PEDESTRIAN FLOW BEHAVIOUR ALONG SIDEWALKS

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ABSTRACT

Pedestrian walking is a major mode of transportation in Indian cities and also effective mode of transportation for short trips. In this study pedestrian sidewalk data was collected from three locations in Rourkela city in India. The obtaining three locations data was bi-directional flow unsteady data and also collect uni-directional flow data from L.A.Hall with in the NIT Rourkela campus. These data was analyzed for finding pedestrian characteristics like speed, flow and density as well as to draw the fundamental diagrams. Pedestrian fundamental diagrams and pedestrian characteristics are depends on gender of the pedestrian, age of pedestrian and type of facilities (sidewalks, wide sidewalks and prescient's). " pedestrian characteristics, fundamental diagrams for uni-directional flow as well as bi-directional flow, comparison of pedestrian fundamental diagrams between uni-directional and bi-directional flow, capacity and level of service (LOS) for above three sections" was done in this study. Hypothesis testing was conducted for compare the pedestrian speed between different sections and different combinations was done in this study.
Keywords: pedestrians, sidewalks, pedestrian characteristics (speed, flow and density), hypothesis testing, capacity and level of service.

INTRODUCTION

Pedestrian walking is a mode of travel to a given destination on foot. In transportation this type of mode are effectively used for short trips. Walking is a major mode of transportation in middle and low class cities. In transportation many trips are originated and ended walking only. Developing country like India pedestrian walking is a major mode of transportation. The urban population in India was increased year by year; in 2001 the urban population was 27.81% after 10 years in 2011 this population reached to 31.16% because better facilities for pedestrians have been provided by us. One study told that Tiruchirapalli city 64.7% of the total trips are made on foot (arasan et al., 1994). Another study conducted in Mumbai they can told that all persons walk in a day irrespective of their income (Montgomery, 2006). Because better facilities have been provided for pedestrians are important criteria in urban areas. Now a day the local authorities are interested to provide good pedestrian facilities to encourage walking.

According to modal split study conducted in Mumbai in India told that out of nearly 2.85 million trips, 52.4% trips are walking trips (MMRDA 2008). African cities have more walking trips comparatively Asian and Latin-American cities. The average walking trips percentage of Africa, Asia and Latin-America cities are 57, 37and 22% respectively (Montgomery 2006).

Pedestrian movements are classified into two types they are pedestrian sidewalk and pedestrian crosswalk. In this report pedestrian sidewalk has been considered by me. The sidewalk facilities provided and improved was more important in urban areas. They have different types of sidewalks in urban areas they are sidewalks,

wide-sidewalks and precincts. In this report pedestrians capacity and level of service (LOS) will be considered. If we can consider capacity, "it means the maximum no of pedestrians passing through a point per unit of time". Level of service (LOS) is a quality measure for sidewalks in terms of speed, flow, comfort and convenience. Capacity and level of service of pedestrian sidewalk are depends on pedestrian speed, density and flow.

Pedestrian walking speed was depends on age of pedestrian, gender and type of facilities. Pedestrian walking speed is more on wide-sidewalk less on precincts. Male pedestrians walking speed is more compare to female pedestrians walking speed. Elder pedestrians speed is less compare to younger pedestrians speed.

The thesis has been divided into four chapters, in these four chapters introduction is first one. The second chapter considered past work done on pedestrian sidewalk characteristics, pedestrian dynamics, and models of pedestrian behavior. It can be seen in literature review after this chapter. These literatures have been prepared by reading of many papers and reports of these topics.

In chapter 3, I have been describing, experimental set-up, data collection and data decoding in detailed. In this chapter experiments conducted on fundamental diagrams of pedestrian sidewalk and comparison between male and female pedestrians. And also use Z-test to compare between different sets of data collecting from three locations. Next, it concentrates

how to affect fundamental diagrams on different pedestrian flows.

In chapter 4, presents the results obtained from above analysis and also have graphs obtained from above data analysis. These results are told that how to change pedestrian characteristics like flow, speed and density in different sidewalks and different conditions (age, gender and facilities). In this chapter results and conclusions have been considered by this topic.

LITERATURE REVIEW
The literature has been divided into 3 parts, the first one considered pedestrian characteristics; second part describes pedestrian dynamics and third part on different types of pedestrian streams.

Pedestrian characteristics
The pedestrian's characteristics and facilities study has very important for provided a successful pedestrian system. In before many studies have been conducted by many persons. Experiment on analyzed properties and characteristics of pedestrian flow on sidewalks will be conducted by Pouls (1983). Experiment on pedestrians of central businessdistrict of Haifa, Israel has been conducted by him. In this paper pedestrian flow and level of service analysis has been explained by him. Increase in pedestrian density, there was a significant decrease in walking speed. Male pedestrian's speeds have more than female pedestrian's speeds. Experiment on pedestrian characteristics like speed, flow and density under mixed traffic condition have been explained by Oeding (1963), and also in 1968 he was done study on walking characteristics of Britain

shoppers. Some researchers studied on comparison between different cultures and countries. Pedestrian speeds between Asian countries and Western countries have been studied by Morrall (1991), in this study speed of Asian countries pedestrians significantly lower than the western countries.

Pedestrian characteristics in Singapore have been studied by Tanaboriboon (1986). Average speed of Singapore pedestrians significantly lower than American pedestrians has been concluded by him. However, the maximum flow rate obtained here is more than western countries flow rates. Modelling of pedestrian walking speeds on sidewalks have been studied Robert Raeside (2007). Experiment in United Kingdom using slow motion video survey to collect pedestrian data to develop speed-flow-density relationships has been conducted by him. Experiment on Pedestrian's characteristics between two different cultures like India and German have been conducted by Chattaraj (2009). Density of pedestrians increases, German pedestrian speeds more influenced than Indian pedestrian speeds has been explained by him.

Design criteria for an urban sidewalk landscape considering emotional perception have been explained by Weiji Wang et al. (2009). This experiment conducted in Iksan inner city of Korea. The least sidewalk width is 1.5 m, and the least tree width is 1.5 m and the maximum widths for both are set as 6.0 m was explained by him. The results show that the sidewalk width of 3.50 m and the tree width of 3.52 m are optimal at the level of normal satisfaction. Experiments on pedestrian's perception of sidewalk facilities in KualaLumpur's commercial areas have been conducted by Arshad, A. K (2012). In this study data was collected on-street questionnaires survey. In this research 50 number of pedestrians opinion was collected. In this 50 pedestrians 25 are age between 19- 49 remaining are age above 50 years old. The interviewer waits at the end of the sidewalk and aim at the selected pedestrian who walk from the beginning of the sidewalk towards the end.

Pedestrian dynamics

Methods of assessing pedestrian level of service for sidewalk have been studied by Bian Yang et al. (2007). In this research data was collected from 12 road way segment sidewalks. In this survey 725 questions are formed about level of service (LOS). After collecting data from pedestrians we can give score for each roadway segment. After giving the score give rank of LOS. Experiments on fundamental diagrams and pedestrian characteristics have been reported Hoong Chor et al. (1986), Daly et al. (1991), Daamen and Hoogendoom (2007), Ronald Jhon Galiza and Luis Ferreia (2013). These researchers studied on pedestrian speed, flow, density and their relations. Effect of gender on pedestrian speed, flow and density has been reported Pouls et al. (1983), Jaisung Choi et al (2013). Project on Modelling Pedestrian Walking Speeds on Sidewalks has been reported by Marwan Al-Azzawi (2007). In this study the researcher 38 h of data was collected in U.K. and total number of observations of 7,535 pedestrians. The procedure for abstracting the relevant data from the videos and

identify pedestrian speed, flow, and densities. The concept involves marking out a rectangular box on the video monitor screen, set to approximate the dimensions of a virtual box on the ground of set breadth and length.

Types of pedestrian streams

Project on pedestrian crosswalk how to influence due to bidirectional pedestrian flow and its influences on the fundamental diagrams have been done by Seyfried (2012). In this study told that no significant difference in the fundamental diagrams for densities bellows 2.0 m^{-2} after that unidirectional flow have more flow and density comparatively bidirectional flow.

Project on empirical characteristics of different types of pedestrian streams have been done by Jun Zhang and Armin Seyfried (2012). In this study researcher compare fundamental diagrams of unidirectional and bidirectional flow with different studies.

METHODOLOGY

In this section trust that the principal factors that affected by pedestrian flow along sidewalks are the gender of pedestrian and direction of pedestrian flow. In this study two types of experiments are conducted. The first type of experiment has conducted the impact of gender on pedestrian characteristics like speed, flow, density and their relations along sidewalks. This study gives the fundamental diagrams between speed, flow, density and distance headway. Section 3.1 presents the experimental set-up and data collection.

In this chapter methodology for calculating pedestrian sidewalk characteristics like pedestrian speed, flow, density and their relations will be explained by me. Interest to study about this area will be more scope for further research purpose. Till now many researchers have been conducted many studies on this area but further more scope to research in this area. After choosing this study area, experiment will be conducted many places in Rourkela city. First of all select different places in Rourkela city after that choose which place have more pedestrian crowed. After found this area select a location for data collection.

Four steps to hypothesis testing:
1. State the hypothesis: total pedestrians at any locations mean (μ1) is equal to some sample mean (μ2) at that same location (μ1=μ2) we can use null hypothesis (H0), if null hypothesis is wrong at that time we can use alternative hypothesis (Ha/H1). Alternative hypothesis (H1) will come in these three cases there is μ1$\neq$$\mu$2; μ1>μ2; μ1<μ2.
2. Set the criteria for decision: to state criteria for decision, we state the "level of significance" for a test. Probability of obtaining a statistic measured in a sample if the value stated in the null hypothesis were true. The criteria or level of significance is typically set at 5%. When the probability of obtaining a sample mean is less than 5% if the null hypothesis were true.
3. Compute the test statistic: test statistic is mathematical formulae it is using when the null hypothesis was true.
4. Make a decision: we can use the test statistic to make a decision about the null hypothesis. This is depending on probability of obtaining sample mean (%).

Null hypothesis is true – probability of obtaining sample mean (<5%).

In this paper hypothesis will be used for finding pedestrian speed comparison between different locations and same location also. In this study two tailed Z-test will be used.

Experiments on impact of pedestrian flow direction on pedestrian characteristics

This is the second experiment was conducted in this study; the study was how pedestrian characteristics will be changed in uni-directional and bi-directional pedestrian flow. In this study first of all bi-directional flow data was already collected from three locations, two locations at daily market and one location at nala road in Hyderabad city. The data collection was done in the above places, bi-directional flow means pedestrian flow will be occurred left to right and right to left in two directions but in uni-directional flow, pedestrian flow will be occurred left to right/right to left. In bi-directional flow pedestrian flow will be in two directions because pedestrian interruption will be more comparatively uni-directional flow. In bi-directional flow pedestrian required sufficient place for to give the place who entering the opposite side in the same section. Pedestrian required more place in bi-directional flow comparatively uni-directional flow.

In this study after completed data collection have found pedestrian speed, flow, density and their relationships. After completion of pedestrian characteristics have been drawing fundamental diagrams between uni-directional flow and bi-directional flow, after that to find capacities of uni-directional flow as well as bidirectional flow. using the above data have found pedestrian distance head way after that draw the fundamental diagram between distance head way to speed, using this fundamental diagram have been calculated slope and intercept of these line.

RESULT AND DISCUSSIONS
Study on free flow speed
In this paper pedestrian free flow speed will be calculated in different locations in Hyderabad city. The free flow speeds will be

- mean speed of total pedestrians at location 1 (daily market) is 1.17m/s, mean speed of male pedestrians at location 1 is 1.24m/s and mean speed of female pedestrians is 1.09m/s.
- mean speed of total pedestrians at location 2 (daily market) is 1.24m/s, mean speed of male pedestrians at this location is 1.34m/s and mean speed of female pedestrians at this location is 1.14m/s.
- The above two locations are in the same area but mean speeds of first location have very low comparatively second location. In the first location they have some obstruction are present because pedestrian speeds will be less. In the second section they have no obstruction because pedestrian speeds will be more.
- Mean speed of total pedestrians at nala road is 1.30m/s, mean speed of male pedestrians at this section is 1.40m/s; mean speed of female pedestrians at this location is 1.21m/s.

- Mean speed of total pedestrians at Ambagan market is 1.24m/s, mean speed of male pedestrians at this section is 1.27m/s, mean speed of female pedestrians at this location is 1.20m/s.

- Mean speed of total pedestrians at near sector 2 circle is 1.22m/s, mean speed of male pedestrians at this section is 1.26m/s; mean speed of female pedestrians at this location is 1.17m/s.
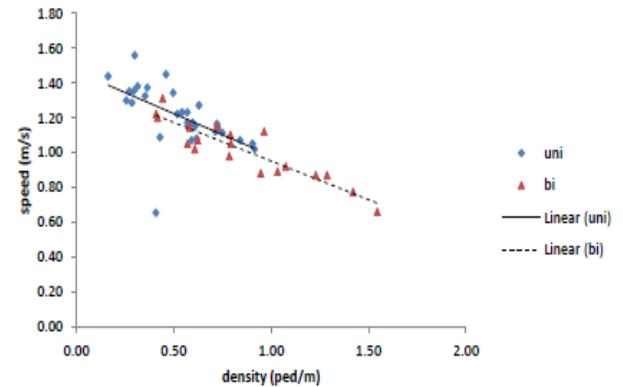

Figure: Speed vs Density

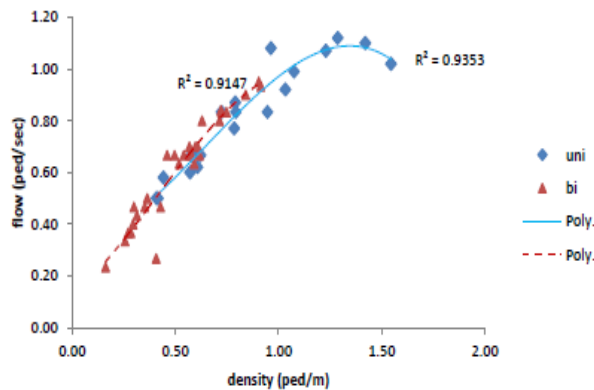**Comparison of pedestrian fundamental diagram between uni-directional and bi-directional flow**
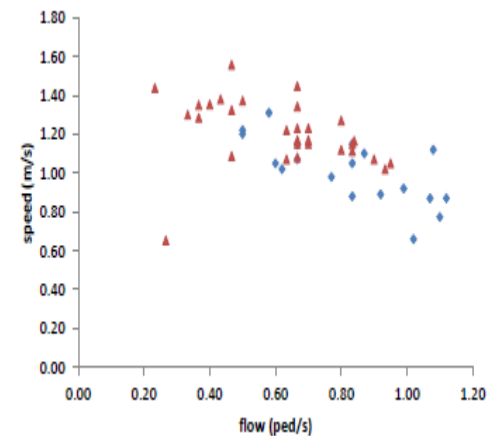

Figure: Flow vs Density

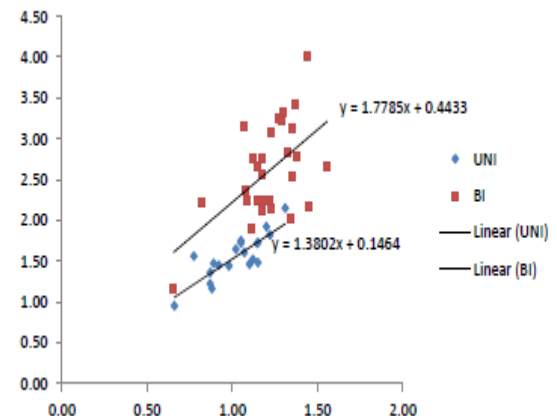
Figure: Speed vs Flow

Figure: Distance Headway vs Speed

The above figures data are obtained from pedestrian uni-directional flow and pedestrian bi-directional flow in Hyderabad city. The above all diagrams have been explained pedestrian speed, flow and density values are more in uni-directional flow comparatively bi-directional flow. Pedestrian flow versus density curve have been explained, initially uni-directional and bi-directional flow curves will be coincide, after that uni-directional flow will be more comparatively bi-directional flow. Pedestrian speed versus density curve also represents uni-directional flow line will be present above the bi-directional flow line, in this figure at any specific density values speed of pedestrians in uni-directional flow will be more comparatively speed of pedestrians in bi-directional flow. Figure (d) speed versus distance headway diagram represents intercept of bi-directional flow will be 0.0894 and intercept of uni-directional flow will be 0.1464. Slope of bi-directional flow will be 2.1086 and slope of uni-directional flow will be 1.3802**.**

Table: Slopes and intercepts for uni-directional and bi-directional flow

Fundamental diagram sets	Uni-directional flow			Bi-directional flow		
	slope	intercept	speed	slope	intercept	speed
1	1.3802	0.1464	1.02	1.292	0.2097	1.07
2	1.3802	0.1464	1.02	2.1748	0.0134	1.25
3	1.3802	0.1464	1.02	1.7785	0.4433	1.21

CONCLUSIONS

In this study experiments conducted on pedestrian flow behaviour along the sidewalks in different places in Hyderabad city and also experiment conducted on pedestrian characteristics variations in pedestrian uni-directional flow and pedestrian bi-directional flow. From this study results male pedestrian speeds are more, comparatively female pedestrian speeds in above all three sections. In this study pedestrian average speed are more in Road (section 3) less in daily market (section1). Road has more pedestrian sidewalk width comparatively remaining sections and also sidewalk surface will be even because pedestrian side walk will be more in road. Hypothesis test will be conducted in different combination of pedestrians in different sections, male pedestrian speeds at section2 and section3 will be similar because Z-observed value is in between Z-critical value, this combination will be significant. In this study pedestrian uni-directional flow will be get maximum flow (capacity) comparatively pedestrian bi-directional flow. Pedestrian flow versus density graph initially these two (uni and bi-directional flow) lines will be coincides after that uni-directional flow line has above the bi-directional flow line.

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