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Impact of Vehicle Pedestrian Interaction on Traffic Flow: Midblock & Intersections

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ABSTRACT: Pedestrian is one of the important component in urban transportation system and also vulnerable at un-protected mid-block locations under mixed traffic conditions. At unprotected mid-block locations, some of the vehicles may yield to pedestrians who are already at crosswalk location. However, some of the pedestrians are using forced gaps to cross the road. Hence, while pedestrians use the mid-block crosswalk with forced gaps, which decreases the vehicular flow characteristics. The pedestrian sidewalks do not show a direct effect on the vehicular flow characteristics when the pedestrian have pleasant walking facilities. 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 results indicate that the pedestrian forced gap condition has significant effect on vehicular characteristics. The study results may be useful for decreasing the travel time for vehicular drivers by controlling usage of pedestrian forced gaps.

KEYWORDS: pedestrian, sidewalk, mid-block, cross-flow, vehicular characteristics

I.INTRODUCTION

Walking has always been the primary means of human motion. And that's why we considered the pedestrians are the basic elements of transportation. In ancient ages there was a huge pedestrian walking take place and walking is the only mode of transportation. For every transport related to travel and journeys must begin and end in walking. This pedestrian walk is an effective mode of transportation for short trips. Walking is a major mode of transportation in Indian cities also.

In order to provide the best design spaces for human motion or circulation like at airport corridors, shopping malls, subways etc. for that pedestrian motion is studied empirically in all aspects. It is carried away by two levels. At macroscopic level one can analyze the basic flow parameters like speed, density of pedestrian motion and at microscopic level one may track the paths followed by individual pedestrians while moving respectively. From this it is clear that the pedestrian may create own paths in their journey trip.

Coming to the pedestrian crosswalks there were several cross walks like zebra crossing are designed for a road, provide gainful work to assist the pedestrians to move from one side to the other side of road, and which plays a significant role in the mobility and safety mode of signalized intersections. In some other places like where the busy traffic takes place, pedestrian choose the mid blocks to cross the road. But there is no safety as compared to signalized intersections. Even many pedestrian crosswalks are taking place in these midblock sections.

Depend on the vehicular pedestrian motion demand cross walk width is defined. Some existing manuals are published about the crosswalk width, but they do not provide clear specifications for the required crosswalk width,

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regarding different pedestrian demand volumes and properties. Pedestrian flow consists of two types, unidirectional (single file motion) and bidirectional. In unidirectional flow, pedestrian motion is in one direction only, whereas in bidirectional pedestrian can walk from the both direction and interact with each other. Pedestrian road safety is one of the major aspects of transportation engineering in urban areas. The illegal crossing behaviour of the pedestrian is a major fact in the road safety issue.

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 significant effect on vehicular characteristics such as an increase in travel times and decrease in vehicle speed. At signalized midblock and intersection, there is the complete right-of-way to pedestrians and vehicles as it results decrease in pedestrian and vehicle conflicts as well as severity of conflicts.

There are numerous studies which deal with the pedestrian road crossing behaviour 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' behaviour 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 (Persson, 1988). 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. The grade separated facilities are provided exclusively based on the vehicle as well as pedestrian traffic intensity. 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 road side 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 behaviour, causing more interference with vehicles. It leads to rigorous change in vehicular flow characteristics such as speed and flow. A number of research studies have been carried out on vehicular f low characteristics on freeways, bottlenecks, merged lanes etc., but studies on effect of pedestrian crossing on vehicular flow characteristics are very few.

II.OBJECTIVE OF THE STUDY

In this context, the objective of present study is to investigate the effect of pedestrian crossing on vehicular speed. 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.

In general, three categories in the traffic performance are focused on, i.e. road safety, energy economy and transportation efficiency.

(1) Road safety

Traffic safety at intersections is of significant importance to researchers. Intersections are responsible for 47% of all vehicle collisions in the United States in 2010. Signalized intersections accounted for 25% of total vehicles in collisions while unsignalized intersections accounted for 22% of total vehicles involved. Conflicts between different participants in the traffic reduce road safety and result in extra travelling time. Among all kinds of conflicts, the vehicle–pedestrian interaction is considered as the most complex and important issue. Especially at large intersections, traffic performance suffers from the vehicle–pedestrian interaction, traffic signal, long crossing distance for pedestrians, large vehicle flow etc.

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According to the driving convention in many places such as China, vehicles move on the right side of the road, that leads to high probability of vehicle–pedestrian emergency on the right-turn lanes at the intersection where the vehicles are not regulated by the signal and always allowed to turn right. Furthermore, signal noncompliance behaviours of pedestrians are common at intersections in China. Jiang et al. found 37.07% of pedestrians not following the signal at several intersections in Beijing, China, that results in strong vehicle–pedestrian interactions especially in the right-turn lanes.

Ni et al. carried out a field study in Shanghai, China and found that the pedestrians violating signals accounted for 47% of all the total, 44% of the pedestrians who arrived during non-green-light time would cross, and 91% of the pedestrians arriving during flashing green preferred to enter the crosswalk rather than stay and wait for the signal to change green. Yang et al. developed a model of pedestrians' noncompliance road crossing behavior in China with data extracted from videotape, where red light jumpers and violation followers of pedestrians were considered.

(2) Energy economy

Despite the rapid development in transportation system, energy crisis and atmospheric pollution are getting worse. The energy consumption in the transportation sector accounts for more than 27% of the total energy consumption in the US. Vehicles also contribute a lot to air pollution in urban areas and are the source of over 40% of volatile organic compounds (VOC) and hydrocarbons (HC), more than 70% of nitrogen oxides (NOx), and over 90% of the emissions of carbon monoxide (CO) in most European cities, for example. Since vehicle growth is mostly centered in cities, times for commuting and queuing at intersections have increased by multifold, that leads to more fuel consumption and gas emissions. Particularly, vehicle queuing time has increased unprecedentedly at junctions, resulting in more wasted energy by vehicles in idle.

(3) Transportation efficiency

Reducing transportation delays and improving traffic efficiency at signalized intersections has long been an imperative issue for researchers. In USA's cities, the congestion cost in 2011 (based on the wasted time and energy) was about $121 billion, and it is continuously increasing in the past years. Ji et al. analyzed the traffic efficiency with the majority-game-based conflict model, where a cellular automata model was proposed to describe the competition behaviour of right-turn vehicles and crossing pedestrians at intersections. Lambrianidou et al. [30] found that the crossing countdown timers (PCCST) at signalized pedestrian crossings are able to provide pedestrians valuable information that makes them react promptly and thus enhances traffic safety. The research results of Lipovac et al. [31] showed that a countdown display significantly reduces the total number of violators regardless of its location and traffic flow. But the reduction is not the same for different kinds of pedestrians (male, female, elderly, young people).

III.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 behaviour on vehicular capacity at the multilane roundabout as a function of the driver yields behaviour. 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

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the crosswalk is beyond three car-length upstream from the yield line. Silva et al. (2013) studied the effect of crosswalk location on roundabout performance, it was considered with vehicular flow and travel times by the simulation model. The results proved that there is a significant influence of the pedestrian crossing in terms of average travel time and for high vehicle traffic. Ashalatha et al. (2013) studied the effect of bus stops on capacity reduction of urban roads under mixed traffic conditions. From the results, they concluded that bus bays and curb side bus stops can reduce the capacity of urban roadways by 8.1% and 25.6% respectively. Chandra et al. (2014) studied the effect of pedestrian cross flow on capacity of urban arterials in mixed traffic condition. From the results, they concluded that pedestrian volume of 100 ped/hour crossing the road will reduce its capacity by 3.52 percent.

Farouki and Nixon (1976) studied the effect of the carriageway width on speed of cars in the special case of free flow conditions in sub-urban roads. From the results, it was found that the mean free speed of cars in suburban area increases linearly with increase in the carriageway width over a certain range of width (5.2m to 11.3m). Yagar and Van Aerde (1983) found that vehicular traffic speed changes exponentially with change in lane width. Raymond and Knoblauch (2000) studied the effect of crosswalk markings on vehicle speed. From the results, it was found that drivers slightly reduce vehicle speed by yielding to the pedestrians. Hakkert et al. (2002) evaluated the effect of the pedestrian crosswalk warning system on vehicle speed by means of embedded flash lights in pavement. The results inferred that vehicle speed will reduce by 2 to 5 kmph due to the yielding to pedestrians. Some authors addressed the characteristics of vehicles and pedestrians on different crossing conditions by studying the three conditions of the pedestrian crossing, including crossing freely, crossing at nonsignalized crosswalk, and crossing at the signalized crosswalk. From the results, they concluded that selecting appropriate crossing mode for pedestrians can effectively decrease the vehicle delay, especially when the heavy pedestrian flow exists (Shumin and Yulong, 2007).

The yielding behaviour is affected by various aspects of the roadway and driving environment, including vehicle dynamics, pedestrian's behaviour, roadway function and design. The driver yield behaviour is rarely observed (those pedestrian waiting at curb location) at un-signalized intersection under mixed traffic conditions. The non-complaint behaviour of pedestrian and non- driver yield behaviour 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 behaviour is more when the pedestrian steps off from the curb and it is more during morning peak hours. Safety at mid-block crosswalks depends 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 behaviour (Brumfield et al., 2013) and some researchers have carried pedestrian road crossing behaviour comparative study between signalized and un-signalized midblock locations (Khatoon et al., 2013).

Pedestrian movement model

In this study, a pedestrian is represented by a point and is assumed to move towards his desired direction when he is away from the road. When he reaches the curb side, he has to decide whether to cross immediately or wait for the oncoming vehicle to pass. The criterion for safe crossing is based on the widely used gap acceptance formulation. Every pedestrian is assumed to have an accepted critical gap which is defined as the time between the crossing pedestrian and the nearest oncoming vehicle. If the time left for the oncoming vehicle to reach the position of the pedestrian with its current speed is larger than a critical value tcg , the gap will be accepted and the pedestrian continues crossing. Otherwise the gap will be rejected, the pedestrian will stop and wait. Critical gap is determined by the lane width Lsw, the walking speed of the pedestrian vpws and a safety factor tsf that reflects the pedestrian aggressiveness. The value of tcg can be obtained by ,

$$t_{cg} = \frac{L_{sw}}{v_{pws}} + t_{sf}.$$

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The smaller tsf indicates the pedestrian to be more aggressive as he accepts shorter gap. vpws is randomly selected between 1.14 and 1.36 m/s for a pedestrian in normal walking condition, and is assumed to increase by 0.25 m/s if he is crossing

Vehicle movement model

Vehicles in the urban area have to obey safety rules to avoid pedestrians and to follow the traffic. A vehicle can be in three different driving regimes depending on the distance to its the leading vehicle without involvement of pedestrians:

(1) free driving,
(2) car-following and
(3) emergency brake.

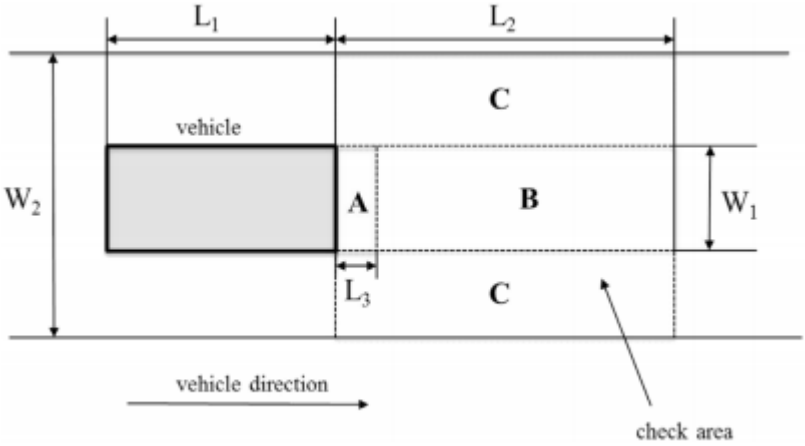
When the vehicle distance is larger than a threshold Dupper, the following vehicle will be in free driving regime and regulate itself to achieve its desired speed which can be also considered as the maximum speed due to speed limit vmax with its inherent maximum acceleration and deceleration. When the gap is between Dupper and a shorter threshold Dlower (Dlower < Dupper), the vehicle will be in car-following regime and is assumed to follow the GHR car-following model, where its acceleration changes with the velocity difference and distance between itself and the leader. When the distance to the leader is smaller than Dlower, the emergency procedure should be activated to extend the distance.

Pedestrian–vehicle interaction

Take the interference of crossing pedestrians into account, the following vehicle movement model with interactions is presented [16]. A moving vehicle should keep checking areas A, B and C in Fig. for possible crossing pedestrians at each simulation time step. Area A represents emergency, the vehicle must brake immediately when a pedestrian appears in area A given a proper small safe distance L3. L2 that is the eyeshot of the driver is determined by L2 = tpthv where tpth is the preferred time headway of the vehicle. The time headway is defined as the time required for the vehicle to arrive at the target place if it keeps the current speed. Let the distance between the nearest pedestrian in area B and the vehicle be Lmin. The vehicle velocity follows the rule

$$v_{des} = \min\left(L_{\min}/t_{pth}, v_{\max}\right),$$

where v_{des} is the desired speed at the moment. When the pedestrians in area C are trying to cross the street, the vehicle must slow down according to Equation.



the check areas for pedestrian of a vehicle when moving along the road.

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IRC: 103-1988 RECOMMENDATIONS FOR UNCONTROLLED MIDBLOCK CROSSINGS

1. Midblock zebra crossings are to be provided only when the distance between two consecutive intersections is more than 300m and simultaneously there is genuine demand for such a facility Eg: shopping or commercial.
2. It must be noted that midblock crossings are more difficult to control and frequently warrant provision of additional safety measures.
3. All such crossings must be properly maintained with respect to painting marking, etc and must always accompanied by suitable pedestrian cross signs.
4. These signs must be located that their visibility is not impaired by road side trees, overhead service poles, bends, bumps or any other physical obstruction.
5. For undivided carriage ways, midblock crossings should be accompanied by "STOP" lines with central barrier line marking being continued on either side of the crossing upto a certain distance on each side.
6. Beacons & flashing signals may be used with advantage in conjunction with pedestrian cross signs at such locations.
7. Guard rails are rather essential for satisfactory operations of midblock crossings.

IV.METHODOLOGY

Site Selection

A zebra cross marked location was selected to allow for a minimum pedestrian cross flow at mid-block location to study the effect of pedestrian crossings on vehicular flow. The selected second location is approximately 300 m away from the previous location on the same roadway corridor with same geometry (mid-block location) and there was a full barrier to prevent the pedestrian crossings for the stable vehicular flow condition. The photographs of the two locations are shown in Fig.

Location (1): Pedestrian zebra cross mid-block

Location (2): Non-pedestrian crossing mid-block

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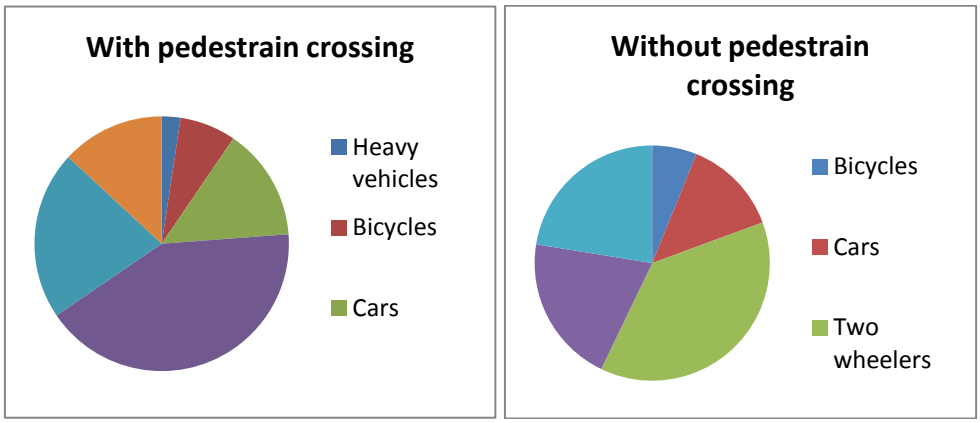

Location (1):Pedestrian zebra cross at mid-block Location (2):Non-pedestrian crossing midblock

Data Collection

Videotaping survey was conducted at both locations during a normal weather working day condition in Maddilapalem, Visakhapatnam, Andhra Pradesh, India. The survey was conducted during two peak flow conditions morning (8:00-10:00 AM) and evening (4:00-6:00 PM). The video camera was located on top of a building. The total road section was divided into 20 m sections of white cello tape to find out the speed of the vehicle and also vehicular flow values. The video was played at traffic control room, maddilapalem, Visakhapatnam. From each time step (5 min), data were collected which includes pedestrian 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 the each hour traffic flow characteristics. The collected data include a number of pedestrians, type of vehicle, vehicular flow, and vehicle speed.

Area of Study

The area under the study was taken as uncontrolled pedestrian crossing location at Maddilapalem RTC complex. This is the place where heavy accumulation of vehicles takes place due to uncontrolled pedestrian midblock crossings.

The above two pictures were taken during the day time at peak hours i.e.;4:00 P.M to 6:00 P.M, showing us that the vehicle accumulation taking place due to uncontrolled pedestrian crossings at the midblock.

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Arise of Problem

The maddilapalem intersection is typical type of intersection where the pedestrian crossing at this intersection is highly difficult as vehicles tend to move spontaneously without break as this emerges the pedestrian crossing at uncontrolled midblock location at maddilapalem RTC complex.

Model Formulation

Explanations of traffic flow theory at a point are based upon the three quantities speed (v), flow (q) and density (k) usually considered in traffic flow modelling. Analysis of their definitions leads in the case of homogeneous traffic directly to the formula that has become known as the fundamental equation (Greenshields, 1935). The fundamental equation as follows:

$$q = k * v \qquad (1)$$

Where q is f low, measured in number of vehicles per unit of time, *k* is density, measured in number of vehicles per length of the road, and *v* is the space-mean speed (Lighthill and Whitham, 1955), measured in length per unit of time. This fundamental equation can be accompanied by the adoption of a model relationship to describe the association between speed and density as given in Eq. (2).

$$v = f(k) \qquad (2)$$

Traffic f low can be analyzed effectively based on these relationships ((Lighthill and Whitham, 1955).

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When Eq. (2) is populated with an explicit form, any one of the three variables (speed v, flow q, and density k) can be used to calculate values for the other two, subject to the ambiguity between free-f low and congested flow values of q.

Complex models of traffic flow have been developed that use Eq. (2) as an equilibrium relationship for steady-state flows, towards which traffic speed will relax over time and the same relationships are also used for the unsteady state of flow condition in order to check the vehicular flow.

V.RESULTS AND DISCUSSIONS

Observations of Field Study

The descriptive statistics of the collected speed of the each category of the mode was presented in the Table 1. From the field survey, it is observed that there is significant difference between speeds of the vehicles at selected locations (with and without pedestrian crossing). The result based on the regression analysis between speed and density, flow and speed, flow and density, arriving at the model equations respectively by using the vehicular speeds listed in the table below.

Vehicular Flow Characteristics Relationships with Pedestrian Crossing Conditions

Location	Type of variable	Speed in Kmph			
		Minimum	Maximum	Mean	Standard deviation
Location I (Mid•block with pedestrian crossings)	Ml vehicles	8.6	35.86	21.04	6.85
	Car	11.4	28.96	21.4	8.84
	Two wheeler	25.22	42.24	28.24	7.65
	Auto Rickshaw (Three wheeler)	8.24	24.04	14.22	9.64
	Heavy vehicles	8.86	21.44	17.04	5.14
Location 2 (Non-pedestrian crossing mid-block)	All vehicles	18.98	65.24	28.75	16.02
	Car	21.24	54.86	32.44	10.46
	Two wheeler	26.68	64.24	33.68	9.88
	Auto Rickshaw (Three wheeler)	17.68	36.67	21.02	8.88
	Heavy vehicles	14.86	32.64	19.44	7.54

Vehicular Flow Characteristics with and without Pedestrian Crossing

The data such as vehicular flow, speed and density were computed at pedestrian crossing and pedestrian crossing restricted location. In order to study the effect of pedestrian crossing on vehicular flow characteristics the total combined traffic was considered and relationship were plotted between speed and density, speed and flow, flow and density and are presented in Fig. 2. The scattered plot of data points recommended a straight line relation between vehicle speed and density; quadratic relationship between vehicular speed and flow, and vehicular flow and density. In order to study the effect of pedestrian crossing on individual vehicle; individual vehicular flow, speed and density (each type of vehicle separately treated) were also measured from the field data and relationships were also developed. From these individual vehicular characteristics, the driver's yield behaviour at pedestrian crossings can be studied. If the particular vehicular flow characteristics change drastically, it implies that vehicular drivers give more space to the crossing pedestrian. The relationships were developed for combined data (see in Table and Fig) and also for individual

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mode; the calculated relationships from the analysis of data at two study locations, are presented in Table . The correlation coefficient R2 varies from 0.11 to 0.94 at various conditions.

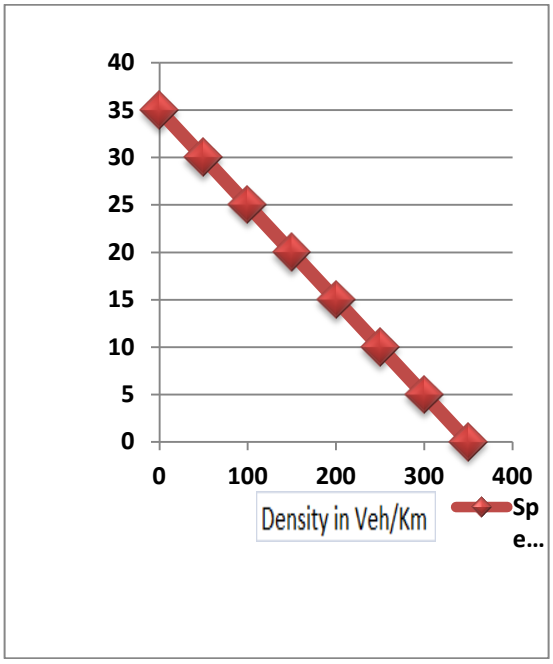

FIGURE (a): Speed vs Density

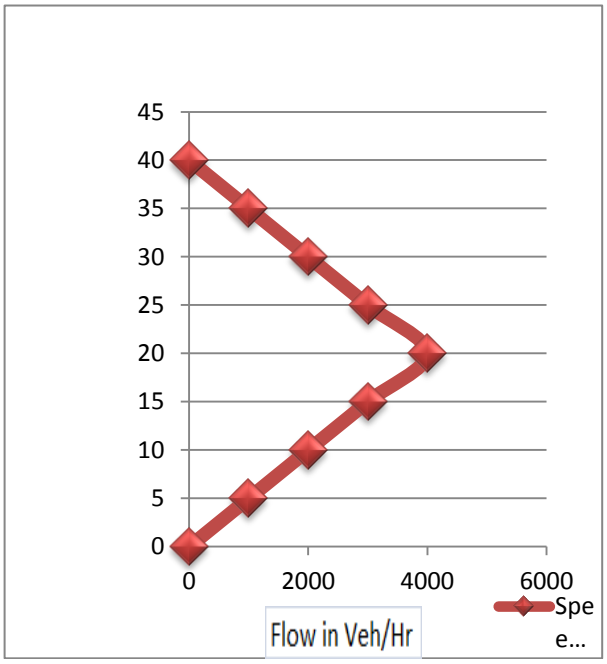

FIGURE (b): Speed vs Flow

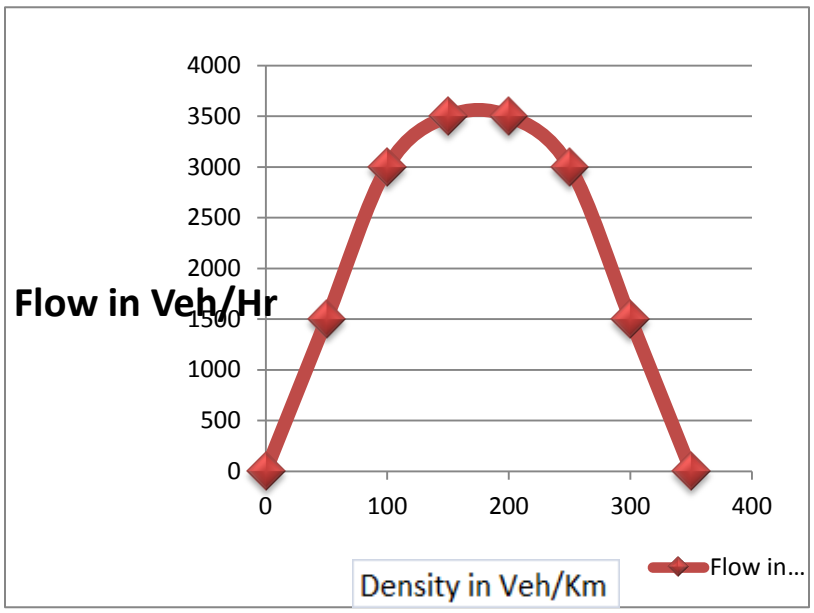

Figure: Flow vs Density

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Traffic Flow Fundamental Diagrams with Pedestrian Crossing: (a) Speed and Density Relationship, (b) Speed and Flow Relationship, (c) Flow and Density Relationship

Vehicular Flow Characteristics Relationships with Pedestrian and without Pedestrian Crossing Conditions

Location	Traffic Type	Crossing Condition	Relation	Model equation	R^2 value
1	All vehicles	With pedestrian	Speed-density	v= 29.91−0.065 * k	0.647
			Flow-speed	q= v (29.91−v) /0.065	0.212
			Flow-density	q= k (29.91−0.065 * k)	0.676
1	Car	With pedestrian	Speed-density	v= 21.83−0.209 * k	0.404
			Flow-speed	q= v (21.83−v) /0.209	0.38
			Flow-density	q= k (21.83−0.209 * k)	0.618
1	Two wheeler	With pedestrian	Speed-density	v= 40.10−0.205 * k	0.645
			Flow-speed	q= v (40.10−v) /0.205	0.201
			Flow-density	q= k (40.10−0.205 * k)	0.256
1	Auto Rickshaw (Three wheeler)	With pedestrian	Speed-density	v= 27.47−0.178 * k	0.415
			Flow-speed	q= v (27.47−v) /0.178	0.12
			Flow-density	q= k (27.47−0.178 * k)	0.776
2	All vehicles	Without pedestrian	Speed-density	v= 39.91−0.101 * k	0.938
			Flow-speed	q= v (39.91−v) /0.101	0.565
			Flow-density	q= k (39.91−0.101 * k)	0.711
2	Car	Without pedestrian	Speed-density	v= 29.89−0.264 * k	0.233
			Flow-speed	q= v (29.89−v) /0.264	0.121
			Flow-density	q= k (29.89−0.264 * k)	0.256
2	Two wheeler	Without pedestrian	Speed-density	v= 42.43−0.188 * k	0.556
			Flow-speed	q= v (42.43−v) /0.188	0.112
			Flow-density	q= k (42.43−0.188 * k)	0.256
2	Auto Rickshaw (Three wheeler)	Without pedestrian	Speed-density	v= 34.92−0.293 * k	0.769
			Flow-speed	q= v (34.92−v) /0.293	0.110
			Flow-density	q= k (34.92−0.293 * k)	0.252

Discussions

The mathematical relationships were developed between speed, density and flow in the present study. The theoretical vehicular speed was found as 30 kmph at pedestrian crossing locations and 40 kmph at restricted pedestrian crossing location (See in Table 2, if the density (k) equal to zero for all the vehicles case). From the field survey, it is also observed that there is a reduction in speed (7.7 kmph) at pedestrian crossing location as compared to the pedestrian crossing restricted locations. The speed represented here are average speed of all the vehicles, including two wheeler, car and auto rickshaw (three-wheeler). The interaction between pedestrian and vehicles will be more at un-signalized pedestrian crosswalk locations and the change in vehicular flow characteristics increase with an increase in non-complaint behaviour of pedestrian as well as multiple stage of road crossing behaviour of pedestrian. From the field survey, it is observed that, the higher jaywalking or higher multiple stage of road crossing behavior (forced gaps), parked vehicles and waiting pedestrians for bus or auto further reduction in roadway width results in an increase in interaction between vehicles and pedestrian. It leads to further reduction in vehicular speed as well as other characteristics (flow etc.). The theoretical capacities were observed as 3676 vehicles/ hour and 2486 vehicles/hour without pedestrian crossing and with pedestrian crossings respectively. The fundamental diagrams of vehicular characteristics (all vehicles) with and without pedestrian crossings are shown in the Fig.

VI.CONCLUSION

The vehicular flow characteristics were studied at un-signalized mid-block pedestrian crossing and pedestrian restricted crossing in Maddilapalem, Visakhapatnam, India. The vehicular speeds were implicitly affected with pedestrian

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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. In case of auto rickshaw (three wheeler) also there is a significant drop of speed value. From this study, it concluded that the car and auto rickshaw driver yielding to pedestrians in terms of speed is more when compared to the two wheeler drivers. 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 behaviour 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. The 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. However, this study has some 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. This study result is restricted to single location of 4-lane divide roadway characteristics. There is a need to study the other crosswalk locations with varied roadway geometry and crosswalk types. It is also important to address the effect of pedestrian behavioural characteristics (change in pedestrian speed as well as crossing path) on vehicular characteristics under mixed traffic condition. In spite of these limitations, this study result has great inferences for pedestrian crossing facilities for urban planning policies and design practices for controlling the pedestrian crossings as well as proper location for the pedestrian crossing under mixed traffic conditions.

SUGGESTIVE MEASURES FOR UNCONTROLLED PEDESTRIAN CROSSING AT MADDILAPALEM RTC COMPLEX

- Placing of sign post or sign boards informing the oncoming vehicles about heavy pedestrian crossings.
- Installing digital signal posts on either side of the pedestrian foot boards and assigning a traffic police at either ends to operate the signal post as the pedestrians accumulation happens, pedestrian crossing takes place by switching the pedestrian signal post to RED for oncoming vehicles onto the midblock.
- Constructing a foot over bridge for pedestrian crossing at the pedestrian crossing location.
- Providing a underpass or subway pedestrian crossing facility, as far as considering, this is the best remedial measure for pedestrian crossings at midblock location as this type of pedestrian facility does not interfere with the vehicle movements.
- A huge impact at this point is seen due to pedestrian vehicle interaction, a no. of accidents were registered at this point as these above mentioned remedial measures would make a deal in controlling the pedestrian vehicle interaction.

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