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Pedestrian Behaviour at Crossing Intersection

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ABSTRACT

Pedestrians' road crossings behavior in India has become a major concern in road traffic flow, especially in urban areas where there are no controls for pedestrians' road crossing. With the increase of motor vehicles growth rate, there is an increase in the regulation of motor vehicles on the road but the regulation of pedestrians is completely neglected. Several studies are there to understand the pedestrian movement and all the studies are based on fundamental diagrams only. These studies construct a base to characterize pedestrian flow. Several experiments have conducted to understand the pedestrian flow, likewise some field observations have done to represent fundamental diagrams. Therefore, before going to analyze the data from the observation, it is necessary to note down the pedestrian flow parameters carefully. The aim of the researchpaper is to build up the base to fundamental diagrams and for characterization of pedestrian. And derive the required flow diagrams and results from the field observations. Field survey is conducted to know the vehicle pedestrian interaction, and this field data with respect to pedestrian crossing at signalized, Unsignalized or at midblock sections is aimed to be observed. And the impact of vehicle pedestrian interaction at several intersections/midblock sections is to be studied.

Keywords: Pedestrians, Intersection, Vehicle, Midblock

1. INTRODUCTION

A person who travels on foot is termed as pedestrian. Pedestrian can be any person walking, running, standing or sitting on a road, a pram or in a mobility device or persons in a toy vehicle and not capable of exceeding 10 km/h is known as pedestrian Walking is always recommended for a healthy life and it is also considered to be a clear example of sustainable mode of transport especially suitable for urban use and for shorter distances. Nowadays, pedestrian spaces are becoming increasingly rare due to the importance bestowed to vehicular modes of travel, in the planning and design of transportation systems, pedestrians are not taken into account. At some point every person is a pedestrian. So, it is necessary to consider the various issues relevant to pedestrians such as pedestrian safety, convenience and amenities.

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, 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.

A crosswalk is a fundamental pedestrian facility in the urban roadway system which helps the pedestrians to safely cross the streets. This study identifies pedestrian characteristics such as pedestrian crossing speed and their compliance behaviour towards traffic regulations at the respective study areas and evaluating the significant factors that affect pedestrian crossing speed in the crosswalks at intersections. A video survey is preferred for this study and detailed analyses is needed in order to study the changes of pedestrian characteristics. Length of the crosswalk and pedestrian speed are very important indicators to determine minimum pedestrian crossing timing.

Pedestrian crossing behaviour is analyzed for the provision of proper pedestrian facilities at desired locations, as well as to improve their safety while crossing the road. In this project presents the analysis of pedestrian crossing behaviour from a study conducted at Vadodara city (Gujarat state in India). The effect of pedestrian characteristics like age, gender and that of carrying baggage and luggage as well as their crossing patterns were examined on pedestrian flow characteristics like crossing speed and waiting time. Pedestrian safety was also analyzed with respect to safety margins and gaps accepted by pedestrian in traffic stream. Crossing patterns were observed for different age group and gender.

2. LITERATURE REVIEW

2.1 GENERAL

Many research works on pedestrian have already been done in past few decades. A number of papers have been studied to get the knowledge about the topic of pedestrian behaviour. The brief knowledge of the studied papers is discussed in the next few paragraphs.

Un-signalized intersections are the most common intersection type. Although their capacities may be lower than other intersection types, they do play an important part in the control of traffic in a network. A poorly operating un-signalized intersection may affect a signalized network or the operation of an Intelligent Transportation System. The theory of the operation of un-signalized intersections is fundamental to many elements of the theory used for other intersections. For instance, queuing theory in traffic engineering used to analyze unsignalized intersections is also used to analyze other intersection types.

Walking requires two important features in the built environment: people must walk long streets and they must get across streets. Crossing a street should be easy, safe, convenient, and comfortable. While pedestrian behavior and intersection or crossing design affect the street crossing experience, motorist behavior (whether and how motorists stop for pedestrians) is the most significant factor in pedestrian safety.

Pedestrian networks and vehicle networks overlap at intersections, posing conflicts between different modes

of travel. A number of tools exist to improve pedestrian safety and to make crossing streets easier. Effective traffic management can address concerns about traffic speed and volume. A motorist driving more slowly has more time to see, react, and stop for a pedestrian. The number of pedestrians also influences motorists; in general, motorists are more aware of pedestrians when more people walk. Most tools to address crossing challenges are engineering treatments, but tools from the enforcement, education, and planning toolboxes are also important.

2.2 RESEARCH ARTICLE

In an investigation results show that pedestrians are found at fault in 59% of the crashes, drivers in 32%, and both are found at fault in 9%. Hamed (2010) established that pedestrians who spend more time waiting to cross from one side of the street to the median are likely to have a higher risk of ending the waiting time than when they cross from central refuge to the other side of the street. Location of pedestrian crossing facilities also plays an important role of crash occurrences and crash related injuries. The severity of the crashes increases in non-junction crosswalks because the pedestrians always do hurry to cross the roads to save time. So, they always cross the road in level ground instead of using underpass and foot over bridge. In Israel a detailed analysis of pedestrians accidents in 2006-2007, with an emphasis on the infrastructure characteristics involved, was performed; it was found that 75% of the fatalities and 95% of the injuries occurred in urban areas, the majorities of cases occurring on road sections (not at junction). About 80% of the accidents took place when a pedestrian crossed the road, the majority of them at non-crosswalk locations or at nonsignalized crosswalks. In another study it has been found approximately 38.2% of the crashes occur at non-crosswalk locations, while proportionately more (61.8%) of the pedestrian accidents occur at non-crosswalk locations. From the above literature reviews, it is found that many studies have been done for other areas, but few studies have been done for India. In this study, some measures will be suggested to improve the road crossing behavior of pedestrians in Vadodara city.

The Highway Traffic Act identifies the responsibilities and rights of pedestrians and drivers for different forms of pedestrian crossings. This section provides an overall synopsis of the rules of the road as defined and interpreted in the latest version of the Highway Traffic Act at the time of this publication.

Flow with high densities plays a vital role in the design of pedestrian facilities. Understanding pedestrian flow at high densities is required to design any pedestrian facilities with respect to the safety and comfort. Attention has to be paid by the pedestrian due to their less speed in the field.

[1] Research paper on Pedestrian Crossing Behaviour between Normal Traffic Conditions

Er. Asif Yousuf Seh, Er. Sonu Ram,Dr. Pooja Sharma (2019), Chandigarh is one of the most densely populated cities of the India. Here huge pedestrian gather in roads, junctions and intersections. At presents pedestrian crossing is one of the greatest challenges for the traffic and safety engineering. Present study deals with pedestrian crossing behavior in at intersections and normal traffic roads in Chandigarh city. To carry out the analysis at first number of crossings were collected from CTU and then survey were conducted to find out the existing pedestrian crossing facilities at near about 46 signalized intersections in Chandigarh city. The study reveals that in Chandigarh city area the generalized situation of pedestrian facilities are very poor. It signifies that about 60% intersections have no visible cross marking and about 57% intersections have no foot over bridges and underpasses. Six important intersections will be selected to count the amount of pedestrian crossing at peak period namely , Tribune chowk, old Airport Chowk, hello majra chowk,32 medical chowk, gurudwara chowk, kisan bhawan chowk, and doordarshan chowk etc. In this survey, direction wise amount of pedestrian crossing, number of pedestrian crossing with foot and number of legal and illegal crossing were collected. In some crossings at grade crossing becomes very risky because of its high traffic volume and high vehicle speed. But pedestrians always prefer at grade crossing for this reason at grade pedestrian crossing facilities should be improved by different type of latest technologies. Generalized situations of pedestrian facilities are very poor in Chandigarh city. The study reveals that there is absence of visible cross marking in 60%, foot over bridge in 65%, Refuge Island in 75%. The situation may be overcome by providing more pedestrian facilities in the intersections of Chandigarh city. After studied some generalized

intersections illegal and unsafe crossing is found in most of the intersections which is induced to face any fatal accident any time. Illegal crossings are found by the pedestrian of 16% at Gurudwara chowk, 23% at Tribune chowk, 28% at old Airport Chowk, 12% at Hello majra chowk,19% at 32 medical chowk, and 21% at kisan bhawan chowk. This situation symbolized very chaotic situation. The situation must be over come by introducing strong imposition to use foot over bridge and cross marking. Awareness generation is needed among pedestrian vehicle users citizens and all the concerned stake holders about safe road crossing and pedestrian safety. Scramble pedestrian phase is a tool of safe pedestrian crossing which is successfully being used in different cities of the world. In Chandigarh city it can be introduced in pilot basis in some selective intersections where pedestrian traffic volume is high. This Study proposed exclusive pedestrian phase at some intersections in Chandigarh city and signal designed has been hypothetically modeled incorporating EPP in two intersections of Chandigarh city. Pedestrian crossing behavior depends on the destination, age, education, physical condition and overall awareness of the pedestrian. The issues associated with pedestrian crossing activities generally create considerable emotional concern within the community, especially when the community is reacting to an incident involving pedestrian injury. Pedestrian crossing safety relies on the judgment exercised by pedestrians and drivers. To interact safely requires an exchange of information between the pedestrian and the motorist. Although traffic control devices can help to promote an exchange of information, educating pedestrians and drivers is paramount to providing for a safe operation. Provision of visible cross marking must be installed in all the intersections. Considering the high density of pedestrian traffic all over the city, it should be provided to ensure safe pedestrian crossing. Median island with median barrier must be provided in all the intersections to ensure safe pedestrian crossing. Street lighting around the crossing should be adequate so that cross marks are easily captured by the vehicle drivers to have stopping sight distance to avoid collision. Management of existing physical infrastructure must be enhanced to enable more effective use of crosswalks. It is provided with better road markings, signs, traffic signals, canalization at intersections, turn restrictions and separation barriers, space for bus stops, and parking or waiting areas for public transport vehicles (buses, rickshaws, auto-rickshaws, taxis, etc.). Pedestrian crossing should be considered carefully in traffic engineering and planning of the intersections and mid blocks.

2.2.1 Pedestrian flow and cultural difference

To design a better pedestrian system proper study is required on pedestrian flow characteristics. For that long ago, several studies on pedestrian motion had done. To understand the pedestrian characteristics under mixed traffic conditions Oeding (1963) conducted a study. Older (1968) shows the walking characteristics of Britain shoppers. Pedestrian and vehicular flow diagrams are similar in view, although the speed of the pedestrians is less than the vehicle speed. Moral (1991) determined that the pedestrian speeds of Asian countries are significantly lower than the western countries.

Fruin (1971) observed that the gender difference was unique for each other (male > female) and as speeds are decreased with the age. Henderson (1972) gave a report on the effects of gender on speed. Weidmann (1993) determined the pedestrian walking speeds under different walking conditions like mixed traffic conditions and shows the relation of speed with density in this mixed traffic flow. Fang Z al. (2007) observed that the maximum density of the crowd by developing a crowd dynamic model. Chattaraj U et al. (2009) compared the pedestrian flow fundamental diagrams across the culture in India. Rastogi, R, Ilango T and Chandra S (2011) presented the design implications of walking speed for pedestrian facilities. Rastogi R, Vamsheedhar J, Das V, and Chandra S (2011a) studied the pedestrian walking speeds at midblock crossings empirically. Chattaraj U et al. (2013) observed the differences in the fundamental diagram of pedestrian flow in different cultures by modeling.

2.2.2 Empirical studies on pedestrian movements

Seyfried et al. (2005) has intended to develop an experiment which focused on the effect of density on speed. Heilbing et al. (2007) observed the density with the individual speeds of the pedestrian. The results of the researches varied from place to place, due to the way

of their collection and representing the models and results.

Lam et al. (2002) determined the walking speed under various pedestrian and traffic conditions like bi-directional flow and pedestrian flow relationships at signalized crosswalks are studied. Bi-directional flow Y. S. Lee (2005) was observed the differences in pedestrian walking speeds on a unidirectional and bi-directional flow.

2.2.3 Different Pedestrian Dynamics Phenomena

Henderson and Lyons (1972) observed that speed of female and male is varied in the mixed traffic flow. Similarly Polus et al. (1983) observed that the speed of male pedestrians is greater than the female speed pedestrians. Young (1999) has determined the walking speed of the pedestrian in moving walkways at airport. Baltes M and Chu X (2002) determined speed-flow relation for midblock street crossings. Bhuyan P et al. (2013) shows the level of service of offstreet pedestrian facilities in India.

2.2.4 Vehicle pedestrian interaction

Weidmann (1993) has intended to develop how the density effects on the pedestrian walking speeds under different walking conditions like mixed traffic conditions (disturbed pedestrian movement). Few more studies have done by Seyfried et al. (2005) on density and flow relationship of pedestrian streams.

2.3 MOTIVATION

Till now reasonable studies have been done at pedestrian flow parameters and their interrelationship. No experimental studies available in the literature to understand the vehicle, pedestrian flow parameters changes from place to place in a city like Vadodara. Also, there is no experimental study on fundamental diagrams for this case. These motivated to conduct the experimental studies in this thesis.

2.4 PROBLEMS STATEMENT

Pedestrians are one of the major commuters on Indian urban streets. In India mostly pedestrians are neglected in transportation planning and management. So as the pedestrians are increasing day by day so better facilities need to be provided. As there are no provisions for Indian conditions and the models developed for urban conditions in western countries are not a true representative as the conditions prevailing are different. Study on pedestrian need to be done to provide better facilities to pedestrian in India. Pedestrian Level of service is one of the indicative which represents quality of given intersection in terms of perceived safety, convenience and comfort in terms of pedestrian perspective. In India the number of persons prone to accidents and deaths are mainly pedestrians. The main commuters on roads who are prone to fatal injuries, deaths are mainly pedestrians. When it comes to signalized intersections, intersections are the places where two roads in different directions meet at the same level. So there is high possibility of conflicting traffic at intersections. At signalized intersections the vehicle movement is controlled and orderly movement of vehicles is allowed. Till now mostly in India pedestrians are neglected in the design of various road elements. As the number of pedestrians using the roads increasing day by day and in the case of urban roads it is increasing exponentially. As number of pedestrians on roads increasing and they are the main road users in urban environment so better facilities are needed to be provided for p destrians.

Signalized intersections are the places where vehicles movement is controlled and systematic movement of vehicles is allowed. There are chances of accidents and conflicts more as vehicles and pedestrians using the same space at the same time. Till now in India the concentration of design of roadway elements mostly on vehicles only as they are the main users of roads. But in urban areas at intersections considerable amount of pedestrians using roads. So as to design a given intersection as better transportation facility pedestrians has to be considered in the design of roadways.

The problem of this thesis can be broadly stated as "understanding vehicular, pedestrian flow interactions in varied situations." In some situations, pedestrian motion is observed empirically. This describes the following-

- Crossing time for pedestrian will be measured to evaluate the maximum pedestrian flow, crossing speed, density, and the adequacy of the geometry and location of signalized crosswalk. The signal timing for pedestrian and motorists will also be examined.
- To analyze and study the effect of various factors related to vehicle, pedestrian interactions like pedestrian characteristics, pedestrian movements, traffic conditions, road conditions.

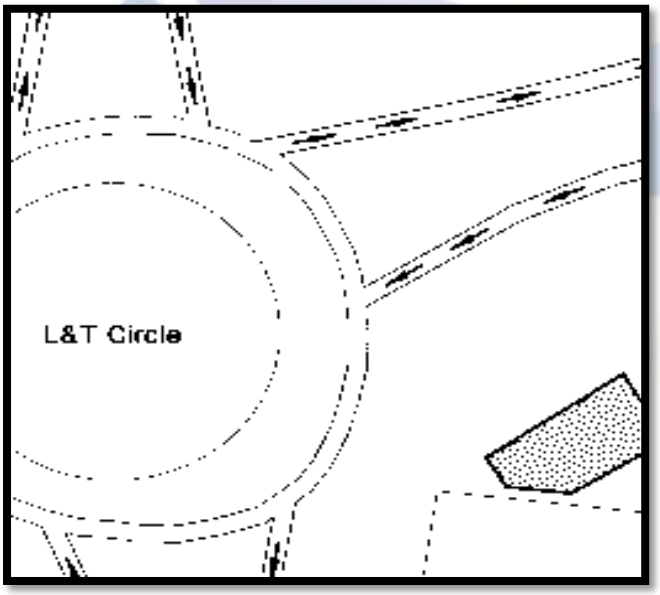
- The signalized crosswalk performance will be examined if it can handle the pedestrians safely and efficiently.

These are part of the overall study aim of providing a general characterization of pedestrian crossing behaviour at signalized intersections based on field observations.

3. PROPOSED METHODOLOGY

Some facts that affect the pedestrian movement are the interactions of the other pedestrian motion, geometry of the road facilities, and alternate ways of the pedestrian has to choose their trip in a multiple ways. The pedestrian flow may take place in a unidirectional, bidirectional, or multi-directional. They do not prefer travel in extreme clear path/lanes although they may do sometimes under heavy traffic. To do that recorded data or experimental/field data is to be taken to extract the pedestrian speed, density and several parameters which are very useful for the study.

There are several experiments were conducted at intersections and midblock. The first experiment was conducted at L&T Circle; Vadodara on disturbed pedestrian movement intended to study the impact of motorized vehicles on the pedestrian. From daily market undisturbed pedestrian movement was recorded to compare with the disturbed data set. The yield of this study is to show the fundamental difference between speed and density of the pedestrians.



[Fig.4.1: L&T Circle Intersection]

4.1 STUDY AREA

Vadodara, also known as Baroda, is the second largest city in the Indian state of Gujarat. It serves as the administrative headquarters of the Vadodara district and is situated on the banks of the Vishwamitri River, 141 kilometres from the state capital of Gandhinagar.

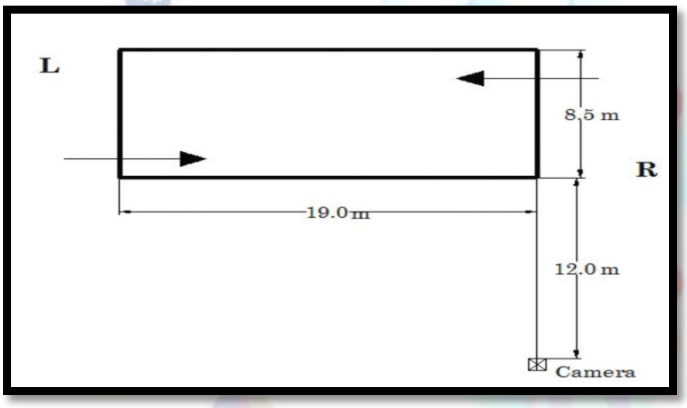
[Fig.4.2: Google Map of Vadodara City]

4.2 METHODOLOGY

In this section, the experiment is conducted to develop the fundamental diagrams between speed and density of pedestrians. It may be mentioned here that many studies have been taking place before this study of the fundamental studies like German pedestrians in Sayfried et al. (2005). Site selection is important and each location was observed clearly and questionnaire survey was very helpful in the experimental setup. Here is the site scene of the rotary intersection at L&T Circle in Vadodara shown in figure 4.3.

[Fig.4.3: Site scene of intersection at L&T Circle]

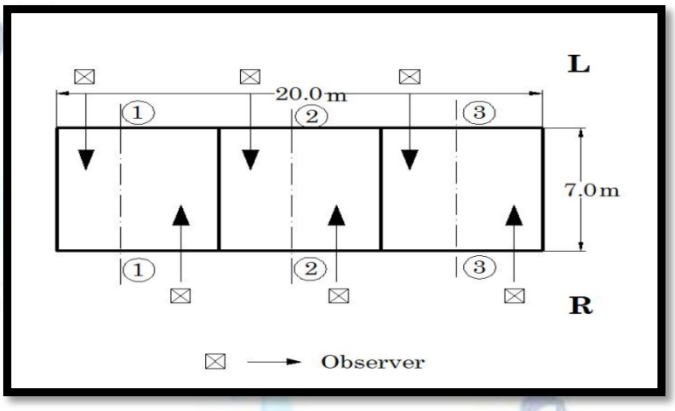
The experiment road section of L&T Circle, Vadodara was framed by ranging rods at four corners; the size of the section is 19 x 8.5m. It is shown in the fig.4.4. So that entry and exit timings can note down easily, i.e. here the pedestrian crossing is a bi-directional flow. Camera should be located at a desired point. So the camera was fixed at required distance from the cross section of the road about 12m from the starting point of the section along the perpendicular bisector of measured section to avoid the parallax error. It also records the crossing behaviour of pedestrian and vehicles which helps in analyzing the flow difficulties. Leveling is to be done by centering the bubble of the tripod. And the next step is to record the valuable pedestrian crossing data by clicking on the record button. The data is to be taken in peak hour timings only it should bring very good results in further steps.



[Fig.4.4: Sketch of the experimental road section of L&T Circle, Vadodara]

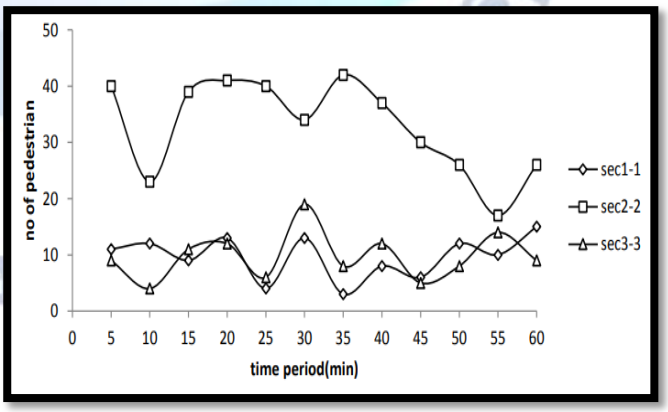
The manual counts are typically used for periods less than a day. For manual count method, three sets of data were counted manually to compare with the disturbed pedestrian as recorded at daily market and these three sections are 300m-400m apart from the adjacent section. Each set has a length of 20m, and it is divided into 3 sections i.e. 6.67m for a section to observe the crosswalk behaviour. Below figure 4.5 shows sketches of the daily market section. Pedestrian movement was counted by 6 observers, were placed opposite to each other for each 6.67m section and the reading was noted down in a sheet. Everyone is to carry a separate stop watch to read the values for every 5min. The peak hour timings of the sections are from 6:00 pm to 7:00 pm.

The manual count method is less accurate than the automatic method even though it brings us congested pedestrian crosswalk and how it changes from place to place. Graphs are plotted here to show the difference in pedestrian crosswalk from one location to another location. That is if the road is wide demand is less and speed is more. From this lane density is calculated easily with respective to the time. The lane density varies with the width of the section preferably. Lane density is inversely proportional to the width of the section. So that at the intersections width of the section is very important. It is shown in the below figure 4.5.

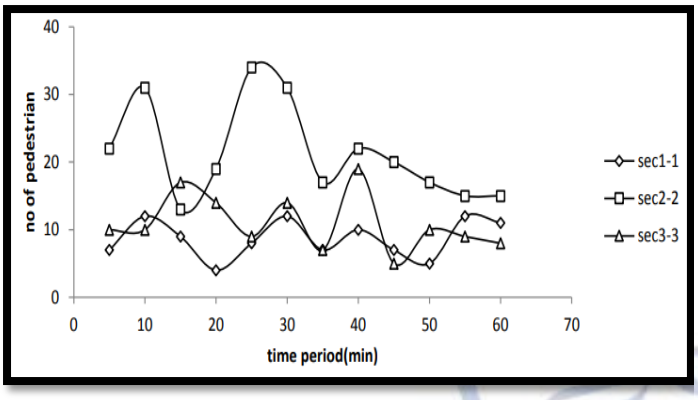


[Fig.4.5: Neat sketch of daily market section]

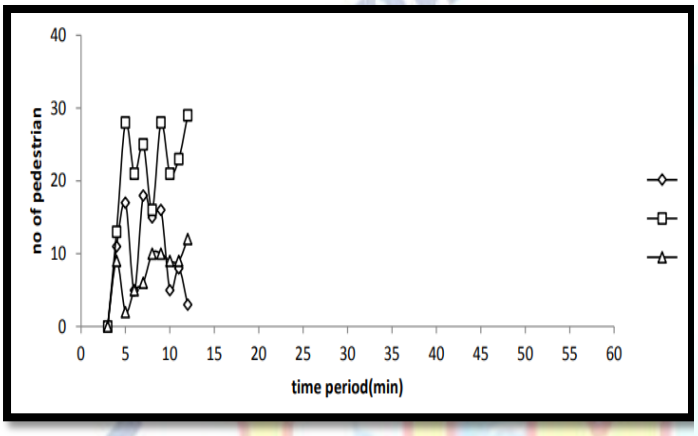
The lane density is inversely proportional to the width of the section, which is clearly confirmed by observing three different data sets from Vadodara. Those are Bhaili, Manjalpur and Makarpura. And these 3 locations are approximately 500m apart from each other. That is a 20m lane is divided into three equal parts and the flow varies like shown in the graphs. Maximum flow was observed at these locations during 6.00pm – 7.00pm. If we observe the graph it is clear that the middle of the section has higher flow than the other two sections. The width of the section provided is 20m and most of pedestrian using center part of the section i.e. setion2.



[A]



[B]



[C]

[Fig.4.6: flow diagram of undisturbed pedestrians [A] Bhaili [B] Manjalpur [C] Makarpura]

Most of the pedestrian used the middle section of the road and the demand is different from location to location. It has been observed that the three locations 4.6. a, b and c have maximum crosswalk taken place in the middle of the section. Weaving, merging and diverging was observed from left to right and right to left in the field while crossing the road section. The flow observed was equal to 628, 492 and 483ped/hr respectively.

4.3 DATA COLLECTION

To collect the data, a digital video camera (Make: Sony), with resolution (640 x 480). In this experiment four ranging rods are used to locate the road section, to get the crossing time of pedestrian entry and exit time was noted in a sheet. A different set of data was recorded and compared with the other sets of data for better safety and facilities. The snapshots are shown here in figure 4.7.

To get the undisturbed pedestrian crosswalk manual count method is preferred, which is very easy to collect the data. For these three sections are selected, those are Bhaili, Manjalpur and Makarpura. To get the pedestrian flow for every 5min time period. The pedestrian count was noted down for every 5min interval. Like that 1hr data was noted down in a sheet. The undisturbed pedestrian movement was collected from Daily market, Vadodara. This is very helpful for further comparison with the disturbed pedestrian crossings.

[a]

[b]

[c]

[Fig.4.7: (a), (b) and (c) Snapshots showing the experimental set–up for the pedestrian crosswalk at intersection, L&T Circle.

4.3.1 Study on vehicle, pedestrian interaction

In this section results from the experiments on the mixed traffic flow are shown in the speed density and flow-speed relationships. Due to the impact of vehicle motion some disturbance caused in pedestrian flow and speed, it leads to delay both the vehicle and pedestrian motion. The pedestrian flow behaviour at these sections was observed to develop the pedestrian characteristics. To understand the impact of vehicle pedestrian interaction, the geometry of the section is considered, i.e. the lane width and the width of the crosswalk and several parameters like road conditions, traffic conditions i.e. signalized or unsignalized. It affects the pedestrian flow and speed. To overcome from those problems zebra crossings, foot bridges, traffic signals etc. is designed. But it is difficult to provide signals and zebra crossings at midblock sections. In that case thorough study is needed to design a foot bridge. Parameters like pedestrian behavior, collisions, vehicle speed, vehicle flow, pedestrian flow in peak hour durations was considered.

4.4 DATA DECODING

The next is to decode the recorded data with the known software players. For disturbed data, the data was decoded by playing the video using the Avidemux video player software. Entry and exit time was noted down for each pedestrian crosswalk, the speed and density calculated for individual pedestrian. The calculated values are noted down in an excel sheet.

It is mentioned here that this study have been taken place in Young, S.B. (1999). AlGadhi S.A.H et al. (2002), speed of each pedestrian is calculated from the extracted data in the following way as given below.

$$u = \frac{lo}{ti - to}$$

Where;

u - Speed (m/s)

lo - length of the section

ti - entry time

to - exit time

$$k = \frac{N}{lo}$$

Where;

N - Total number of pedestrians.

K – Density (Ped/m)

The reciprocal of density is equal to distance headway.

Pedestrian flow characteristics are obtained. So it is easy to plot the fundamental diagrams between pedestrian flow parameters. It may be mentioned here that many studies took place before this study of flow characteristics in Wheeler, R.J. (1969) and William H. K. Lam et al. (2006).

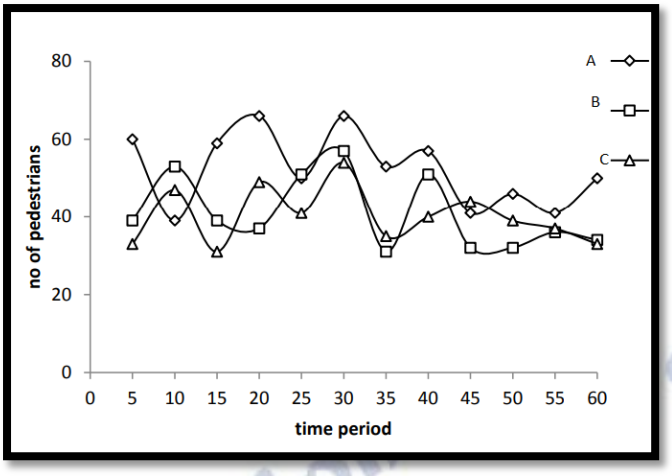
5. RESULTS AND DISCUSSIONS

5.1 GENERAL

In this chapter data was analyzed and the result shows the fundamental relation between the speed-density and speed-distance headway of pedestrian flow. As referring U Chattaraj et al. (2009) for comparison of fundamental diagrams across cultures. And the differences between the disturbed and undisturbed pedestrian flow is shown by hypothesis testing. Regression analysis has been conducted to get the statistical results. Simple linear regression analysis is well known statistical technique for fitting mathematical relationship between dependent and independent variables.

5.2 RESULTS AND DISCUSSIONS

From the manual count method pedestrian flow is calculated for every 5minutes. From this it is noted down that the pedestrian flow varies from section to section and from place to place. 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.



[Fig.5.1: undisturbed pedestrian cross walk (manual count method)]

Every 5min data was noted down in a sheet. The graph shows the undisturbed pedestrian flow, i.e. impact of vehicle was absent. And the three sections are apart from 400m-500m. The number of pedestrian crossing the road was observed and represented in the graph with time for each 5min interval.

5.2.1 Flow density relation

Flow and density relation of pedestrian is similar to that of the vehicular traffic stream. And it can be expressed as-

q= u*k

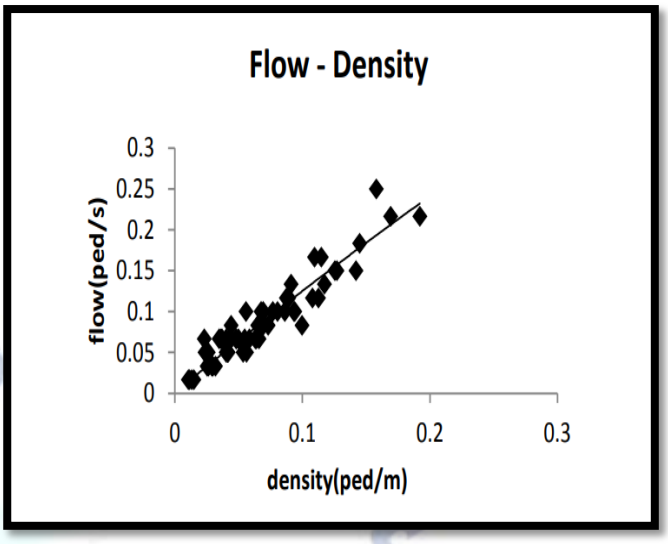
Where;

q – Flow (ped/s)

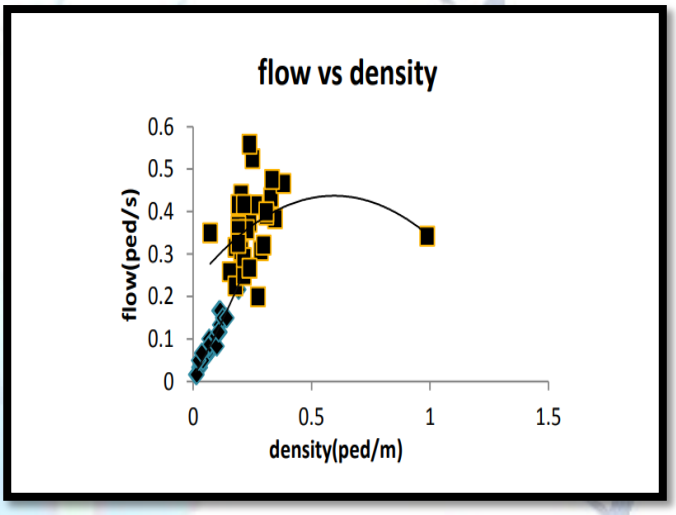
u – Speed (m/s)

k – Density (ped/m)

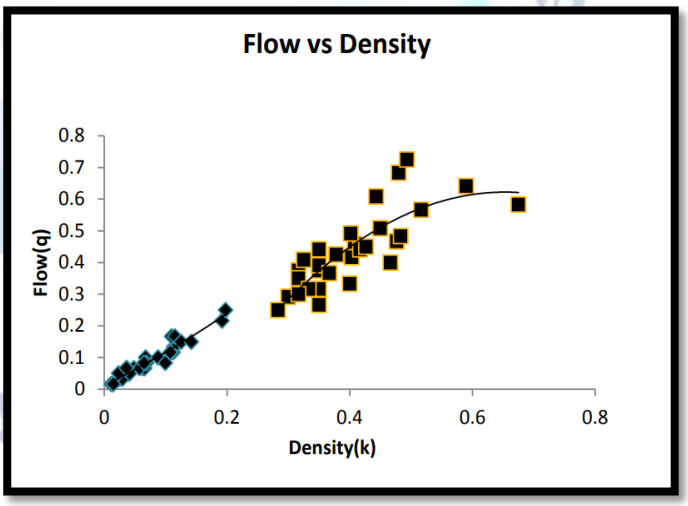
From the above equation it is clear that the speed and density are inversely proportional. Which gives an ideal condition at zero flow i.e. because absence of vehicle/pedestrian on the road. Practically it is not possible because of presence of vehicle/pedestrian on the road. And the relation between pedestrian flow parameters is drawn to observe the fundamental differences. Flow-density is normally represented by a parabolic curve.



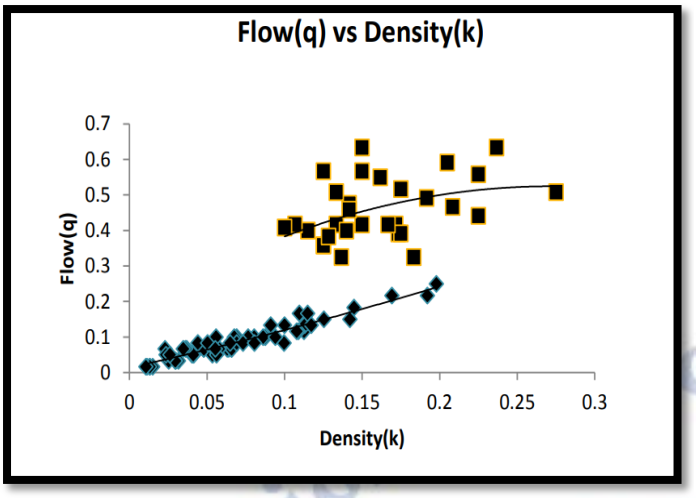
[A- L&T CIRCLE]



[B- BHAILI VS L&T CIRCLE]



[C- L&T CIRCLE VS L&T CIRCLE]



[D- MANJALPUR VS L&T CIRCLE]

[Fig.5.2: Fundamental relationships between flow and density]

The above figure (a), (b), (c) and (d) shows the flow and density relationship Vadodara. When the speed of the traffic flow decreases the density attains the maximum value. Whereas flow decreases, then becomes zero.

In a hypothetical case, when flow approaches to zero at very high speeds, the density also approaches zero. With an increase in speed, the flow increases up to a certain limit and then decreases. Thus, at the optimum values of speed and density, the flow is maximum achievable capacity flow. From the regression statistics r^2 value was observed and it is equal to 0.9112. P value is 0.0244 which is less than 0.05, i.e. the test results were significant.

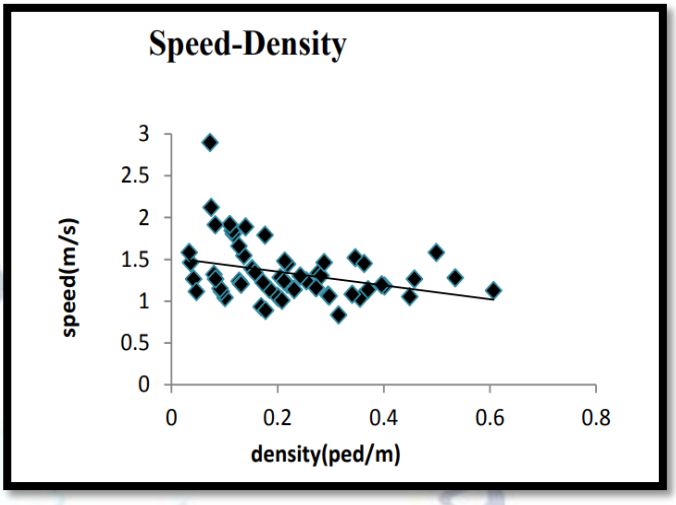
5.2.2 Speed Density Relation

The relation between speed and density is linear. And speed is the basic input for the fundamental diagram. Practically it is not possible in all cases like zero density and free speed on the road. From the beginning one set of data was taken from L&T Circle to set the fundamental diagrams of pedestrian flow. Linear Regression Analysis is a well-known technique for fitting a straight line between dependent and independent variables.

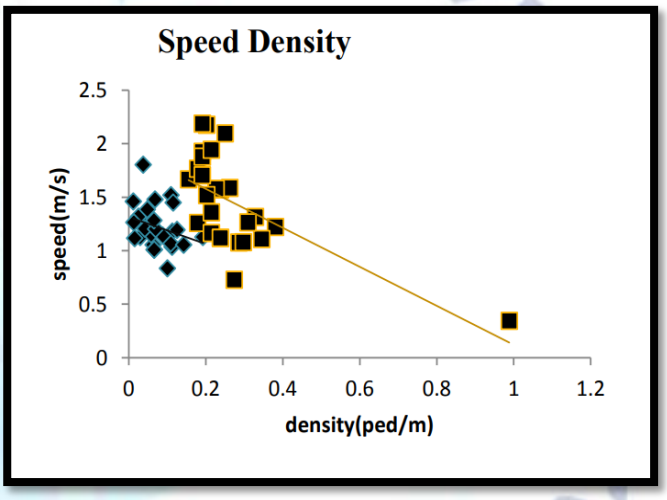
$$Y = a + bX$$

Similarly speed and density are related in a linear form, i.e.

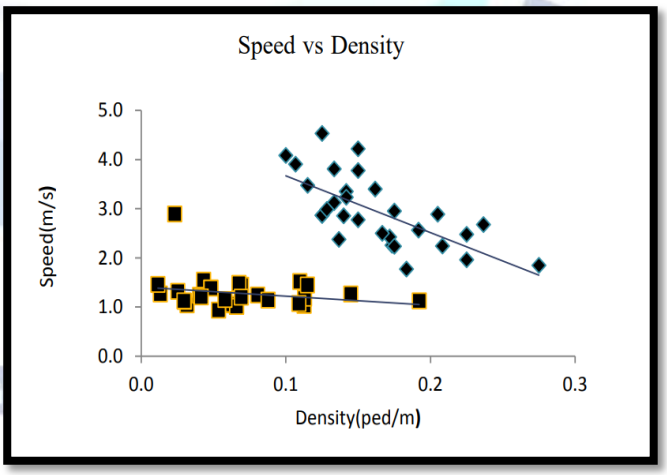
$$u = a + bk$$



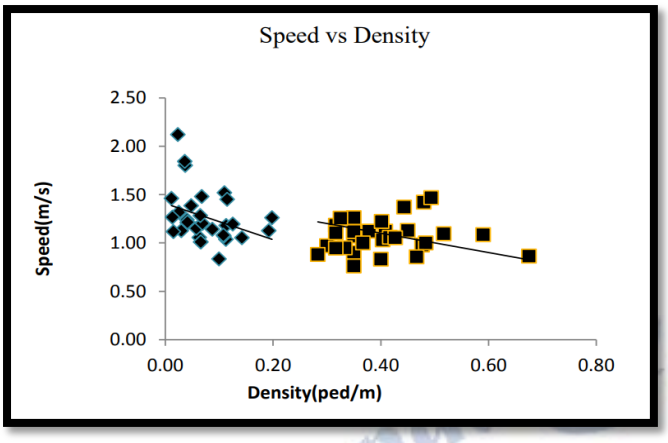
[A- L&T CIRCLE]



[B- BHAILI VS L&T CIRCLE]



[C- L&T CIRCLE VS L&T CIRCLE]



[D- MANJALPUR VS L&T CIRCLE]

[Fig.5.3: Fundamental relationships between speed and density]

The above figure (a), (b), (c) and (d) shows the speed and density relationship of vehicle and pedestrian motion at Vadodara.To improve the test results number of experiments were conducted. The above graph which show the linear relationship between speed and density of pedestrian flow. The data were collected in the peak hour period. From the figure with increase in speed of a stream of vehicles on a roadway, the density per unit length decreases. This is because gap or spacing between vehicles is increasing with increase in speed.

5.2.3 Distance headway- Speed relationship

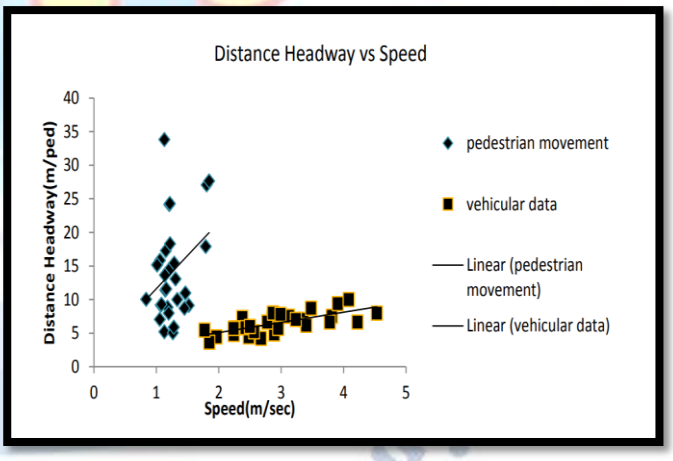
Data was collected here to compare the disturbed and undisturbed pedestrian movement, by using the hypothesis, testing it is concluded that the two data sets are different each other. That is impact of motorized vehicles is affects the pedestrian movement at the signalized intersections. Speed-distance headway relationship is crucial to know the space required for a pedestrian from two different locations. Here we can observe the difference of distance headway-speed relationship for disturbed and undisturbed pedestrian movement.Hypothesis test was done to determine the differences within the two different groups of people (experiments), disturbed and undisturbed pedestrian movement and impact of motorized vehicles in traffic flow. Depends upon the sample size hypothesis tests are conducted. If the sample size is less than or equal to 30 t-test is preferred otherwise we will go for z-test. To show the differences between the disturbed and undisturbed pedestrian movement z-test was conducted. The t- test was conducted for the disturbed pedestrian crosswalk to the motorized vehicular flow.

L&T Circle V/S L&T Circle-

Variable	Observations	Mean	Standard Deviation
Distance headway (Ped)	29	23.731	18.94
Distance headway (veh)	29	6.582	1.551

T- Test for two paired samples: two tailed test 95% confidence interval of the difference between the means] 9.425, 23.954 [

Difference 16.689
To 4.706
Tc 2.048
DF 28
P-value ≤0.0001
Alpha 0.05



[Fig.5.4: Distance headway – speed plot for L&T Circle V/S L&T Circle, Vadodara]

The above figure shows the distance headway-speed sketch for L&T Circle V/S L&T Circle (vehicular motion) data set, Vadodara. In this it is observed that the speed and distance headway are in linear in nature. And speed is increasing the distance headway will be decreasing. The linear equations are displayed in the graph.

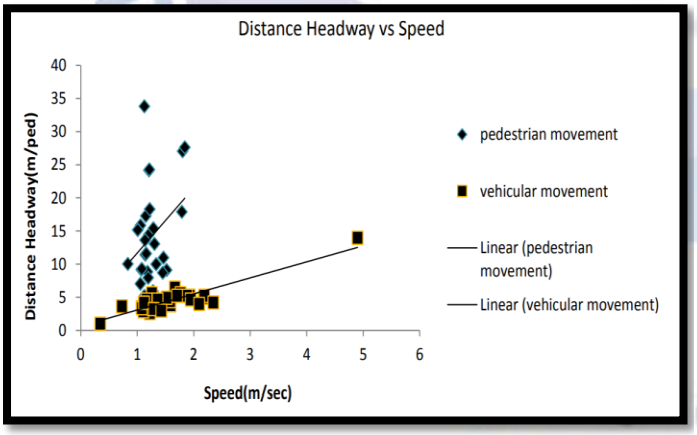
Data set	Intercept (c)	Slope (m)	R^2
Pedestrian movement	1.7868	9.8572	0.1057
Vehicular movement	2.051	1.5171	0.4879

BHAILI VS L&T CIRCLE-

Variable	Observations	Mean	Standard Deviation
Distance headway (Ped)	29	23.731	18.94
Distance headway (veh)	29	4.554	2.129

T- Test for two paired samples: two tailed test 95% confidence interval of the difference between the means] 11.36, 26.073 [

Difference 16.689
To 5.212
Tc 2.048
DF 28
P-value ≤0.0001
Alpha 0.05



[Fig.5.5: Distance headway – speed plot for BHAILI VS L&T CIRCLE, Vadodara]

The above figure shows the distance headway-speed sketch for BHAILI VS L&T CIRCLE, Vadodara. In this it is observed that the speed and distance headway are in linear in nature. And speed is increasing the distance headway will be decreasing. The linear equations are displayed in the graph.

Data set	Intercept (c)	Slope (m)	R^2
Pedestrian movement	1.7868	9.8572	0.1057
Vehicular movement	0.6461	2.4227	0.7779

5.2.4 Hypothesis test between disturbed & undisturbed pedestrian flow

Two different groups of data collected in one place of Rourkela. The first date, i.e. unsignalized pedestrian crosswalk (or disturbed pedestrian crosswalk) was collected from the L&T Circle, Vadodara. Second one undisturbed pedestrian movement (sidewalks) was collected from the daily market, Vadodara. To show the speed differences t test was done. As a result the p-value is less than P-value ≤0.0001, which is considered as significant. Similarly, one more data set (undisturbed pedestrian crosswalks using the manual count method) was compared with the L&T Circle disturbed pedestrian speeds, as a result the p-value is less than 0.0001 P-value ≤0.0001, is considered significant.Linear regression analysis is done in order to predict the value of the dependent variable for individuals for concerning the explanatory/independent variable is available. R^2 is a measure of goodness of fit linear regression. The hypothesis test results are significant.

6. CONCLUSION

In this study, several experiments were conducted in different locations (L&T Circle and daily market, Vadodara) to compare the disturbed and undisturbed pedestrian movement, interaction of motorized vehicles with pedestrian and to establish the fundamental diagrams between speed flow, speed-density and speed-distance headway. The pedestrian crosswalk data were collected from different locations; entry time and exit time were recorded using the video camera to get the speed and flow of a particular pedestrian stream. Using the manual count method pedestrian flow was determined and this undisturbed data is very useful to compare with the disturbed data and how it is different from this undisturbed pedestrian flow. For that

hypothesis test difference was determined.In this thesis two types of experiments were collected from the field. The first one experiment intended to study the fundamental relationship between speed, flow and density. Distance headway speed was also observed in pedestrian motion. Second one is an approximate data set to know the direction of pedestrian movement and desired details of pedestrian volume count by the time.

For better and easy way for pedestrian crossing is by implementing pedestrian safety interventions for road geometry. Following are some key reasons give the brief about pedestrian safety interventions:

(i) Reduce pedestrian exposure to vehicular traffic - Examples of interventions like providing sidewalks install and upgrade traffic and pedestrian signals, constructing the pedestrian refuge islands, raised medians, enhanced marked crossings, overpasses/underpasses and improving the mass transit route design.

(ii) Reduce vehicle speed- Examples of interventions like reduce speed limit, implementing area wise lower speed limit, install speed management measures at intersections.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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