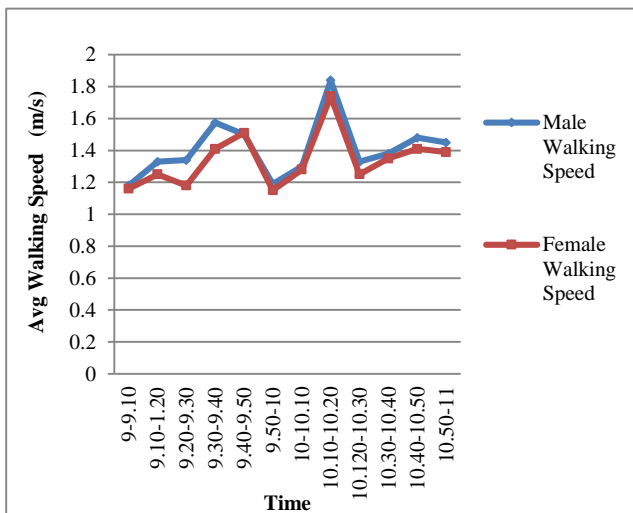


Fig 4: Pedestrian walking speed based on gender on Pattom-Murinjapalam Stretch

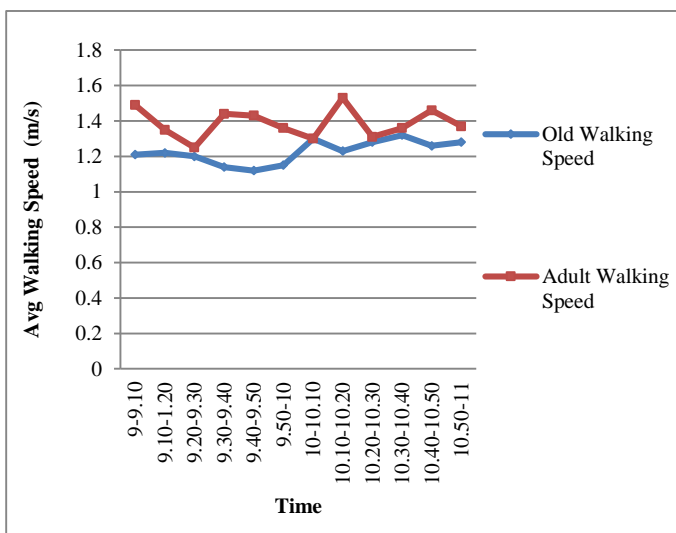


Fig 5: Pedestrian Walking Speed based on Pedestrian Age group at PATTOM- NATPAC Stretch

C. Results

Comparisons of pedestrian walking speed based on pedestrian characteristics were analyzed and the following observations were made.

- The average walking speed of a male pedestrian (1.5 m/s) is more than that of a female pedestrian (1.4 m/s)
- Adult pedestrian (of age 21 years to 60 years) walking speed (1.5 m/s) is more than that of an old pedestrian (1.2m/s) (of age > 60 years) .
- Pedestrian walking speed was found to be largely varying from the assumed constant value of 1.2 m/s recommended by IRC (1985) [12].

IV. CONCLUSION

Video-graphic survey is conducted at a selected intersection of Trivandrum for peak and off peak hour. Pedestrian walking speed is a parameter observed in the study. A total of 717 pedestrian samples were observed from the video data. The study attempts to analyze the pedestrian demographic characteristics like age, gender and crossing patterns (One step crossing, two step crossing and combined one step and zigzag crossing). Complexity prevailing in the behavior of pedestrians made it difficult to analyze the walking speed of pedestrians. The constant value of pedestrian walking speed at the crossing has been found to be varying from the assumed constant value 1.2m/s recommended by IRC (1985).The key findings from the study are given below.

- Two types of crossing patterns were observed from the site: one step crossing and two step crossing. A significant number of pedestrians avoid using crosswalk provided.
- Female pedestrians and old pedestrians were found to cross the road at a slower rate than males in both the scenarios due to their safety concern.

- It was observed that 15th percentile crossing speed of pedestrians in both cross walks considered lesser than the crossing speed (1.2 m/s) used in pedestrian facility design as per Indian Road Congress (IRC 1985).

Limitations of the study includes the selection of the old adult pedestrians according to the visual appearance and considering the crossing type as a whole without taking minor sub divisions. Other major problems detected from the site are given below.

- No separate pedestrian green phase provided for the pedestrian to cross. They usually cross during red phase (when vehicles stops) but pedestrians have a tendency to cross during the green phase putting them at risk.
- Many pedestrian vehicle conflict points were detected as they even avoid the crosswalk provided to cross.
- Complexity in the crossing behavior (pedestrians do not follow a particular crossing pattern, in many cases they found to be running while crossing.)
- Lack of awareness and strict enforcement of traffic rules.

ACKNOWLEDGMENT

The authors would like to thank the Department of Civil Engineering, RIT, Pampady, Kottayam for the whole hearted support granted throughout the progress of the study.

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