COMPARISON OF PEDESTRIAN FUNDAMENTAL DIAGRAM: A CULTURAL AND GENDER ASPECT

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Under the guidance of

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NIT Rourkela

CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled "**COMPARISON OF PEDESTRIAN FUNDAMENTAL DIAGRAM: A CULTURAL AND GENDER ASPECT**" in partial fulfilment of the requirements for the award of **Master Of Technology** Degree in **Transportation Engineering** submitted in the department of **Civil Engineering** at **National Institute of Technology, Rourkela** is an authentic record of my own work carried out under the supervision of **Dr. Ujjal Chattaraj**, Assistant Professor, Civil Department.

The matter presented in this thesis has not been submitted for the award of any other degree of this or any other national or international level institute/university.

(Manoj Kumar Biswal)

This is to certify that the above statements made by the candidate is correct and true to best of my knowledge.

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This thesis is dedicated

To the my beloved parents,
May God bless them and elongate them live in his obedience.

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Abstract

Study of pedestrian motion can be done by various means, like; empirical observation, conduction of controlled experiments as well as by developing pedestrian dynamics models. All these different sorts of studies are dependent on pedestrian fundamental diagrams to a great extent. So, in this thesis it is aimed at studying pedestrian flow at fundamental level. But because of a lot complexities and stochasticities involved in pedestrian flow systems, it is not possible to study pedestrian flow fundamentals completely in unbiased way. Literature on pedestrian flow studies also supports the fact, yielding wide varying fundamental diagrams by various researchers. So, in this study efforts are made to avoid all sorts of disturbing influences on the basic study of pedestrian flow. In a similar earlier study, pedestrian fundamental diagrams of two widely varied cultures namely, Indian and German are compared statistically and significant differences were found. Motivated by that study, in this thesis it is targeted to see whether these differences are diluted in less varied cultures.

To do this, two cultures are chosen; from two places far distance apart within India, namely, Kanpur and Rourkela. In addition, also, in the same thesis work, it is aimed at observing whether pedestrian fundamental diagram is different between subjects of same gender and a mix of male and female pedestrians in alternate positions. To nullify the disturbing factor, like, pedestrians moving side by side, overtaking, tail-back-effect, etc., a very simple pedestrian flow system is used in which pedestrians move in a single file under closed boundary condition. In this study, it is found that; fundamental diagram from Rourkela is significantly different than that from Kanpur.

Similar is the case for the other set of experiment, i.e., fundamental diagram between same gender pedestrians and mixed gender pedestrians are also significantly different.

The first part of the study indicates towards the fact that, if cultural differences are compared between nearer cultures gradually, one point will come when this difference will be dissolved. Similarly, in a group of same gender, if fraction of opposite gender adulteration is reduced, in a certain lesser fraction of adulteration, the difference in fundamental diagram will be dissolved.

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Abbreviations and Symboles

P	Crossing time of every individual pedestrians
t_p^{in}	Entry time of every individual pedestrians
t_p^{out}	Out time of every individual pedestrians
u_p	Speed of individual pedestrians
l_o	Length of the observed section
k_p	First density in a frame
k_f	Average density
N_f	No of pedestrians in a frame 'f'
F	Total no of frames
Φ	Frame rate of camera

Chapter 1

Introduction

Walking is one man's magnificent abilities, a vital factor in his long journey up the evolutionary ladder and his progress towards civilization. Walking has always been the primary means of human motion. In ancient ages walking is the only mode of transportation. Even larger studies are made in developing faster and safe modes of transportation, walking remains an integral part of the trip as it continues to be a mode which can provide very high levels of accessibility and sustainability of different facilities. Walking is reducing the use of vehicle and could be made a dramatic benefit to society. Each and every trip starts and ends with walking. With the common concern of physical fitness and environmental pollution, walking is becoming a sustainable and popular mode of transportation. It's an acknowledged fact that pedestrianigation in one hand would help to deprive, vehicle emission, travel cost and environmental pollution and on the other hand, it's a primary mode to social interaction. Thus in one word pedestrianigation is the key to socio-economic development. From last six decades or so gigantic progress has been made towards vehicular traffic flow, unfortunately very infant effort has been made towards understanding pedestrian flow. Whatever work has gone on, while adding to the body of knowledge on pedestrian flow, has remained disseminated. In a finite modal split study of Mumbai, India, clearly shows that, nearly 52.4% trips are walk trips, (MMRDA 2008). It's a reason to say that India should procure a world-class pedestrian facilities. The urban population of India is increasing subsequence from 27.81% in the 2001 census to 31.16% in 2011 census and it expected that by 2021 the urban population will be 37%. So it's true that in developing countries like India deserves adequate pedestrian facilities to meet the aspiration. Because of inadequate pedestrian facilities in India, the lack of data set is very less in the case of pedestrian study. Consequently, it's the major hurdle to the area of pedestrian research.

In order to provide better design spaces for human circulation (for example, in airports, shopping malls, subways, fairgrounds or even footpaths) one need study pedestrian motion empirically. At different levels pedestrian motion can be studied empirically. At macroscopic level one may analyze the basic flow parameters (like speed, density) of pedestrian motion. At microscopic level one may track the paths followed by individual pedestrians while moving. By this study one can easily understand that, when the pedestrians are moving through a flow space at various densities at the same time they plan their paths. At a mesoscopic level the flow parameters change spatially (both in the transverse and longitudinal directions) and temporally. This thesis is about mesoscopic study of pedestrian. These studies, guidance to understanding the pedestrian flow at a fundamental level and also an alleviation to perceive how the geometric features of different pedestrian facilities impact the pedestrian motion.

Pedestrian flow consists of two types, uni-directional pedestrian flow (single-file motion) and bi-directional pedestrian flow. In uni-directional flow pedestrians walks on one direction and in bi-directional flow pedestrians walks from both direction and interact with each other. Uni-directional pedestrian flow (single-file motion) is the elemental aspect of pedestrian motion. Speed-density relationship (or fundamental diagram) is one of the basic inputs for designing the pedestrian facilities of different cultures. The civilization has determined as the manner of life of the people, languages, religions, dance, music, architecture, food, and customs differ from place to place across the cosmos. In this study the effort is to show the cultural differences of north and east India by conducting single file pedestrian experiment. By doing this experiment we will able to dimensioning the pedestrian facilities like, (footpath, buildings with a large number of occupants) in respect to comfort and safety aspect. The basic pedestrian movement characteristics such as, (speed, density and distance headway or space) will compare between north and east India to learn and explain differences that would very effective to design different pedestrian facilities in Indian context.

Chapter 2

Literature Review, Motivation and Problem Statement

As it is stated in the previous chapter, by studying pedestrian flow of high densities is vital for the design of any pedestrian facility. Understanding pedestrian motion at high densities pedestrian facilities to design any pedestrian facilities with respect to safety and comfort. Perhaps it's a reason to say that least attention has been paid to the field of pedestrian flow due to its less speed. Considering all the aspects, the urban population rising across the world, especially developing countries like India, the importance of this field can't be neglected. There is lack of pedestrian facilities in India, on the other hand, there are slews of people using the finite pedestrian facilities. As the India moves towards urbanization, the urban population of India growing rapidly day by day, so it is needed to put more emphasis on pedestrian flow. In recent past, there are lots of stampedes and crowd crushes occurred at various places across the India, these occurred in Allahabad railway station crowded with Kumbh Mela pilgrims in Uttar Pradesh (2013), Rath Yatra at Puri in Odisha (2013), Makara Jyoti day at Sabarimala in Kerala (2011), Bhavnath Temple at Junagadh in Gujarat (2013, Ratangarh temple at Datia in Madhya Pradesh (2013) and Funeral of Muslim spiritual leader at Mumbai (2014); which caused several deaths and injuries.

2.1 Literature Review

The literature review is divided into four parts, as basic pedestrian flow, empirical studies on pedestrian movements, Different pedestrian dynamics phenomena and cultural difference of pedestrian.

2.1.1 Basic Pedestrian Flow

The pedestrian characteristics are the most important criteria for designing a successful pedestrian system. Over the years, various studies on pedestrian characteristics. Oeding (1963) conducted a study to understand the pedestrian characteristics under mixed traffic condition. Chandra (2010) determined the pedestrian flow characteristics in Indian mix traffic conditions. Older (1968) shows the walking characteristics of Britain shoppers. Speed is one of the fundamental characteristics of pedestrian flow, although the pedestrian speed is very less than the vehicle speed. Various researchers determined pedestrian speed of different cultures and countries. Morrall (1991) determined that pedestrian speeds for all groups in Asian countries are significantly lower than the Western countries. Navin and wheeler (1969) found the speed of U.S.A students. Fruin (1971) observed that walking speeds of females are slower than males and the speeds of pedestrian decrease with age. Tanaboriboon et al. (1986) found that walking rates on sidewalks in Singapore are higher than those in Western countries. Koushki (1988) observed that the slowest pedestrians are in Riyadh, and the fastest in the Tokyo. Tarawneh (2001) observed that pedestrians in groups walk slower than the individual walking speed. Finnis and Walton (2008) found that the New Zealanders walks faster than the average walking speed found in previous international studies.

Density is the primary characteristics of the pedestrian traffic flow to designing the facilities with respect to a large number of occupants. Weidmann (1993) determined that how density effects on the pedestrian walking speed under mixed traffic conditions. Older (1968) shows that how speed and density is related to each other in footpaths of shopping areas. Similarly Hankin and Wright (1958), Oeding (1963), Navin and wheeler (1969), Mori and Tsukaguchi (1987), Helbing et al. (2007) and Seyfried et al. (2005) shows the fundamental relationships of pedestrian streams.

2.1.2 Empirical Studies on Pedestrian Movements

Empirical studies on pedestrian flow is the primary input to the field of pedestrian research. Over the years studies on pedestrian dynamics by considering speed-density (or flow-density or speed-flow) relationship (fundamental relationship) of pedestrian streams, as example, Hankin and Wright (1958), Oeding (1963), Older (1968), Navin and Wheeler (1969), Mori and Tsukaguchi (1987), Weidmann (1993), Seyfried et al. (2005) and Helbing et al. (2007). The results of these researches varied from each other because of the way the data were collected and represented. Seyfried et al. (2005) has intended to develop an experiment scenario which tries to capture only the impact of density on speed. Others have studied such relations in the specific case of an experiment or observation without abolishing the impacts of various factors like overtaking, pedestrians moving side by side, the width of the corridor, entrance and exit condition of the corridor.

2.1.3 Different Pedestrian Dynamics Phenomena

Some studies have based on determining capacity and specifying guidelines for Level of Service (LOS). Prominent among these are the work by Polus et al. (1983), Hoogendoorn and Daamen (2005) and Seyfried et al. (2009). Polus et al. (1983) have tried to determine LOS definitions in terms of nature of flow (free flow, unstable flow, dense flow and jammed flow) for uniform width sidewalks and determine that the walking speeds of women is less than man, all speeds were found to be inversely related to densities. Hoogendoorn and Daamen (2005) have analyzed capacity and walking behavior of pedestrians in bottlenecks, also shows the microscopic behavior of pedestrians inside bottleneck. Seyfried et al. (2009)'s study relates exit widths to immediate upstream capacities. There are yet other studies which relate to speed of pedestrians only. For example, Henderson and Lyons (1972) observed that the speed distributions of male and female pedestrians in the same homogeneous mix is different. Similarly, Polus et al. (1983) observed that speeds of male pedestrians are far greater than female pedestrians. Young (1999) has shown a new insight into the walking speeds of airport pedestrians and examined pedestrian walking speeds on the effect of moving walkways. Empirically observed various airport terminal corridors and found that there is no significant difference in the mean walking speeds of pedestrian within airport terminals and other pedestrian facilities.

Many studies relate to empirical observations on interesting phenomena that occur in pedestrian flow. Many authors, for example, have studied the spontaneous formation of lane like structures in primarily bi–directional flow. Isobe et al. (2004) have observed pattern formation and jamming transition (occurrence of jam when the density exceeds certain threshold value) in pedestrian counter flow. Kretz et al. (2006) have plotted frequency distribution of number of lanes formed for bi–directional pedestrian flow. Hoogendoorn and Daamen (2004) have studied lane formation and cluster formation for bi–directional pedestrian flow. In another study Hoogendoorn and Daamen (2005) have observed zipper effect (staggered positioning of pedestrians when the width of the corridor is in excess than that required for single file movement but not sufficient for two pedestrians moving side by side) at bottlenecks. Oscillations at bi–directional bottlenecks (alternate passing of pedestrians from one direction blocking pedestrians from the opposite direction) with emphasis on alternate passing time and frequency distribution of time headway was studied by Helbing et al. (2005). Helbing et al. (2007) have observed upstream moving (back–propagating) stop and go shock waves forming in pedestrian streams.

2.1.4 Cultural Difference

Speed-density relationship (or fundamental diagram) is the very enthusiasm with respect to the cultural aspect. Researchers doing experimental studies in various cultures have obtained different shapes for the fundamental diagram. This observation points to the fact that there are differences in walking pattern among people of different cultures. One of the first studies conducted to understand this cultural difference in pedestrian motion was by Morrall (1991) found that Pedestrian speeds for all groups in Asian countries are significantly lower than the Western countries. Similarly Tanaboriboon (1986) determined that, the walking speed of Singaporeans is relatively slower than American but the flow rate of the Singapore is higher than western countries.

Again Tanaboriboon (1991) observe that pedestrian facility design standards should be reform and need to adopt Western pedestrian design standards. Lam (2000) determined that the pedestrian flow characteristics are different for different types of walking facilities in Hong Kong. Hall (1966) observes that the behavior of Indian people may be assumed closer to middle-eastern behavior. Chattaraj (2009) founds that pedestrian motion from two widely varying cultures (Indian and German) does exist as the density of Indian test persons less influence the speed than German test persons. Interestingly the unorganized behavior of Indian persons is more than that German persons. Chattaraj (2013) shows the dissimilarities in the fundamental diagram of pedestrian flow in different cultures by modelling.

2.2 Motivation

It is noticeable from the literature reviewed in this chapter that till now reasonable number of experimental studies have been done on speed, density and their interrelationship. But, till now there is no experimental study available in literature to understand how pedestrian flow parameters (speed and density) change spatially and temporally, especially, in response to the cultural differences in India. Also, there is no experimental study on fundamental diagram for Indian pedestrians of different region. These motivated the experimental studies conducted in this thesis. Also, it is evident from the literature reviewed in this chapter that among the existing models on pedestrian flow, force based models involve high computational cost and did not voice the impacts of cultural differences; whereas, the available decision based models are based on ad–hoc rule sets and are typically applicable to specific situations. Also, the existing models do not acceptably listen address the imprecisely nature of human decision making. Thus a pedestrian flow model with reduced computational cost which attempts to take into account the imprecise human decision making process is proposed.

2.3 Problem Statement

The problem of this thesis can be broadly stated as “to show the cultural differences between north and east India.” In particular, pedestrian motion of Indians are empirically observed to show the cultural differences between North India and East India by conducting three sets of similar experiments on single file pedestrian motion.

Chapter 3

Empirical observation: Experiment, Data collection and Data decoding

It is considered that the major factors that affect pedestrian movement are the interaction with other pedestrians, the geometry of the facility in which the pedestrian is motioning and the choices the pedestrian may have to make when faced with multiple contending goals. In this study three similar types of experiments are conducted. The first experiment is on I.I.T. Kanpur intended to study the impact of space between pedestrians in the direction of motion on pedestrian speed. The yields of this study is the "fundamental diagram" between speed and linear density of pedestrians, much like in other traffic streams. Section 3.1 represents the experiment part and the results from the experiments.

Section 3.2 represents the data collection and its methodology from experiments where pedestrians have to move in a single file. These single file experiments on pedestrian motion are designed to understand the variation in density and speed in pedestrian streams of different cultures. Experiments are designed, where different choices of goals are given to pedestrians and their motion studied, in order to perceive the effect multiple competing goals have on pedestrian motion. Different group and gender of pedestrians are also introduced in these experiments. The experiment and their results are presented in Section 3.3.

In this study by using similar experimental set up of single file motion (Chattaraj et.al 2009) three experiments are executed, as the first experiment was conducted in I.I.T., Kanpur by using male pedestrians of Kanpur, second experiment was conducted in N.I.T. Rourkela by using male pedestrians of Rourkela, third one was also conducted in N.I.T., Rourkela by using pair of alternate males and females of Rourkela moving in single file pedestrian motion.

3.1 Experiments on Single File Movement

In this section, experiments designed to develop the fundamental diagram for Indian pedestrians are presented. It may be mentioned here that similar experiments were conducted before this study to develop the fundamental diagram for German pedestrians in Seyfried et al. (2005) and Chattaraj et al. (2009) for experimental set up and data collection. The next subsection presents the details on experimental set–up, data collection and data decoding.

3.1.1 Experimental Set–up

The experiment corridor is framed by chairs and ropes. The size and shape of the corridor is same as mentioned in Chattaraj et al. (2009) for similar experiment in India and Germany. The length of the corridor and measured section is l_p = 17.3 m and l_m = 2 m. The measured section was set up by erecting two ranging rods at the entry and exit line of the measured section as shown in fig. 3.2., so that when a person is exactly at entry and exit positions the time can be noted. The video camera was fixed at a sufficient distance of 10m from the measured section along the perpendicular bisector of the measured section to avoid the parallax error.

The path in which pedestrian motion is studied as shown in Figure 3.1. Despite the data collection was only for the rectangle shaded section as illustrate in the figure 3.1. The width of the path in the straight section is 0.8m, sufficient for single file movement and to avoid the overtaking. In the curved section of the path width is increased to a maximum of 1.2m through elliptic transition curves. The main reason for this is that the curved portion of the flow space may reduce speed. The experiment in I.I.T Kanpur was done outdoor but on paved ground, whereas the experiment in N.I.T Rourkela was done on Community Hall. The subject's characteristics for the experiment consisted of Indian graduate students of I.I.T., Kanpur and N.I.T., Rourkela, local persons of Kanpur and Rourkela. Local residents of the city Kanpur and Rourkela thus putting variation in population. They were counseled not to overtake and not to push others.

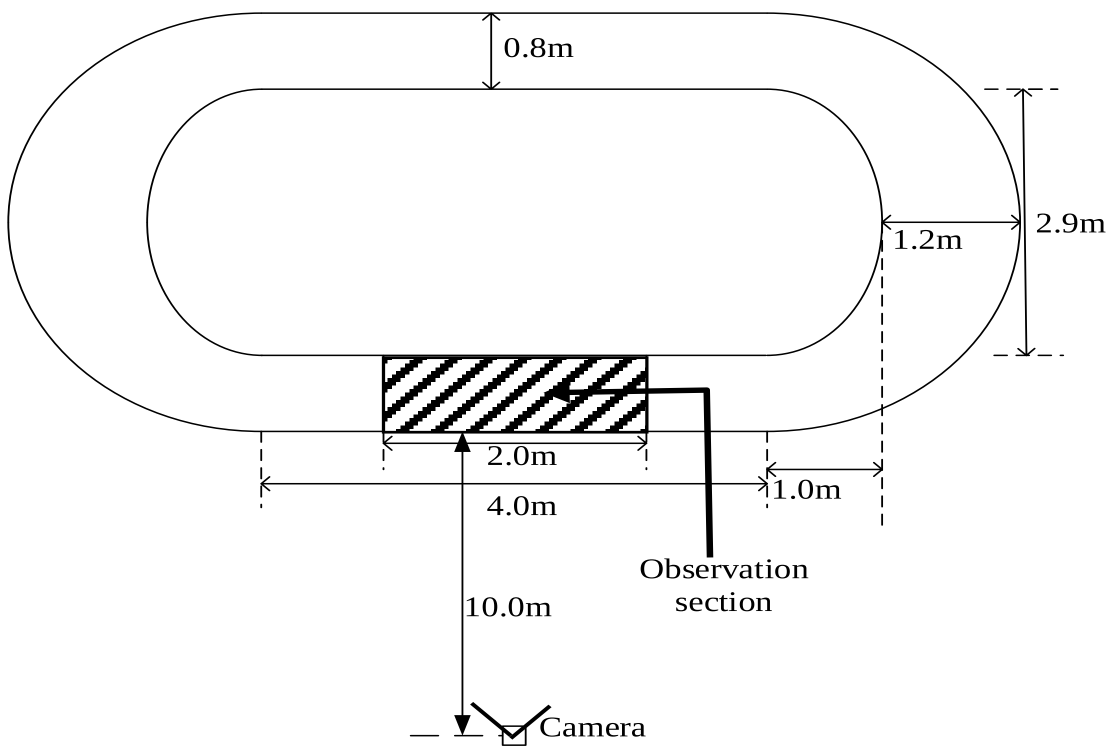

Fig 3.1: Sketch of the corridor used for the North and East India experimental study, adapted from (Chattaraj, Seyfried, and Chakroborty, 2009)

To obtain data on various densities six sets of experiments with number of subjects N = 1, 15, 20, 25, 30, and 34 were performed on I.I.T Kanpur experiment, similarly eight sets of experiments with number of subjects N = 1, 6, 10, 16, 20, 26, 30, 34. For the experiments (except N = 1) all the subjects used in that cycle were initially distributed uniformly in the corridor one after another. Then the direction to start was given every subject goes around the corridor three times. After that an opening is shaped in the closed corridor through which the subjects are allowed to leave and keep walking for an adequate far distance away from the corridor to avoid tailback effect.

The experimental setup for the I.I.T Kanpur study is described in detail in Ref. 18, same is adopted for N.I.T Rourkela study. All the shape and size of the experimental setup like, length and the width of the corridor, the position and dimension of the measurement area, the instruction of the test persons, as well as the measurement method are exact for N.I.T., Rourkela study. The moving direction is similar but differences in the composition of the test subjects. The characteristics of test persons for I.I.T., Kanpur study was composed of male graduate students of the Institute and local persons of Kanpur. The N.I.T., Rourkela study the group consist of both male and female graduate students of the Institute and local persons of Rourkela. The moving direction of the experiment was clockwise as per Indian design aspect. Figure 3.2, Figure 3.3, Figure 3.4 shows snapshots of the I.I.T., Kanpur and N.I.T., Rourkela experiment.

Fig. 3.2: Snapshots for the run with N = 30 of I.I.T., Kanpur males

Fig. 3.3: Snapshots for the run with N = 30 of N.I.T, Rourkela males

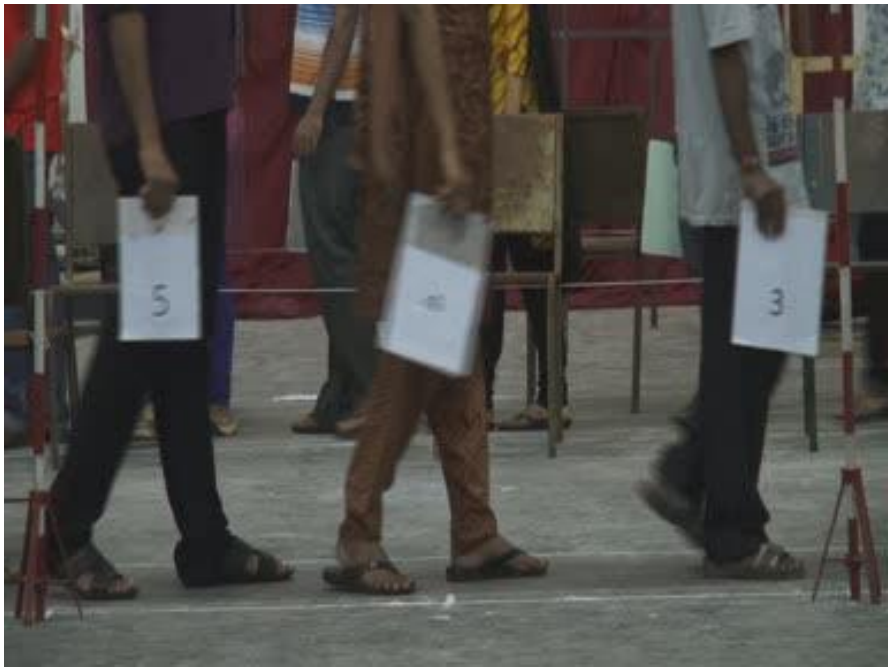

Fig. 3.4: Snapshots for the run with N = 30 of N.I.T., Rourkela pair of alternate males and females

3.2 Data Collection

First to collect the speed-density data, a digital video camera (Mode: HXR-NX30E/NX30P, Make: Sony), Frame rate (25 frames/s) with Resolution (640 × 480) is placed as shown in figure 3.2 and figure 3.5. and recorded the movement of pedestrians. In the experiment two ranging rods are placed separately to locate the rectangular measured section shown in fig. From the video data as shown in fig, the snapshot of the measured section is obtained. To obtain the crossing time of the every individual (say individual p) from the rectangle section, entry time (t_p^{in}) and exit time (t_p^{out}) is noted. From these time points the information on speed and density are obtained. The I.I.T Kanpur data were collected in the same manner as mentioned above. By these data set, speed, density for the individual pedestrian is determined. After obtain the density data set, the distance headway is determined by the reciprocal of the density. As the pedestrians are moving so slowly, appropriate precision was taken at the time of data collection.

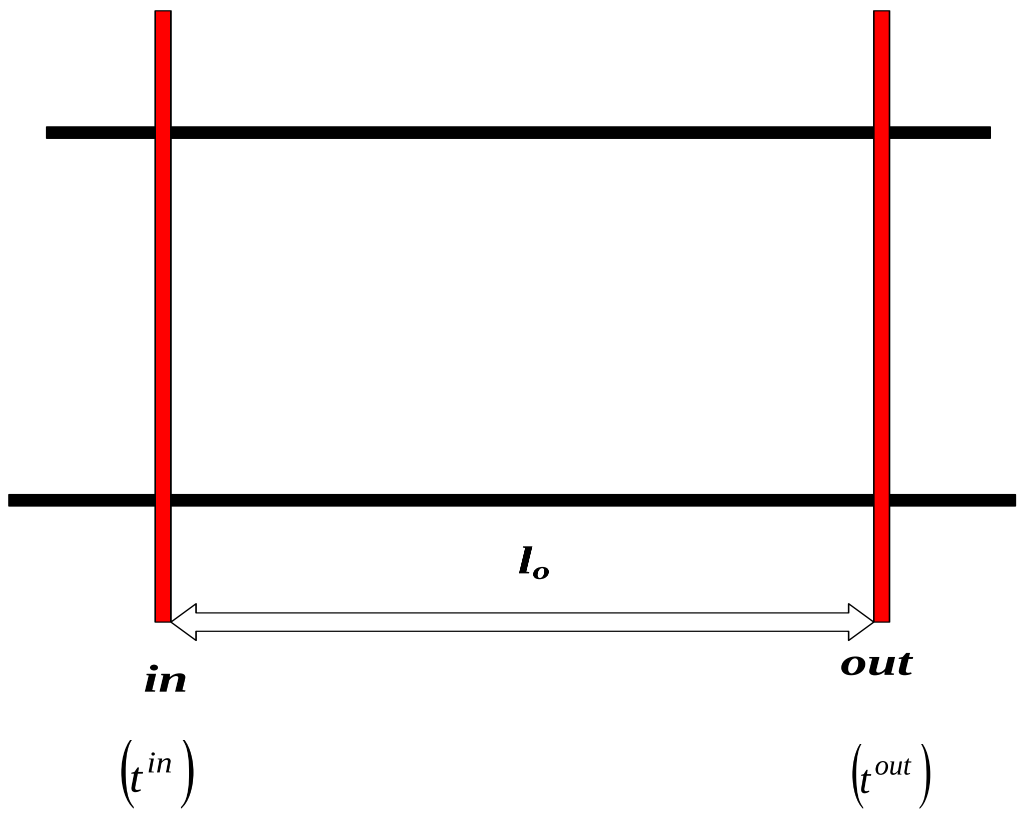

Fig. 3.5: Observed section for data collection

3.3 Data Decoding

The data was decoded by playing the video using video playing software Avidemux. As referring Chattaraj et al. (2009) for data decoding, results and discussions. As the entry time and exit time was noted from the video to determine the speed and density. From these time points speed of individual p in the observation section u_p is determined in the following way as given below.

$$u_p = \frac{l_0}{t_p^{out} - t_p^{in}} \tag{3.1}$$

To determine the average density, k_p first density in a frame, is determined. After knowing the density in a frame, k_p average density, k_f is obtained as given below.

$$k_f = \frac{N_f}{l_0} \tag{3.2}$$

where, N_f is the number of pedestrians in frame "*f*." Next, k_p is obtained from k_f thus:

$$k_p = \frac{\sum_{f=1}^{F} k_f}{F} \tag{3.3}$$

where, F is the total number of frames for which k_f is observed during the time interval

$t_p^{out} - t_p^{in}$

and can be obtained as Φ×($t_p^{out} - t_p^{in}$), where Φ is the frame rate camera (here Φ = 25 frames/second). Reciprocal of k_p gives the average distance headway.

Chapter 4

Results and Discussions

In this chapter the data is analyzed and represented to show the result of cultural differences in India. This results are divided into three parts. In the first part results represent the fundamental relation (speed-density, distance headway-speed relation) of pedestrian flow. In the second part the cultural differences, is shown by means of hypothesis testing. In the third part results represents the free flow speed of Indian pedestrians.

4.1 Speed-density Relation in Indian Culture

Speed-density relationship is the basic input to the pedestrian fundamental diagram. The speed (u)‑density (k) was obtained in closed corridor condition from two place India, which is I.I.T., Kanpur and N.I.T., Rourkela.

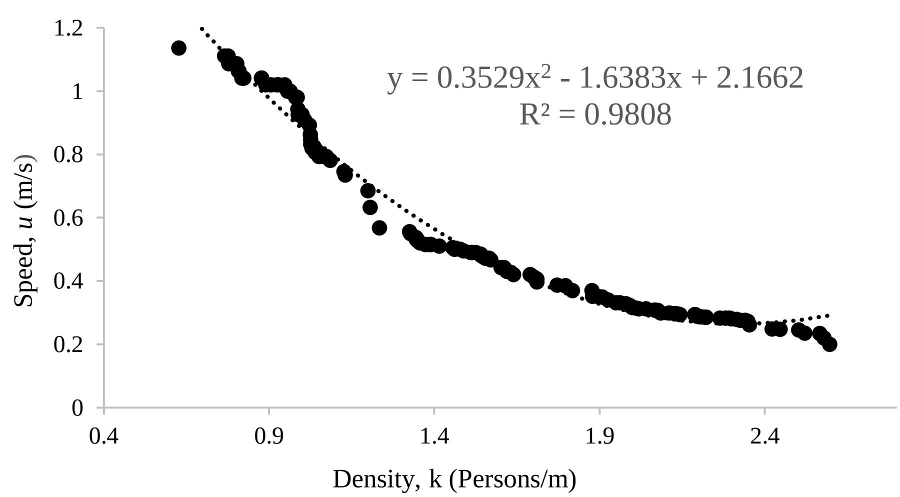

Fig. 4.1: Speed-density plot for I.I.T., Kanpur data set

Figure 4.1 Shows the Speed-density plot for I.I.T., Kanpur data set, in which its observed that when density is increasing speed will be decreasing and vice versa. By visually it is seen from the graph that the speed-density relationship is non-linear and logarithmic in nature. The logarithmic equation is given below. The R^2 value is 0.9808.

$$y = 0.3529x^2 - 1.6383x + 2.1662 \tag{4.1}$$

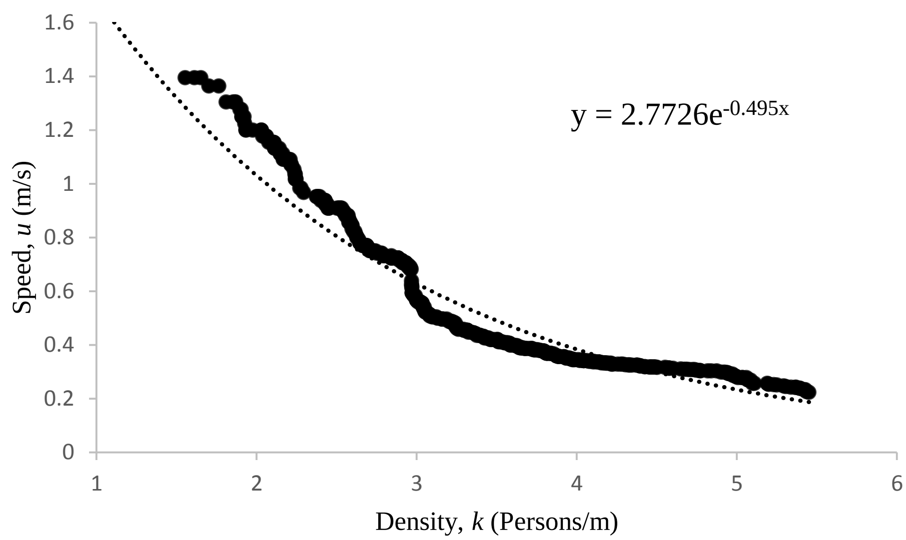

Fig. 4.2: Speed-density plot for N.I.T., Rourkela males data set

Above Figure 4.2 Shows the Speed-density plot for N.I.T., Rourkela males data set, in which its observed that when density is increasing speed will be decreasing and vice versa. By visually it is seen from the graph that the speed-density relationship is non-linear and power in nature. The power equation is given below. The R^2 value is 0.924.

$$y = 2.7726e^{-0.495x} \tag{4.2}$$

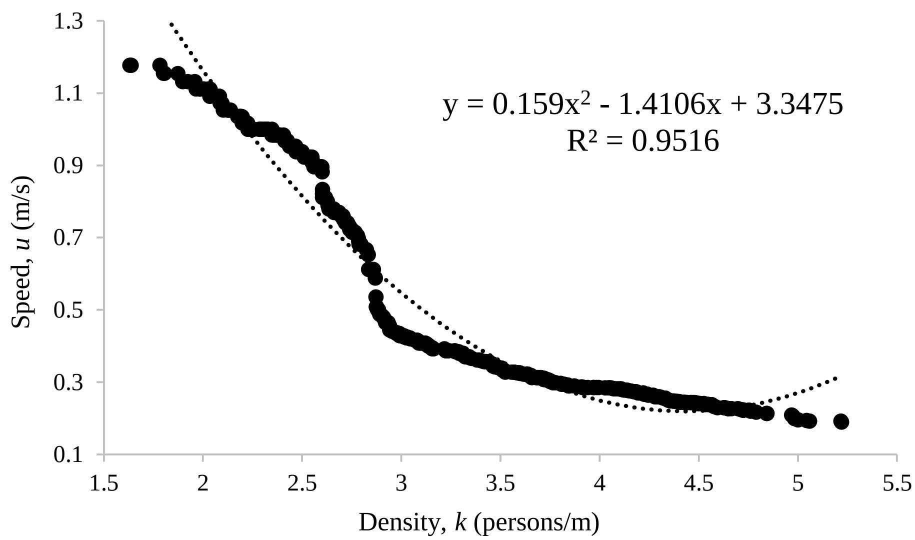

Fig. 4.3: Speed-density plot for N.I.T., Rourkela pair of alternate males and females data set

Showing by the above figure 4.3, Speed-density plot for N.I.T., Rourkela pair of males and females data set, where the females following the males in experiment. In above fig its observed that when density is increasing speed will be decreasing and vice versa. By visually it is seen from the graph that the speed-density relationship is non-linear and power in nature. The power equation is given below. The R^2 value is 0.9516.

$$y = 0.159x^2 - 1.4106x + 3.3475 \tag{4.3}$$

4.2 Distance Headway-Speed Relation in Indian Culture

Another primary input to the pedestrian fundamental diagram is distance headway-speed relationship. The distance headway(s)–speed (u) was obtained in closed corridor condition from two place India, which is I.I.T., Kanpur and N.I.T., Rourkela.

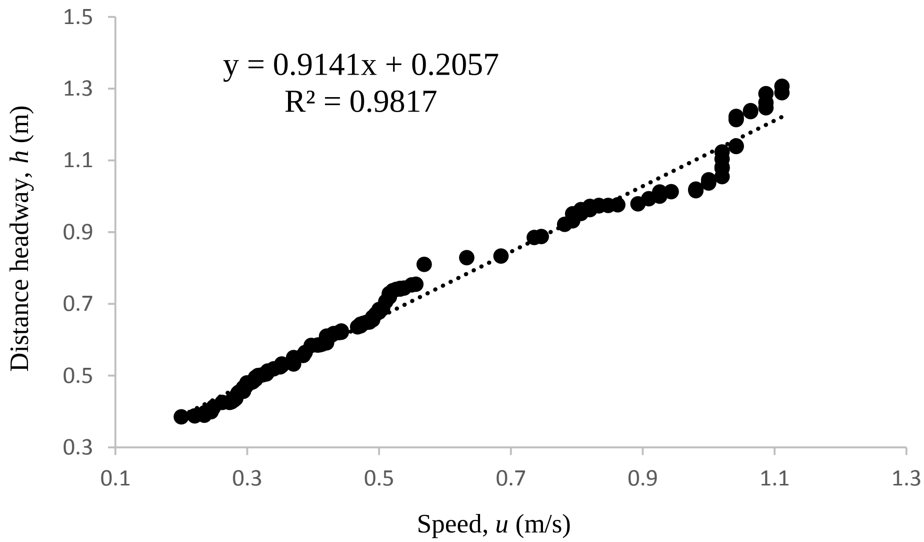

Fig. 4.4: Distance headway-speed plot for I.I.T., Kanpur Boys data set

The above figure 4.4 Shows the distance headway-speed plot for I.I.T., Kanpur data set, in which its observed that when speed is increasing distance headway will be increasing and vice versa. By visually it is seen from the graph that the distance headway-speed relationship is linear and in nature. The linear equation is given below. The R^2 value is 0.9817.

$$y = 0.9141x - 0.2057 \tag{4.4}$$

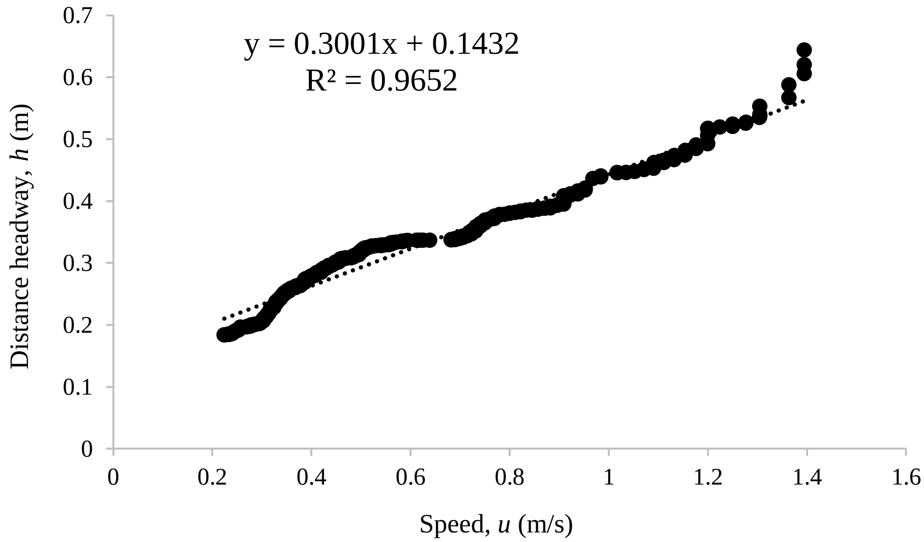

Fig. 4.5: Distance headway-speed plot for N.I.T., Rourkela males data set

As above Figure 4.5 Shows the distance headway-speed plot for N.I.T., Rourkela males data set, in which its observed that when speed is increasing distance headway is increasing and vice versa. By visually it is seen from the graph that the distance headway-speed relationship is non-linear and power in nature. The power equation is given below. The R^2 value is 0.9652.

$$y = 0.3001x + 0.1432 \tag{4.5}$$

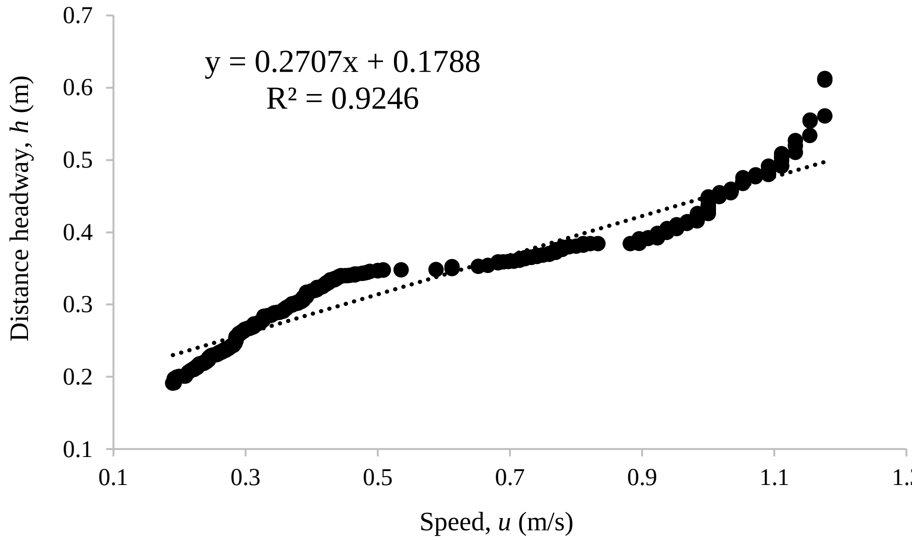

Fig. 4.6 Distance headway-speed plot for N.I.T., Rourkela pair of alternate males and females data set

Showing by the above figure 4.6 Distance headway-speed plot for N.I.T., Rourkela pair of males and females data set, where the females following the males in experiment. In above figure 4.6 its observed that when speed is increasing distance headway will be increasing and vice versa. By visually it is seen from the graph that the distance headway-speed relationship is non-linear and polinomialic in nature. The power equation is given below. The R^2 value is 0.9246.

$$y = 0.2707x + 0.1788 \tag{4.6}$$

4.3 Differences in Distance headway-speed relation in Indian culture

Pedestrian flow is very well-known for its self-organization phenomena, like speed, density and distance headway. Distance headway is one of the vital phenomena in pedestrian flow. Pedestrians wants to keep some space or distance from other pedestrians in static as well as dynamic condition. Distance headway-speed relationship is crucial to knowing the space requirement of pedestrians from two different cultures in Indian. To observe whether the space or distance headway vary with two different Indian culture, figures are presented below.

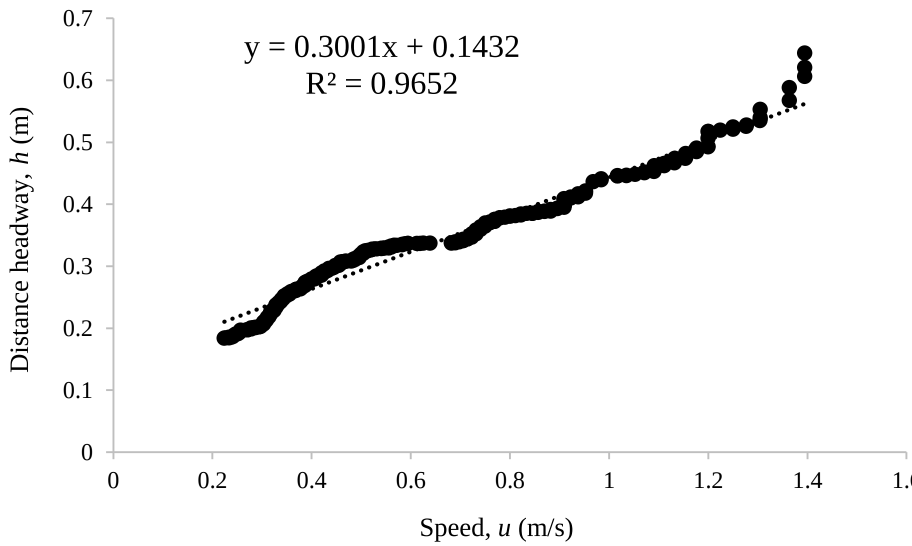

Fig. 4.7. (a): Observed distance headway-speed data and fitted relationships for N.I.T, Rourkela males conditions

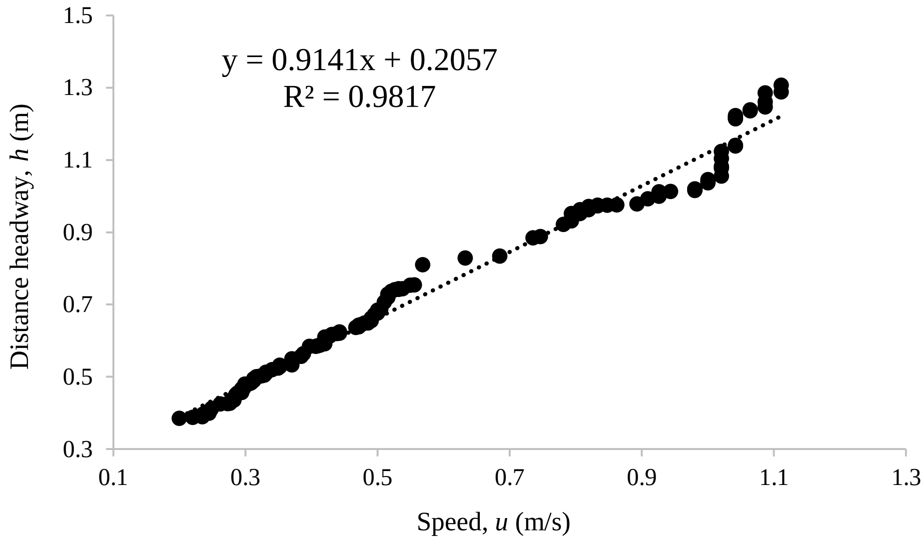

Fig. 4.7. (b): observed distance headway-speed data and fitted relationships for I.I.T, Kanpur males conditions

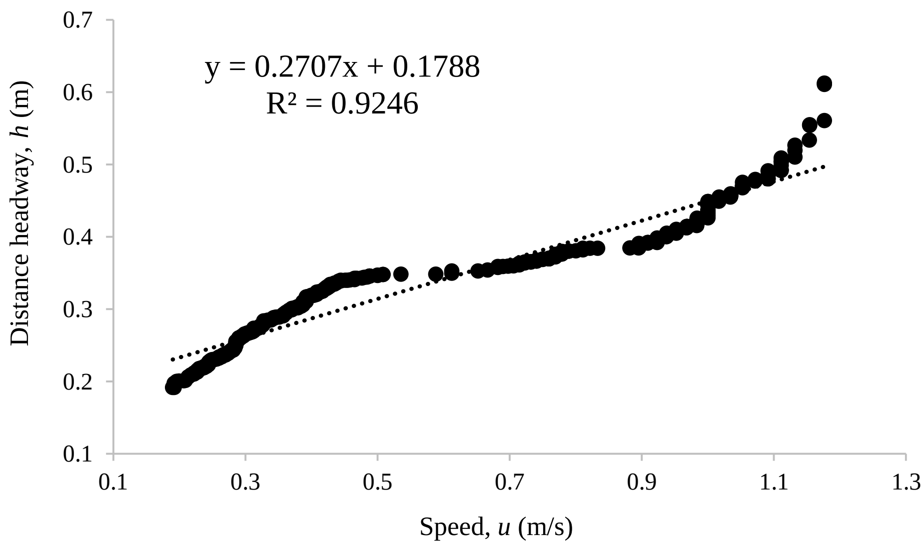

Fig. 4.8. (a): Observed distance headway-speed data and fitted relationships for N.I.T, Rourkela pair of alternate males and females conditions

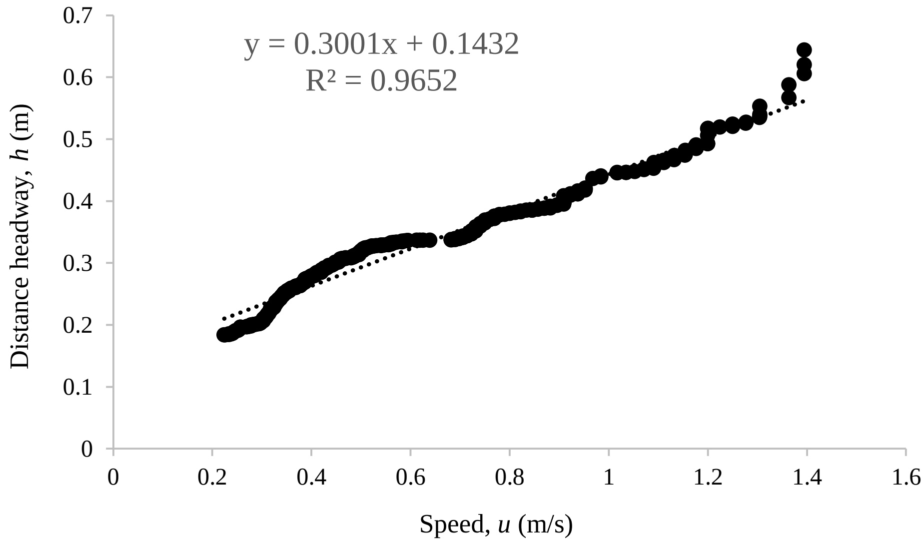

Fig. 4.8 (b): observed distance headway-speed data and fitted relationships for N.I.T, Rourkela males conditions

4.4 Show the Cultural Differences by Hypothesis Testing

Hypothesis test was conducted to show the cultural differences in India. First hypothesis test was done to illustrate the cultural differences between North and East India. Then another hypothesis test was done to determine the differences within two different group of experiment, as N.I.T., Rourkela males and pair of males and females.

4.4.1 Hypothesis Testing between North and East India:

To showing the cultural differences t-test was conducted. Friedman (Non parametric repeated measures ANOVA) test was done. As the result, the p value is less than 0.0001 ($p < 0.0001$), which is considered extremely significant. The p value is approximate from chi-square distribution. The compared I.I.T., Kanpur and N.I.T., Rourkela speed, p value is less than 0.001 ($p < 0.001$), which is significant. Similarly the compared I.I.T., Kanpur and N.I.T., Rourkela distance headway, the p value is less than 0.001 ($p < 0.001$), considered as significant.

The hypothesis test results are significant.

4.4.2 Hypothesis Testing between Two Different Groups of Experiment in East India

Two different groups of experiments was conducted in one place of East India (N.I.T., Rourkela). The first experiment was conducted by N.I.T., Rourkela males and second experiment was by pair of N.I.T., Rourkela males and females. To showing the cultural differences t-test was conducted. Kruskal-Wallis (Non parametric ANOVA) test was done. As a result the p value is less than 0.0001 ($p < 0.0001$), considered as extremely significant. The p value is approximate from Chi-square distribution. The compared N.I.T., Rourkela males speed and N.I.T., Rourkela pair of males and females speed, the p value is less than 0.001 ($p < 0.001$), which is considered as significant. Similarly the compared N.I.T., Rourkela males distance headway and N.I.T., Rourkela pair of males and females distance headway, the p value is less than 0.01 ($p < 0.01$), considered as significant.

The hypothesis test results are significant.

Chapter-5

Summary, Conclusions and Future Scope

7.1 Summary

In this study, three experiments on single file pedestrian motion was conducted in two places, (I.I.T., Kanpur and N.I.T., Rourkela) of India to show the cultural and gender differences. An experimental set-up was built to conduct the experiment as mentioned in Chattaraj et al. (2009). Different groups of pedestrians was used for this experiment as a subject. Then the direction was given to entry group of subjects to goes around the corridor three times. After moving these subjects three rounds, an opening was shaped in the closed corridor to keep the pedestrians out. In the experimental set-up, two ranging rods are placed separately to locate the rectangular measured section, from which video was taken for data decoding. Fundamental relation was established and by hypothesis testing cultural differences was determined.

7.2 Conclusions

In this thesis experiments on single file pedestrian motion under closed boundary condition are conducted to observe cultural differences in fundamental diagram between two widely spaced places, namely, Kanpur and Rourkela within India. From the experimental results, it is observed that, statistically significant cultural differences exist between these two cultures. Also, it is seen that, pedestrians from Rourkela are much more disorganized in terms of walking in a queue in comparison to Kanpur. Also, in the same thesis, experiments are conducted to see the differences between male pedestrians and a mixture of alternate male and female pedestrians. Here, also, statistically significant differences in fundamental diagram are observed.

7.2 Future Scope

In this thesis work, it is observed that; fundamental diagram from Rourkela is significantly different than that from Kanpur. Similarly, fundamental diagrams between male pedestrians and mixture of male and female pedestrians are also significantly different.

Thus, it is expected that, in future, if cultural differences are compared between nearer cultures gradually, one point will come when this difference will be dissolved. Similarly, in a group of same gender pedestrians, if fraction of opposite gender pedestrians is reduced, in a certain lesser fraction of embedment, the difference in fundamental diagram will be dissolved.

In a nutshell it can be said that:

i) In the earlier experimental work, cultural difference between two far spaced countries were studied and significant differences were observed. In the present experimental work, cultural difference between two far spaced states within the same country are studied and significant differences are observed. In the future, same study will be conducted between two districts of a same state to see whether the differences dissolve or not, and so on.

ii) In the present experimental work, fundamental diagram of equal number of male and female pedestrians in alternate position is compared the fundamental diagram of all male pedestrians of same sample size and significant differences are observed. In the future, same study will be conducted with gradually reduced fraction of female pedestrians of same sample size to see whether the differences dissolve or not.

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List of Publications

Journals:

1. Chattaraj, U., Seyfried, A., Chakroborty, P., Biswal, M.K. (2013). Modelling single file pedestrian motion across cultures. *Elsevier*, Vol.104, pp. 698-707

2. Biswal, M.K., Mandel, T., Subhasini, N.A., Kumar, R.V., Chattaraj, U., (2013). Analysis of Different Parking Space and its Comparison, *International Journal for Scientific Research & Development*, Vol. 1, pp.1506-1509