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IMPACTS OF VEHICLE PEDESTRIAN INTERACTION ON TRAFFIC FLOW: MIDBLOCK AND INTERSECTION

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Abstract

Various studies have been done to understand the pedestrian movement and all the studies are based on fundamental diagrams only. These studies construct a base to characterize pedestrian flow. 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 paper is to build up the base to fundamental diagrams 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.To do this, several places are chosen from Rourkela. It is aimed to observing whether the pedestrian fundamental diagram is different in alternate locations or not. In this study it is found that fundamental diagrams are different in different locations of Rourkela.

*Keywords:*Fundamental diagrams, pedestrian flow, signalized, unsignalized, midblock sections, vehicle pedestrian interaction

1. Introduction

The primary means of human motion have always been walking. 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 analyse 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

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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 cross walks are taking place in these midblock sections.

2. Literature review

Depend on the vehicular pedestrian motion demand cross walk width is defined. 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 behavior of the pedestrian is a major fact in the road safety issue.The paper here is focused on developing pedestrian motion which can describe the vehicular pedestrian interaction at the cross sections. For that vehicle pedestrian flow interaction at several intersections was collected from Rourkela.

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 al. (2007) observed that the maximum density of the crowd by developing a crowd dynamic model. Chattaraj et al. (2009) compared the pedestrian flow fundamental diagrams across the culture in India. Rastogiet al (2011) presented the design implications of walking speed for pedestrian facilities. Rastogi et al (2011a) studied the pedestrian walking speeds at midblock crossings empirically. Chattaraj et al. (2013) observed the differences in the fundamental diagram of pedestrian flow in different cultures by modeling.

3. Empirical Observation: Data collection and Decoding

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 Ambagan, Rourkela 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.

3.1. Experiment on pedestrian movement

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 Seyfried et al. (2005).

Figure 1: Site scene of intersection at Ambag Walking

3.2. Experimental set up

The experiment road section of Ambagan, Rourkela was framed by ranging rods at four corners; the size of the section is 19 x 8.5m. It is shown in the fig.2.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 behavior 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.

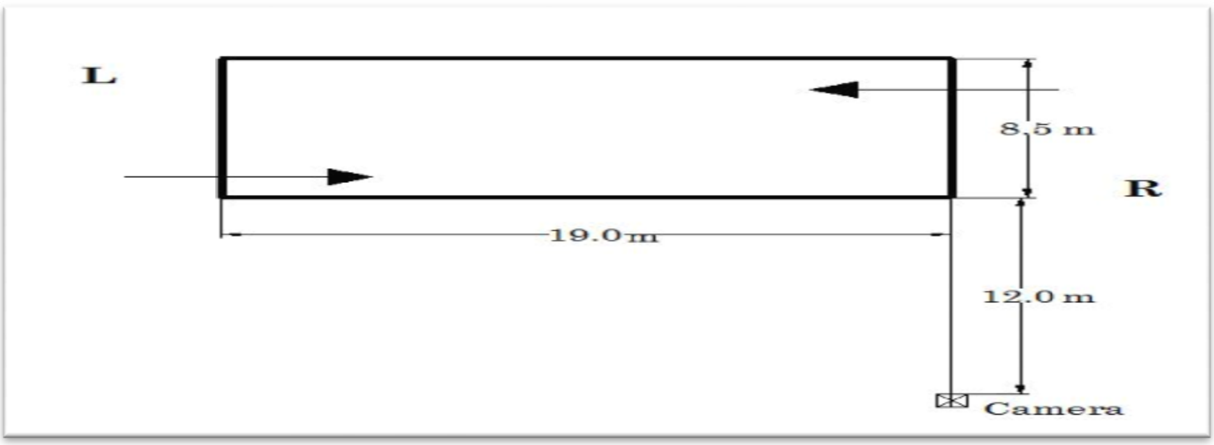


Figure 2: Sketch of the experimental road section of Ambagan, Rourkela.

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 behavior. Below in Fig. 3 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 fig. 3.

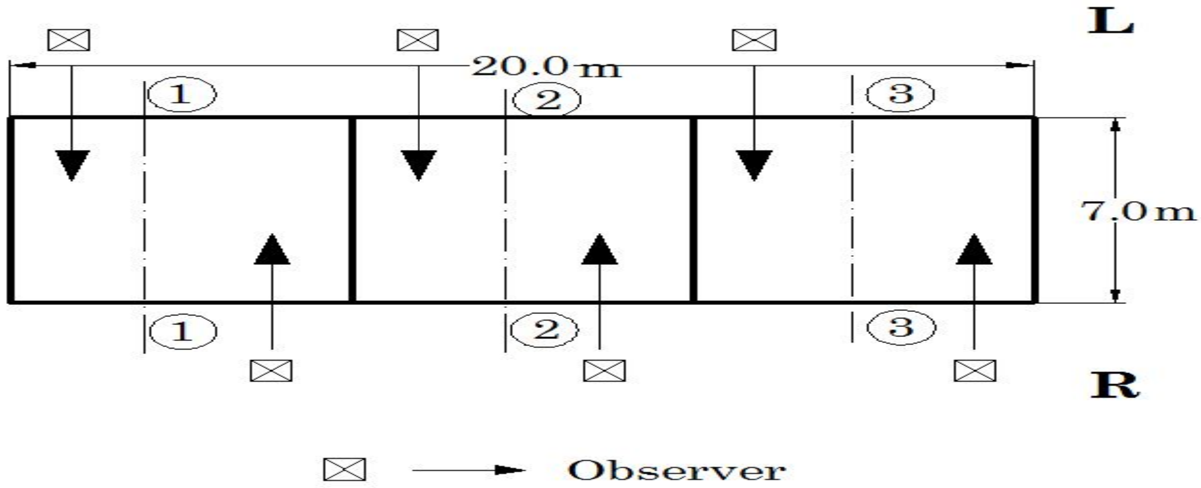


Figure 3: Neat sketch of daily market section.

The lane density is inversely proportional to the width of the section, which is clearly confirmed by observing three different data sets from Rourkela. Those are Nala Road, Plant Street and Mangal Bhavan. 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.

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 shown in Fig. 4, 5 and 6 have maximum crosswalk taken placeinthe 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.

3.3. Data collection

To collect the data, a digital video camera, 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 snapshot is shown here in fig. 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 Nala Road, Plant Street, Mangal Bhavan. 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, Rourkela. This is very helpful for further comparison with the disturbed pedestrian crossings.

Figure 4: Snapshot showing the experimental set–up for the pedestrian crosswalk at intersection, Ambagan.

3.3.1. 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 delayboth the vehicle and pedestrian motion. The pedestrian flow behavior 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. Itaffects thepedestrian 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.

3.4. 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 (1999). AlGadhi et al. (2002), speed of each pedestrian is calculated from the extracted data in the following way as given below.

$$u = \frac{lo}{ti - to} (1)$$

u - Speed (m/s), l_o- length of the section, t_i- entry time, t_o- exit time

$$k = \frac{N}{lo} (2)$$

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 (1969) and Lam et al. (2006).

4. Results and conclusion

The data was analyzed and the result shows the fundamental relation between the speed-density and speed-distance headway of pedestrian flow. As referring 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 analysisis well known statistical technique for fitting mathematical relationship between dependent and independent variables.

From the manual count method pedestrian flow is calculated for every 5minutes. From this it isnoted 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.

Every 5 min 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.

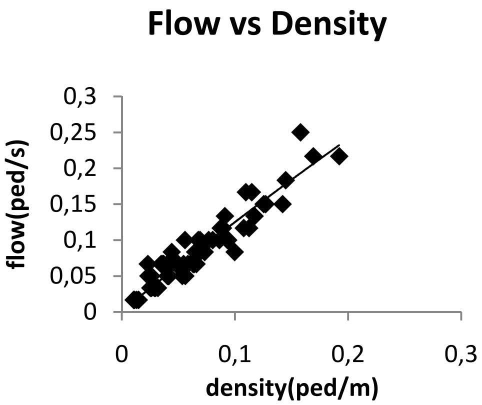
4.1. Flow-density relation

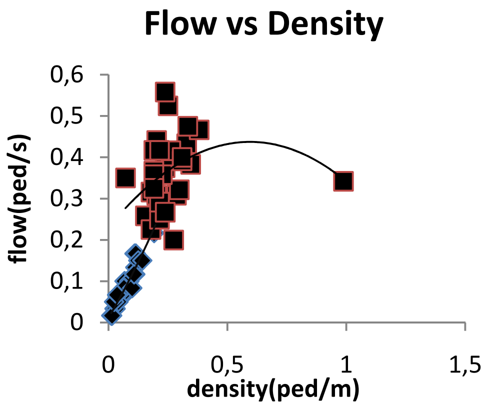
Flow and density relation of pedestrian is similar to that of the vehicular traffic stream. And it can be expressed as

$q = u*k$(3)

q – Flow (ped/s), u – Speed (m/s), k – Density (ped/m)

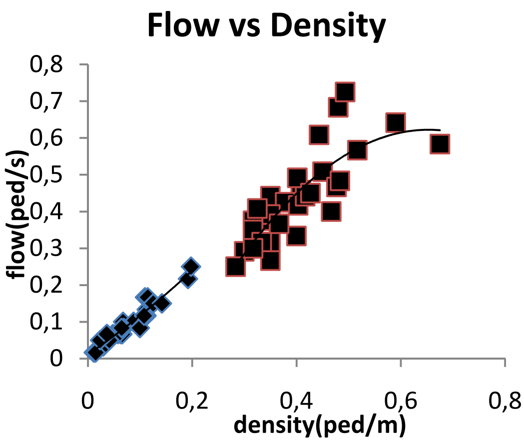
From the above equation it is clear that the speed and density are inversely proportional. Which gives an ideal condition at zero flow i.e. because absence of vehicle/pedestrian on the road. Practically it is not possible because of presence of vehicle/pedestrian on the road. And the relation between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

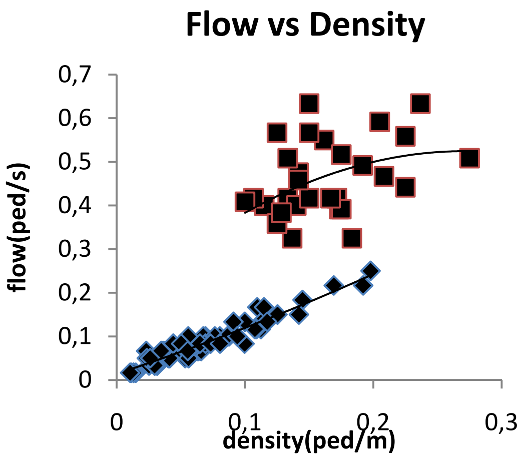




(a) Ambagan (b) Bisra Chowk vs Ambagan

Figure 5: Fundamental relationships between flow and density.





(a) Ambagan (b) Konark vs. Ambagan

Figure 6: Fundamental relationships between flow and density.

The above Fig.5.and 6. shows the flow and density relationship.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.

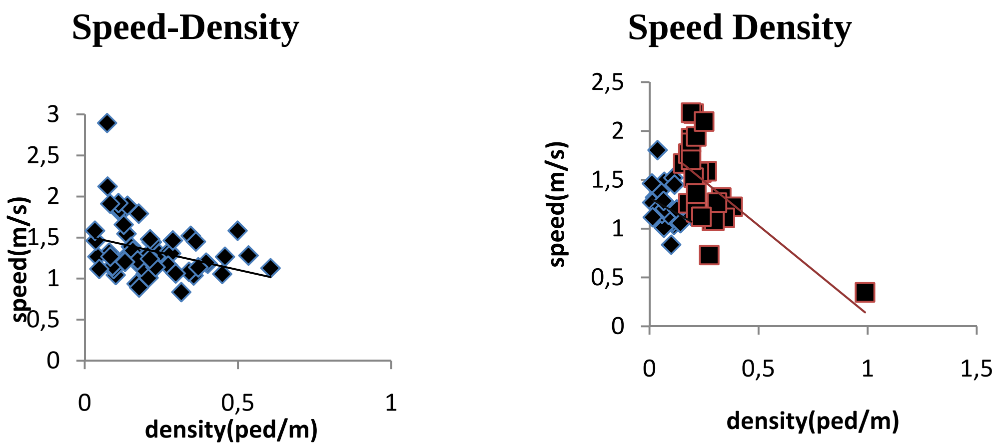
4.2. Speed-density relation

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 Ambagan 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.

$Y=a+b.X$ (4)

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

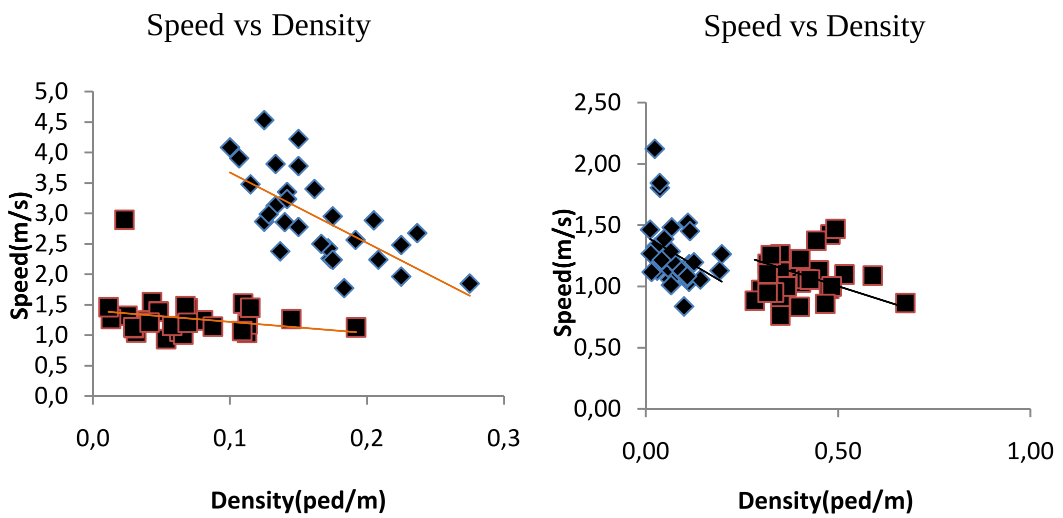
$u = a+b.k$ (5)



(a) Ambagan

(b) Bisra chowk vs. Ambagan

Figure 7: Fundamental relationships between Speed density.



(a) Konark vs. Ambagan

(b) Ambagan

Figure 8: Fundamental relationships between speed and density.

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.

4.3. 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.

Table 1. Distance headway Ambagan (ped) vs. Ambagan (veh)

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

Table 2: 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
T_o	4.706
T_c	2.048
DF	28
P-value	<0.0001
Alpha	0.05

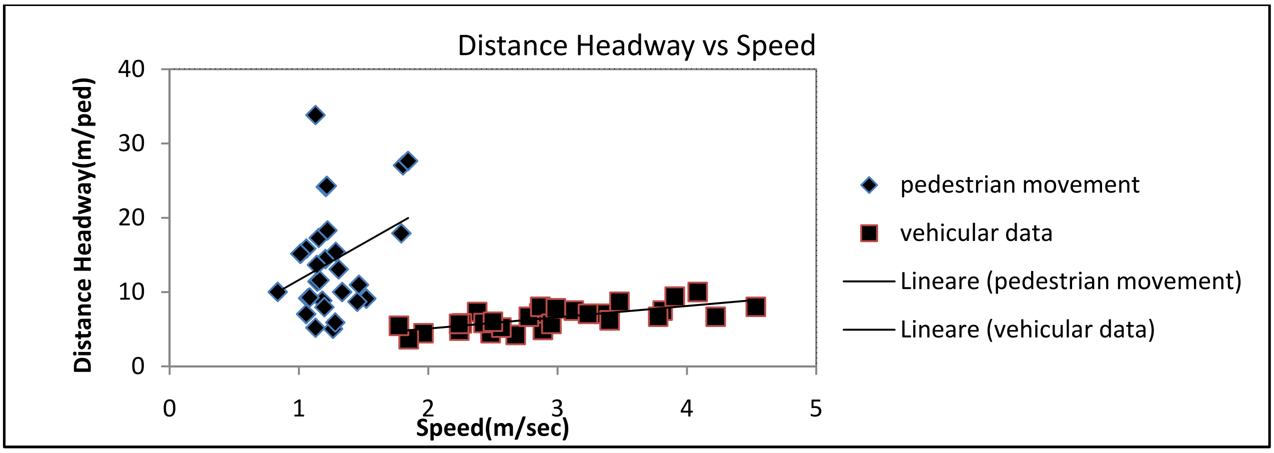


Figure 9: Distance headway – speed plot for Ambagan, Rourkela.

The above figure shows the distance headway-speed sketch for Ambagan and Ambagan (vehicular motion) data set, Rourkela. 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.

Table 3: Intercept, slope and R^2 values

Data set	Intercept (c)	Slope (m)	R^2
Pedestrian movement	1.7868	9.8572	0.1058
Vehicular movement	2.051	1.5171	0.4878

Table 4: Distance headway Bisra Chowk (ped) vs. Bisra Chowk (veh)

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

Table 5: 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
T_o	5.212
T_c	2.048
P-value	<0.0001

DF 28

Alpha 0.05

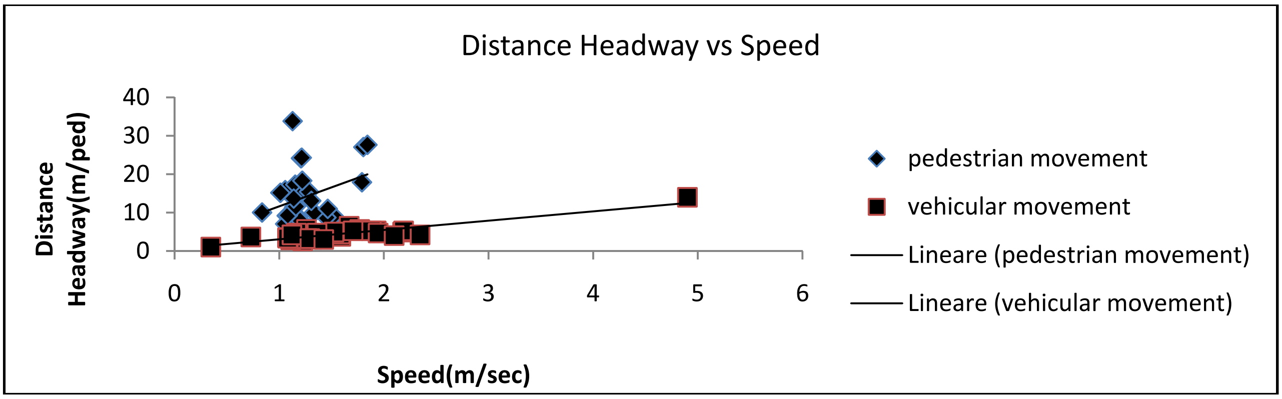


Figure 10: Distance headway – speed plot for Bisra Chowk and Ambagan, Rourkela.

The above figure shows the distance headway-speed sketch for Ambagan and Bisra Chowk data set, Rourkela. 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.

Table 6: Intercept, slope and R^2 values

Data set	Intercept (c)	Slope (m)	R^2
Pedestrian movement	1.7868	9.8572	0.1058
Vehicular movement	0.6461	2.4227	0.7779

4.4. Hypothesis test between disturbed and 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 Ambagan, Rourkela. Second one undisturbed pedestrian movement (sidewalks) was collected from the daily market, Rourkela. To show the speed differences t test was done. As a result the p-value is less than 0.001 ($p<0.001$), which is considered as significant. Similarly, one more data set (undisturbed pedestrian crosswalks using the manual count method) was compared with the Ambagan disturbed pedestrian speeds, as a result the p-value is less than 0.001 ($p<0.001$), considered as 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.

5. Summary and Conclusion

Several experiments were conducted in different locations (Ambagan and daily market, Rourkela) 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:
(i) Pedestrian exposure is reduced to vehicular traffic
Examples of interventions like providing sidewalks install and upgrade pedestrian and trafficsignals, raised medians, constructing the pedestrian refuge islands, 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.

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