EFFECT OF PEDESTRIAN CROSSING BEHAVIOR AT MID-BLOCK SECTION OF URBAN ROADS ON TRAFFIC FLOW CHARACTERISTICS

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ABSTRACT

In general, there are two types of crossings i.e. at-grade and grade separated. If the pedestrians are completely segregated (grade-separated) with vehicular traffic, then there is no effect of pedestrian crossings on vehicular flow characteristics. If such grade separated crosswalks are too apart from each other, then pedestrians either change their road crossing choice according to their destination which will result in more travel time or pedestrian will use forced gaps to cross the roads. Also, due to poor construction of grade separated facilities and roadside development, pedestrians usually cross the road at unprotected mid-block locations under mixed traffic conditions. However, in mixed traffic condition, it is very rare to get adequate vehicular gaps to cross the road. Hence, pedestrians will exhibit non-complaint road crossing behavior, causing more interference with vehicles. It leads to a rigorous change in vehicular flow characteristics such as speed and flow. The present study is carried out with the objective to study traffic flow characteristics at such sections.The present study has analyzed the effect of pedestrian crossing on the characteristics of vehicular flow at mid-block location under mixed traffic conditions. The study results may be useful for decreasing the travel time for vehicular drivers by controlling usage of pedestrian forced gaps.

Introduction

Traffic has grown in recent years with urbanization and hence became major consent for the developing nations. The un-protected mid-block location is one of the important components in the urban transportation system for pedestrian activities under mixed traffic conditions especially in countries like India. The number of such un-protected mid-block pedestrian road crossing activities has been increasing in Indian context and growth of these activities may also result in pedestrian accidents. The increase in un-protected midblock pedestrian road crossings has been a significant effect on vehicular characteristics such as an increase in travel times and a decrease in vehicle speed. At signalized midblock and intersection, there is the complete right-of-way to pedestrians and vehicles as it results a decrease in pedestrian and vehicle conflicts as well as the severity of conflicts.

There are numerous studies which deal with the pedestrian road crossing behavior at intersection and mid-block locations. The importance of these crossing studies is related to the evaluation of pedestrian facilities, traffic control features and road safety treatments by means of before and after crossing studies on pedestrians' behavior as well as safety. Pedestrians need to cross the road at some location during the course of travel and crosswalks are important for pedestrians to cross the road. The crosswalk locations should provide safe and comfortable movement.

In this context, the objective of present study is to investigate the effect of pedestrian crossing on vehicular characteristics. More precisely, this research aims to study the vehicular flow characteristics with and without pedestrian crossings along the same roadway section with same geometry properties. Hence we study the effect of pedestrian crossing on unprotected midblock without crosswalk available for pedestrians.

Literature Review

The designing of pedestrian crossing facilities at proper location is a complex problem under mixed traffic conditions in countries like India. The choice of a particular type of pedestrian crossing facilities (at grade or grade separated) influences the safety of pedestrian and results in change of vehicular flow characteristics. It is very important to avoid the sudden change of vehicular flow characteristics caused by

unexpected pedestrian crossings by improving typical crossing locations usually by implementing refuge median islands or signalized crossings or complete segregation (grade separated) by considerations of both vehicle as well as pedestrian volume. In this line, Bak and Kiec (2012) studied the influence of mid-block pedestrian crossings on roadway capacity by the simulation model. The results indicate that the vehicular driver willingness to give a right of way to pedestrians on urban roads results in decrease in capacity reduction and increase in delays and it is also observed that there is significant reduction in roadway capacity at zebra crossing locations. Schroeder et al. (2012) found that effect of pedestrian non-complaint behavior on vehicular capacity at the multilane roundabout as a function of the driver yields behavior. Duran and Cheu (2012) studied the effect of crosswalk location as well as pedestrian volume on roundabout capacity by the simulation model. From the results, they concluded that if the crosswalk is placed further upstream from the yield line then the entry capacity of roundabout approach increases. But, there is no significant change in the entry capacity when the crosswalk is beyond three car-length upstream from the yield line.

The yielding behavior is affected by various aspects of the roadway and driving environment, including vehicle dynamics, pedestrian's behavior, roadway function and design. The driver yield behavior is rarely observed (those pedestrian waiting at curb location) at un-signalized intersection under mixed traffic conditions. The non-complaint behavior of pedestrian and non- driver yield behavior the interaction between pedestrian-vehicle increases at un-signalized mid-block crosswalk locations. Dulaski and Liu (2013) studied the interaction between the pedestrian and vehicular driver at un-signalized mid-block locations when pedestrian is waiting at curb and stepping off the curb. From the results, it was concluded that, the driver yield behavior is more when the pedestrian steps off from the curb and it is more during morning peak hours. Safety at mid-block crosswalks depend on the ability of drivers and pedestrians to recognize potential conflicts. Some of the researchers explored pedestrian safety at mid-block crosswalk location and they concluded that pedestrian safety is governed by driver yield behavior (Brumfield et al., 2013) and some researchers have carried pedestrian road crossing behavior comparative study between signalized and un-signalized midblock locations (Khatoon et al., 2013). But, there is trade-off between pedestrian safety and vehicular flow characteristics (speed, vehicular flow etc.) at un-protected midblock locations due to non-complaint road crossing behavior of pedestrian.

In summary, a midblock path provides pedestrians a safer and a lot of visible thanks to cross a street than crossing at a random and infrequently dangerous location. Midblock crosswalks are most helpful in suburbs and areas wherever it's common to seek out long stretches while not intersections. Midblock crosswalks ought to be settled wherever there's significant traffic and major destinations, like faculties, looking centers, or transit stops. whereas all midblock crosswalks should be marked, they will even be increased with medians, refuge islands, signals, signs, lighting and curb extensions.In the urban transportation system at some locations (school zone and residential areas) the effect of vehicular traffic is reduced by implementing raised pedestrian crosswalks. Some research studies were carried on effect of raised pedestrian crosswalks on urban vehicular traffic. However, the improper midblock crosswalk location was deliberating the pedestrian crossing behavior. Moreover, this crossing behavior leaves a deleterious impact on traffic stream. Few research studies address the effect of pedestrian. The present research work is directed to the improvement and development of mid-block section and road intersection and to regulate the traffic volume and its downside by traffic style in urban areas in the developing nations like Indian. The objectives of the current study area formulated to study the pedestrian crossing characteristics and behavior in urban roads and to study the effect of pedestrian crossing behavior on traffic flow characteristics.

Study Location

Following are the factors considered for selection of study section:

- The midblock section should be free from the effect of any kind of side frictions like speed breakers, bus stops, signals etc. other than pedestrian crossing.
- The midblock section should be free from the effect of intersection gradient, horizontal and vertical curve with uniform geometry.
- The midblock section should have good traffic and pedestrian flow.
- The midblock section should not have any crosswalks available for pedestrian to cross.

By considering all the above criteria, the sections selected were NagavaraandYelahankaNew Town, Bengaluru.

Nagavara is in north Bengaluru and has a population of 35264according to 2011 census (conducted by BBMP). The main cause of traffic and its congestion in this area is Manyata Tech Park (also called Manyata Embassy Business Park),which is a software technology park in Bangalore. The park is situated in Nagavara (near Hebbal) on Outer Ring Road, and has a building area of 9.8 million square feet.

First midblock section was located near outer ring road of Nagavara which has mixed traffic in immense amount and second midblock section was located 80m away from first location and had vast amount of vehicle traffic and reduced pedestrian traffic. Figure 1 shows the Google Maps Image of Nagavara.

Yelahanka New Town is a suburb of Bengaluru and has population of 30,000 according to 2011 census (conducted by BBMP). YelahankaNew Town is connected with downtown Bangalore through Yelahanka Old Town which is in turn connected to a network of roads and a six lane dual carriageway highway. The same highway connects Yelahankawith Kempegowda International Airport and other villages near Devenahalli.

A midblock section was located near dairy circle of Yelahanka which had ample amount of pedestrian and vehicle traffic and the second midblock section was located 125m away from first location which had low pedestrian traffic and moderate amount of vehicle traffic. Figure 2shows the Google Maps Image of Yelahanka New Town area

Figure 1. Google Maps Image of Nagavara

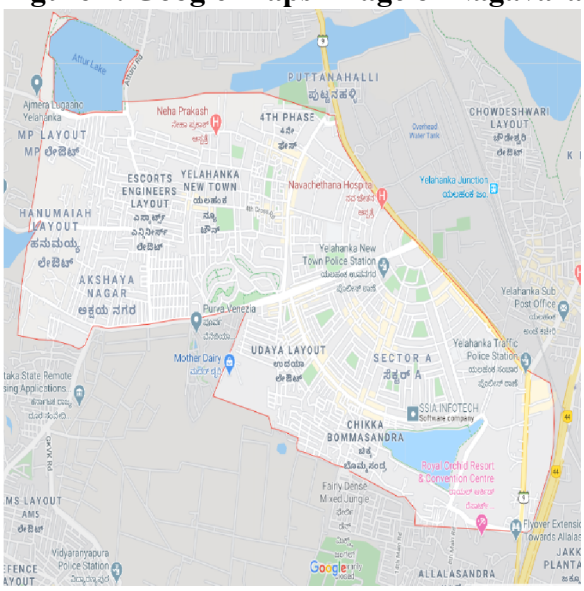


Figure 2. Google Maps Image of Yelahanka New Town

Data Collection

Videotaping survey was conducted at both locations during a normal weather working day condition. The survey was conducted during peak flow condition in morning (8:00-10:00AM). The video camera was located at the side of the road/ on the footpath. Figure 3 shows the video camera setup for capturing the

vehicular and pedestrian traffic at the study locations.

Data that was collected includes pedestrian and traffic characteristics. In particular, to study the individual vehicular effect by pedestrian crossing, data was collected for 2 hours. The collected data includes a number of pedestrians, vehicular flow, and vehicle speed. The video-graphic data was captured with the help of high-resolution cameras to capture vehicular characteristics.

Figure 3. Video Camera Setup

Data was collected in time step of 5 minutes. From each time step (5 min), data was collected which includespedestrian and traffic characteristics.In particular, to study the individual vehicular effect by pedestrian crossing, data was collected every 5 min and it is approximated to hourly traffic in order to get each hour traffic flow characteristics. Data collected consists of mean speed of vehicles, density and flow of vehicles, total number of vehicles traversing and number of pedestrians crossing the road.

Analysis

Preliminary observation

- From the preliminary survey, it is observed that there is significant difference between speeds of different class of vehicles at selected locations (with and without pedestrian crossing).
- It was observed that, the higher jaywalking or higher multiple stage of road crossing behavior, parked vehicles and pedestrians waiting for bus or auto rickshaw further increases the interaction between vehicles and pedestrian.
- It was observed that pedestrians neglected the sidewalk or footpath which was in perfect condition, and often used walk on the road.
- Few vehicles were parked on the sidewalk often.

Figure 4 and 5 shows the vehicles parked on the foot path and pedestrians walking on road adjacent to a fairly usable sidewalk respectively.

Figure 4. Vehicle parked on footpath

Figure 5. Pedestrians walking on road adjacent to a good sidewalk

The effects of pedestrian crossing on individual vehicles were studied by considering the

variation of individual vehicle flow characteristics. Vehicle Flow characteristics consist of the following parameters (i) volume count (ii) Speed (iii) density of vehicle on road (iv) Flow and various relationship between various traffic flow characteristics.

From the field survey, it is observed that vehicles such as car, two wheelers were more compared to heavy vehicles and auto rickshaw and cars at the selected site. Hence, individual variation analysis was only carried out for car and two wheelers. The following figures show the variation of both midblock section (i.e. unprotected and protected) from theoretical curves.

5.2 Volume count

Road user volume count data was extracted by using VLC Media player software. The road users classified into five different categories for both sites as shown in following tables. Total number of vehicles recorded in Nagavara are 9390 and Yelahanka New Town are 5823, during 2-hour time period at both protected and unprotected midblock sections. Table 1 and table 2 shows the volume count at unprotected midblock section and protected midblock section at Nagavara and Yelahanka New Town, Bengaluru, respectively.

Table 1 Volume Count at Unprotected Midblock Section and Protected Midblock Section at Nagavara

Road user type	Road users included	Volume Count at unprotected midblock section	Volume Count at protected midblock section
Pedestrian	Pedestrians crossing the road	96	0
2 Wheeler	Scooter, Motorcycle, Bicycle	3343	3002
3 Wheeler	Auto rickshaw, Garbage rickshaw	757	612
4 Wheeler	Cars	809	535
Heavy Vehicle	Buses, Trucks, Big Utility Vehicles	178	154

Table 2 Volume Count at Unprotected Midblock Section and Protected Midblock Section at Yelahanka New Town

Road user type	Road users included	Volume Count at unprotected midblock section	Volume Count at protected midblock section
Pedestrian	Pedestrians crossing the road	110	0
2 Wheeler	Scooter, Motorcycle, Bicycle	1902	2008
3 Wheeler	Auto rickshaw, Garbage rickshaw	375	486
4 Wheeler	Cars	310	514
Heavy Vehicle	Buses, Trucks, Big Utility Vehicles	107	121

Speed Measurement

From the play back videos in theVLC Media player software, the entry and exit timings of vehicles on marked lines for every 5 minutes are noted. The distance between the two lines was known (30m) and the speed extracted are average speeds or mean speeds using the equation 1. Table 3 shows the speed data for the study locations.

$$Speed\ of\ Vehicle = \frac{\text{distance between marked lines(d=30m)}}{\text{time taken to traverse between marked line(t)}} \quad \text{eq (1)}$$

Table 3 Speed data in kmph at Nagavara and Yelahanka New Town.

	Type of Road User	Speed in kmph at Nagavara			Speed in kmph at Yelahanka New Town		
		Minimum	Maximum	Mean	Minimum	Maximum	Mean
Midblock with pedestrian crossing	All Vehicles	12.00	40.00	26.00	12.00	36.00	24.00
	2 Wheelers	21.16	40.00	30.58	19.60	36.00	27.80
	3 wheelers	20.16	36.00	28.08	19.60	31.76	25.68
	Cars	17.60	32.70	25.15	16.61	29.18	22.80
	Heavy vehicles	12.00	27.00	19.50	12.00	27.00	19.50
Midblock without pedestrian crossing	All Vehicles	15.40	51.40	33.40	19.60	54.00	36.80
	2 Wheelers	30.80	51.40	41.10	27.00	54.00	40.50
	3 Wheelers	27.00	41.50	34.25	27.00	41.53	34.26
	Cars	26.30	45.00	35.65	26.34	41.53	33.94
	Heavy Vehicles	15.40	36.00	25.70	19.60	36.00	27.80

Traffic Flow and Density

Density (k) is calculated as the ratio of number vehicles traversed between two marked on lines on a lane in a specified time to distance between the two marked lines on the lane. Here average or mean density has been calculated using the equation 2:

$$Density\ (k) = \frac{\text{Number of vehicles traversed between two marked lines on a lane in a specified time}}{\text{distance between the two marked lines on the lane}} \quad \text{eq (2)}$$

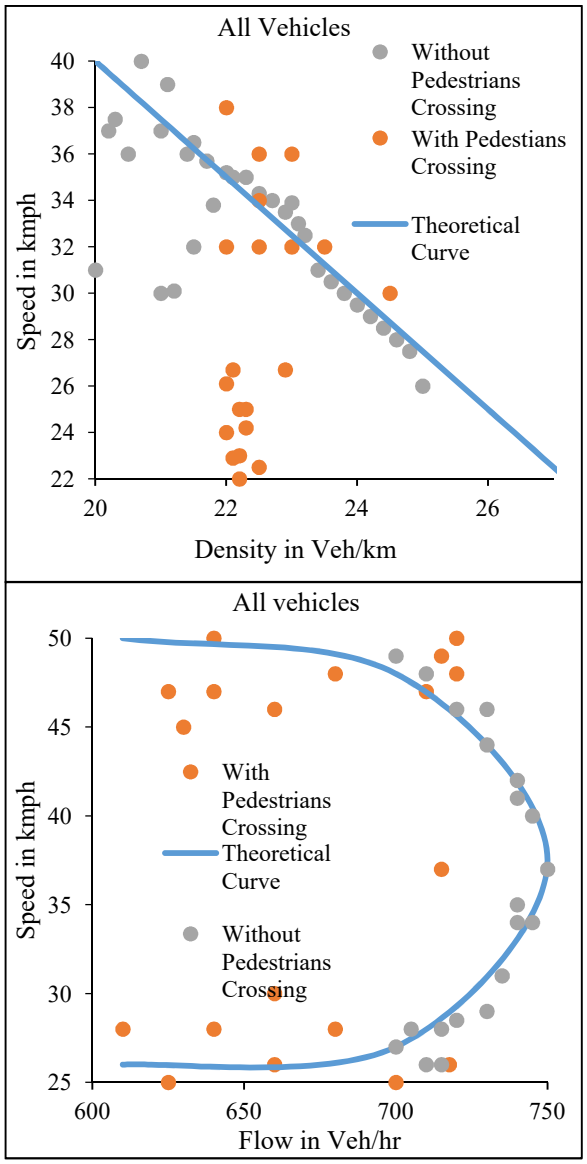
Flow is the number of vehicles passing a reference point per unit of time, vehicles per hour. Here it is calculated as the product of average or mean speed of vehicles (v) and density (k). Equation 3 showa the relation between traffic flow (q), density (k) and speed (v)

$$Flow\ (q) = speed\ of\ vehicles\ (v) * density\ (k) \quad \text{eq (3)}$$

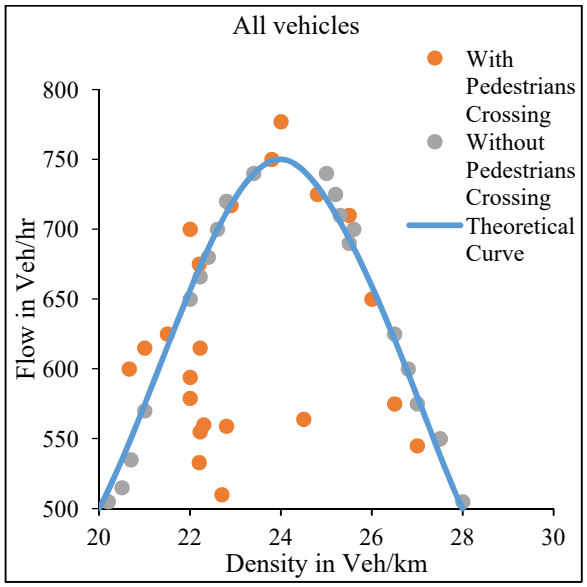
Table 4 shows the density (k) and flow (q) at the Nagavara and Yelahanka New Town

Crossing condition	Traffic type	Nagavara		Yelahanka New Town	
		Density (k) in veh/km	Flow(q=v*k) in veh/hour	Density (k) in veh/km	Flow(q=v*k) in veh/hour
Midblock section with pedestrian crossing	2 Wheelers	15	459	9	250
	3 Wheelers	4	112	5	129
	Cars	5	126	5	114
	Heavy vehicle	3	59	3	58.5
	All Vehicles	28	728	23	552
Midblock section without pedestrian crossing	2 Wheelers	15	617	10	405
	3 Wheelers	9	308	3	103
	Cars	7	250	4	136
	Heavy vehicle	2	52	3	83
	All Vehicles	35	1169	20	736

The speed (v) – Density (k) – Flow (v) relations are developed for the traffic flows with and without pedestrian crossings and are shown in figure 6.



(a) Traffic Speed (v) – Density (k)
(b) Traffic Speed (v) – Flow (q)



(c) Traffic Flow (q) – Density (k)

Figure 6 Traffic Speed (v) – Density (k) – Flow (q) Relationship

The Speed -Density relationship of all the vehicles is approximately equal to theoretical one for midblock section without pedestrian crossing. But irregular variation is recorded for midblock section with pedestrians crossing the road. This variation is due to various reasons including driver and pedestrian behavior.

Results and Discussion

In this study, data was analyzed and the result shows the fundamental relation between the speed-density and speed-flow and flow-density. The study also shows how the pedestrians' crossing at midblock effects the speed, density and flow of different categories of vehicles and how behavior of driver changes from one section to another.Speed characteristics of unprotected and protected midblock section show that there is a significant difference in speed in all categories of vehicles. The pedestrians' crossings negatively affect the capacity of the section.

From the manual count method pedestrians' crossing the section was calculated for every 5minutes. From this, it is noted down that the pedestrians'crossing varies from section to section and from place to place also. The size of the data collection depends on the length of the counting period, the type of count being performed, crosswalks being observed and the road conditions.

The Vehicle count in Yelahanka New Town is lesser than Nagavara region, but pedestrians' crossing the section is higher than Nagavara region, due to less vehicle activity in the suburb. The Vehicles drive slowly at unprotected midblock section and have slightly higher speeds in protected midblock section.

Irrespective of the midblock section, two wheelers are present in higher count than any other vehicles and they also have higher speeds than any other category of vehicle with an average of 29 kmph and 40 kmph at unprotected and protected midblock sections, respectively.Two wheeler tend to change the vehicle path slightly to compensate for the interference of pedestrians.

Cars have higher interaction time with pedestrians' crossing the section as they have to yield and decrease their speed, with an average of 24 kmph and 35 kmph at unprotected and protected midblock sections, respectively. The relation between speed and density and flow are affected by pedestrians' crossing and have greater variation in unprotected midblock section than in protected midblock section.

Heavy Vehicle are not much affected by pedestrians' crossing as they are driven at low speed in District Roads and Urban Roads. But the speed and flow values vary only slightly and they also cause delay to other vehicles in smaller midblock sections with an average speed of 20 kmph and 26 kmph at unprotected and protected midblock sections, respectively. The Density and Flow values do not vary highly as in case of two wheelers and cars.

Three Wheelers tend to be affected by standing pedestrians rather than pedestrians crossing the road as they are anticipating fareswith an average speed of 28 kmph and 32 kmph at unprotected and protected midblock sections, respectively. The Density and Flow values do not vary highly as in case of two wheelers and cars.

Conclusions

The vehicular speeds were implicitly affected with pedestrian crossing when compared to without pedestrian crossing location under mixed traffic conditions. The theoretical capacity is significantly reduced with pedestrian crossings for car. However, increase in capacity is observed with pedestrian crossings in case of two-wheeler. The underlying fact is the variation of the speed of the car and two-wheeler.

The increase in reduction of vehicle speed significantly affects the travel time of vehicular drivers and it further has influence on the fuel consumption. However, the driver yield behavior is the tradeoff between pedestrian safety and vehicular flow characteristics. This study clearly indicates that the importance of pedestrian crossing facilities and the barrier effect on the vehicular flow characteristics.

Reduce pedestrian exposure to vehicular traffic. Better and easy way for pedestrian crossing is implementing pedestrian safety interventions for road geometry and grade separated crossing rather than using at-grade crossing. This judgment of segregating pedestrians from vehicular traffic should be based on the number of pedestrian accidents, illegal pedestrian crossing and demand of pedestrian as well as vehicular flow.

This study has few limitations, in this study the effect of pedestrian crossing on the heavy vehicle is not addressed because of less heavy vehicle flow at selected location.

Jaywalking should be considered a legal offense, at least at some roads where vehicular traffic and pedestrian volume is high.People need to be educated about crossing behavior and the delays and effect it has on day to day traffic.Various vehicles park at or near sidewalks. This should be prohibited in order to keep pedestrian and vehicular traffic separate

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