IMPACTS OF GENDER AND GENDER MIX ON PEDESTRIAN FUNDAMENTAL DIAGRAM

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In

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IMPACTS OF GENDER AND GENDER MIX ON PEDESTRIAN FUNDAMENTAL DIAGRAM

A Thesis

Submitted in partial fulfilment of the requirements
for the degree of

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By

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Under the guidance of
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This thesis is dedicated

To the my beloved parents,

May God bless them and elongate them live in his obedience.

NIT Rourkela

CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled "**IMPACTS OF GENDER AND GENDER MIX ON PEDESTRIAN FUNDAMENTAL DIAGRAM**" 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, Department of Civil Engineering.

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.

(Dharitri Kahali)

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

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ABSTRACT

Pedestrian movement study can be possible done by different approaches like Investigation of walker movement (field data collection), experimental observation, and conduction of controlled tests and also by creating pedestrian models. All these diverse sorts of studies are subject to develop fundamental diagrams. Movement of pedestrian along a line of the corridor under the closed boundary conditions is the simplest method to know how the different condition influences the fundamental diagram. We have to study diverse angle and distinctive effects which impact person on foot movement, to give better pedestrian facilities and also help in design spaces for human circulation.So, here in this thesis it is aimed to study the impact of gender mix condition on pedestrian at different densities at fundamental level.In this contribution it is studied through fundamental diagram, whether the impact of gender and gender mix condition influence the pedestrian behaviour or not. To conduct the experiment, the simplest system, which is known as the movement of pedestrians along a line under closed boundary conditions (single file movement) is chosen with five different gender mix condition. It is found that the Mean free flow speed is $1.27ms^{-1}$ for male pedestrian and it is$1.24ms^{-1}$for female pedestrians. While walking females are more conscious about their private space than the males. This may be because of contrasts in their self-organizing behaviour. Without any statistical proof one can't tell whether there are contrasts or not. By statistical hypothesis test it is discovered quantitatively that these distinctions exist, recommending the gender and gender mix impact in fundamental diagram.

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LIST OF SYMBOLS AND ABBREVIATIONS

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
up	Speed of individual pedestrians
l_o	Length of 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
$\emptyset$	Frame rate of camera

CHAPTER 1

INTRODUCTION

Walking is perhaps the most useful, necessary and basic transportation system which is available to mankind and used by almost every person in the world. Walking is additionally included in many outings made by different modes. Whatever the fundamental method for travel, walking is normally the first and last mode utilized, giving an essential connection between area utilize and mechanized travel. It is additionally sound, economical and environmental friendly. As per DEMOGRAPHIC OF INDIA, WIKIPEDIA (2014), India is the second most crowded nation on the planet more than 1.27 billion people, more than a 6th of the world's populace. As of now contains 17.5% of the world's populace and India is anticipated to be the world's most crowded nation by 2015, surpassing china so India should need a adequate pedestrian facilities to provide better design spaces for human circulation, to empower and energize walking for distinctive purpose, the physical facility must be available to backing the physiological, psychological and social need of walkers and guarantee them against overexertion, interference by other person on foot and mischance. For this reason, exploration of walker movement streams has just been given constrained consideration amid the most recent decades. Since walking is a part of the transportation chain without which barely any development is conceivable. Samples are get to and departure to open transport administration, person on foot streams in inward city ranges, focal business areas and malls, and groupamid discharging of theatres and games stadiums and amid celebrations. In this thesis an attempt is made to study the behavior of the Indian pedestrian empirically on the basis of their gender analysis. Empirically, the motion of the pedestrian can be studiedby conducting different type of experiments such as single file movement, flow through open corridor, bottleneck experiment, and evacuation from a hall etc.

1. In single file and bottleneck experiments, impact of space between pedestrians in the direction of motion can be observed on pedestrian speed.
2. In flow through open corridor experiment one can observed the lateral and longitudinal variation in density and speed in pedestrian streams due to different corridor geometry.
3. In the experiment of evacuation from a hall one can study the effect of choice of goals and the positions of the obstacles on pedestrian motion.

In this thesis, single file experiments on pedestrian movement are considered to know the impact of space between pedestrians in the direction of motion on pedestrian speed. Because to know the impacts of gender and gender mix condition on pedestrian fundamental diagram, it is necessary to study speed/density/volume relationship to add to a comprehension of any traffic flow phenomena because these parameters are important portrayal of stream qualities They are reasonably simple to gauge and to understand The past investigations of vehicle stream have recognized essential prerequisites in the relationship between these parameters that are valuable in comprehension stream systems, administration properties, and outline standards. Several studies that managed vehicular stream portrayed the fantastic relationship in between speed and density, which was picked as a beginning stage for an investigation of the attributes of pedestrian movement stream to know the gender effect in pedestrian traffic flow. Empirical investigations of passerby streams can be followed back to the year 1937. Right up till the present time a focal issue is the relation between flow and density or velocity. This reliance is termed the fundamental diagram and has been the subject of numerous examinations from the earliest starting point. The fundamental diagram is utilized for the assessment of models for walker movement, and is an essential test of whether the model is suitable for the depiction of pedestrian stream. In this thesis, pedestrian fundamental diagram is used to detect the impact of gender and gender mix condition in

pedestrian flow. The relationship between the principal variables of traffic flow, namely speed, volume, and density is called the fundamental relations of the pedestrian traffic flow. The relation between speed and density, speed and flow, and flow and density, can be represented with the help of some curves. They are considered as the fundamental diagrams of traffic flow. A fundamental diagram applied to a specific condition and is drawn up on the basis of observations.

The motion of the pedestrian can also be studied at different levels:

1. At the macroscopic level one may study over the essential stream parameters of pedestrian movement.

2. At microscopic level one may track the way took after by individual walker while moving. Such studies help in seeing how pedestrian arrange their way while traveling through a stream space at different densities.

3. At mesoscopic level one can contemplate pedestrian movement by focusing on how the stream parameters change spatially (both in transverse and longitudinal directions) and briefly. Such studies helps in comprehension pedestrian stream at sensible essential level furthermore help in seeing how different geometric elements sway pedestrian movement.

In this thesis, macroscopic and mesoscopic data collected from experiment to understand the speed-density relationship of pedestrians and gender effect on pedestrian fundamental diagram. In this study the exertion is demonstrated the gender condition by conducting single file experiment on pedestrian movement. This work will able to help in dimensioning the pedestrian facilities like person on foot streams in inward city ranges, focal business areas and malls, and group amid discharging of theatres and games stadiums and amid celebrations with respect to safety and comfort aspect.

Here the basic pedestrian characteristics like speed, density and distance headway will compared between different gender and gender mix conditions to

study the differences which would be very effective to design different pedestrian facilities in Indian context.

The thesis is divided into five chapters of which includes general background, literature review, motivation, experimental setup, data collection and decoding and results andanalysis of empirical data.

Chapter 1: This chapter consists of introduction of pedestrian flow condition in India.

Chapter 2: The second chapter of this thesis represents the literature existing on pedestrian flow characteristics and the past work done on empirical pedestrian studies. This chapter also describes the motivation behind this thesis.

Chapter 3: In the third chapter, the experiment setup and the extraction of the pedestrian trajectories from the video recordings are described.

Chapter 4: The fourth chapter represents the analysis of empirical data obtained from experiment on single-file motion. The result of this chapter used to study the impacts of gender mix condition on fundamental diagram.

Chapter 5: The fifth chapter concluded the thesis by summarizing the work done. This chapter also represents the contribution of this thesis work as well as its shortcomings.

CHAPTER 2

LITERATURE REVIEW, MOTIVATION AND PROBLEM STATEMENT

2.1 LITERATURE REVIEW

An attempt has been taken in this chapter to collect together different aspect of past research in pedestrian flow for design of any pedestrian facilities which provides safety and comfort, it is necessarily important to understand pedestrian movements specially at high densities because the speed of the pedestrians are low compared to the speedof the vehicles. It is perhaps a main factor to state that comparatively lesser attentionhas always been given to the field of pedestrian flow. But considering the global urban popu- lation, it indicated that the urban population increasing across the globe, especially in developing countries. As India is considered a developing country as well as the 2nd highest population country so the importance of the pedestrian cannot be neglected. In the countries like India where lots of stampedes and crowd crushes occurred to several death and injuries. Recently stamped and crowd crushes occurred at Allahabad railway station in Uttar Pradesh (2013) at sabarimala on makara jyothi day in Kerala (2011) at Bhavanth temple (junagadh) in Gujarat (2013) and funeral of Muslim spiritual leaderMumbai (2014) so it is strongly demanded the need of pedestrian facilities. Here in this chapter some of the literature studies related to pedestrian flow are presented below.

The literature studies related to pedestrian flow is divided in to three parts: the first part represents the literature on speed, density and their inter relationship and the second part describes the work relevant to the empirical studies on pedestrian flow and the third one relevant to the gender effect on pedestrian flow.

2.1.1 SPEED, DENSITY AND THEIR INTERRELATIONSHIP

Hankin et al. [2] studied the flow of passenger in subways including the effect of constrictions such as stairs and corners in order to assist in the design of new facilities. They introduced a non linear speed density graph. They found movement on stairs in markedly slower than in subways and stairs are therefore likely to form bottlenecks in passengers movement system operating under full load. When a subway becomes more crowds there is an unconscious slowing down due to the natural desire to avoid treading on the heels of the person in front. This result in flow reading an effective manbeyond which increased crowding (and consequent discomfort) is compensated by reduced speed. The net effect is that for practical purpose no gain in flow is obtained. Oeding et al. [3] conducted an experiment to understand the pedestrian behavior and characteristics under mixed traffic condition and represented the relationship of speed flow and density for different types of pedestrian i.e. shopper people going to or from work people going to a sport meeting etc. Older et al. [4] Studied movement on pedestrian on front ways in shopping streets.

A relationship was made between the speed and density of pedestrian walking on the footpath at the three different sites inshopping streets and he was found that as expected that increasing in density reduced the speed of the fast pedestrians rather than that of the slower once and thus the range of speed available to pedestrian was reduced. He also considered the effect of the congestion and found that as the footway becomes crowed people are more likely to walk in the carriage way. He also found that the observed speed/density and flow/density relations are slightly different at these two sites. Site 1 where the footway is narrow has for the same densities speeds which are higher than site 2, where the footway is widermore efficient use is made by pedestrians of the narrow foot way than of the wider one. A.Hoel [5] studied on pedestrians travel rates in central business distinct and found that pedestrians travel rates affected by the environmental factor such as time of the day, external influences and the temperature. He also found that the variations in rates of speed in between males and female pedestrians. Francis Navin et al. [6] considered the pedestrians flow characteristics and they found

that the two ways flow will reduce side walk capacity at higher concentration. The more orderly the walking pattern of the pedestrians the higher the flower per unit width as in the in the case of displayed matching formations. Mean speed observed on the test sections were significantly different from each other. The percentage of side works used by a traffic stream is proportional to the percentage of the stream relative to the total flow. They gave the conformation ofthe speed concentration relationship described by hankin and wright. With the increase in density and pedestrian traffic in opposite direction; they found decrease in flow rateand speed of pedestrian.

Fruin et al. [7] studied the basic vehicle flow relationship to pedestrians' volumes, average speed and density. A term modulus of square feet which it may stated as reciprocal of density was taken and the increase in modulus was described by taking a semi-parabolic curve. He found that pedestrian speeds tend to have less variability as increased crowd density restrict the ability to bypass slower moving pedestrians and to select a desired walking speed. Polus et al. [8] studied pedestrian flow and level of distinct of traffic Israel using one and three regime linear speed-density regression model. They observed that the walking speeds of women are lower than men speeds. The both men and women speeds were inversely related to densities. Tanaboriboon et al. [9] conducted a study to examine the characteristic of pedestrian in Singapore shows that the mean walking speed of Singapore was 74m/min. Singaporeans has a slower walking rate than his American counterpart. This speed is relatively slower than that of his American counterpart. However, the maximum flow rate obtained here is higher than that of the obtained in the western countries. Mori and Tsukguchi [10] described two different methods to evaluate ordinary sidewalks in urban areas. One is an evaluation based on pedestrian behavior and the other is an evaluation based on the pedestrian opinion. The former method is recommended for all sidewalks, especially with the comparatively heavy pedestrian traffic and the later method is recommended for ones with pedestrian traffic.

Morrall et al. [11] found that flow pedestrian speeds for all groups in Asia countries are significantly lower than these observed its western

counterpart. He found the differences in speeds between Asia and its western counterpart (Colombo and Calgary) may be physical and cultural (dress) differences and attraction (such as pavement hackers) located along sidewalks. He found that pedestrians planning technique for Asian countries should be based on the local pedestrian characteristics' rather than on pedestrian characteristics fro cities with dissimilar culture. Tanaboriboon et al. [12]] stated that walking rates on the pedestrian facilities in Bangkok were determined and compared with those of western standards as well as with findings obtain in other Asian countries. The findings of the study confirmed that Asian pedestrians walk slower compared with their western counterpart. So local design standards are needed for pedestrian facilities in Asian countries.

2.1.2 EMPIRICAL STUDY ON PEDESTRIAN FLOW

Alexander Mintz [13] conducted an experiment to study the non-adaptive group behavior and he found that an panic producing situations cooperative behavior is needed for success and is rewarding to individual as long as everybody cooperates. However, once the cooperative pattern of behavior is disturbed, cooperation ceases to be rewarding to the individuals, then a competitive situation is apt to develop which may lead to disaster. Daamen et al. [14] conducted a laboratory experiment on pedestrians to get qualitative results. They considered the variables like, free speed, walking direction, density and bottle necks. They found that within a bottleneck pedestrian do not walk next to each other, but "zip" in an efficient way and they also found that, when pedestrian come closer to the bottle neck, they try to reach the bottleneck more actively prevent other pedestrians to use the available empty area to quickly pass the bottleneck. Isobe et al. [15] conducted an experiment on pedestrian counter flow and they appeared to be the first to have compared the experiment results with the simulation results the pedestrian counter flow. They described the characteristics properties of pedestrian channel flow like pattern formation, pedestrian speed, jamming transition. Several experiments have been conducted for corridors, intersections, and bottleneck areas by Helbing et

al. [16] along with a group of people. In their analysis, it was found that the capacity of the elements of pedestrian facilities is in relevance with the geometric boundary conditions and also discovered that those boundary conditions have an impact on the time gap distribution of pedestrians. This, in turn, indicates that the phenomena of self organization do exist. Further research proved that the existence of obstacles can help in stabilizing the flow patterns and these obstacles are handy to make the flow more fluidic. Also, the flows which intersect can be well-optimized with the utilization of 'stripe routes' phenomenon in stadia, multiplexes, and auditoria in order to avoid long waiting times for the audience sitting at the back and shock waves when there is a need to emergency evacuation. They concluded that the pressure in panicking crowds can be diminished by the utilization of zigzag shaped geometries and columns.

Later Daamen and Hoogendoom [17] along with his team, performed experiments to prove the correctness of first-order traffic flow theory which describes two-dimensional pedestrian flow operations, particularly in the case of an oversaturated bottleneck whichhas in its front, a large high-density region. Density, speed, and flow have been collectedfrom laboratory walking experiments. The noticed that the different flow conditions are experienced by pedestrians who are on the same cross-section side of the congested region. This, on a whole is dependent on the lateral position of the pedestrian keeping in view the centre of the congested region, and the lateral centre, high densities and low speeds. They found out that congestion of pedestrian traffic over the total cross section width does belong to set of different multiple fundamental diagrams. Movement of pedestrians along a line at medium and high densities was conducted by Seyfried etal. [18] and linear relation was obtained between the velocity and inverse of the density. Obtained results of singlefile movement compared to literature results of movement in a plane and showed a linear relation between the velocity and the inverse of the density. This shows the trivial effect of lateral interference on velocity-density relation. In another effort of Kretz et al. [19] bottlenecks experiment conducted and depicted in the form of time gaps, specific fluxes, total times and fluxes. They found that

when one person can pass at time when width and specific flux are inversely proportional and steady state for larger bottlenecks widths. They showed difference between one person at a time and two people at a time as a distribution of time gaps. An experimental study was conducted by Seyfried et al. [20] On unidirectional pedestrian flow through bottlenecks. It was found that the flow and the width holds linearly depend on each other for different types of bottlenecks and initial conditions. The minor influence of exact geometry of bottleneck on the flow was also found by comparing the different kinds of bottlenecks and lengths. Chattaraj et al. [1] conducted an experiment on pedestrian streams in corridors to compare the fundamental diagram of pedestrians across culture and found that Indian test person's speed is less dependent than Germans test person's speed on density. And the unordered behavior found more in Indians which is more effective than the ordered behavior of the Germans. Chattaraj et al. [21] Developed a modified Blue-Adler model which described the fundamental diagram of pedestrians of different cultures. He also described the differences exist between people's perception of space in different cultures according to the modified Blue-Adler model.

2.1.3 GENDER EFFECT ON PEDESTRIAN FLOW

Navin et al. [6][5] Studied the distribution on pedestrian speeds while considered the pedestrian flow characteristics and found that the women walked slower than men. Henderson et al. [22] found that the males and females were presented in all the crowd and no distinction was made on the basis of sex because it was considered that for each case the uniformity of activity and environment together with attention paid to the selection of the ages of the individuals (where it appeared to be relevant) would produce approximately homogeneous crowds for study. Henderson et al. [23] studied on males and females of an approximately homogeneous crowd gas either in equilibrium or nearly so and composed of statistically independent prime particles will separately obey maxwell-boltzman type statistics in two dimensional velocity space for the fluctuating parts of their motion. For female pedestrians the distribution so significantly skewed

compared to male pedestrians are much more easily perturbed in their motion than males. Henderson et al. [24] applied maxwell-boltzmann gas theory to the motion of the pedestrians. They considered two factors as sex and number of challenges to find out the significant skewness and pedestrians.

They found that the skewness exactly was not directly associated with the number of challenges, but average speed felt with increasing challenge. Women experienced more challenges than menand slowed down more than men for each successive challenge. Morrall [11] studied that walking speed of men and women and observed that walking speed of men faster than women and also walking speed of men were 3 m/min faster than women.

2.2 MOTIVATION

It is clearly noticeable from the literature reviewed in this chapter that although reasonable number of experimental studies have been done on speed, density and their inter relationships. But till now there is no such experiments available in the literature review to show how pedestrian parameters like speed, density changes spatially and temporally, especially in case of geometry and other factors related to pedestrian flow uniquely like gender condition and there is no such experimental study available on fundamental diagram for Indian pedestrian. These motivated the experimental study of this thesis. From the literature reviewed in this chapter it is clearly evidenced that with the available decision based model, it is easy to simulate large number of pedestrian movements and are typically applicable to specific situation so pedestrian flow model, which consider to attempt the uncertain human choice making procedure is proposed.

2.3PROBLEM STATEMENT

The problem of this thesis can be extensively expressed as “to show the impacts of gender and gender mix conditions on pedestrian fundamental diagram”. Here the motion of the Indian pedestrian are empirically studied to show the existence of the gender effect on fundamental diagram by conducting single file experiment on pedestrian movement.

CHAPTER 3

EXPERIMENTAL OBSERVATION: EXPERIMENT, DATA COLLECTION AND DATA DECODING

Pedestrian activity has been discovered to be affected by mental, physiological, social and ecological variables. The elements which affect studies for characterizing the qualities of pedestrian stream are age, sex, physical wellness, pedestrian interaction and the geometry of the facility. In this study five similar types of experiments are done. All the five sets of experiments are done in N.I.T. Rourkela to study the impact of space between pedestrians in the direction of motion which can be observed on pedestrian speed. The fundamental diagram between speed and linear density of pedestrian motion is obtained from this study.

In this chapter, Section 3.1 presents the experiment on single file movements. Section 3.2 represents the information accumulation and its approach from investigations where pedestrians need to move in a single file experiment. These single file tests on walker movement are intended to comprehend the variety in speed and density in walker's stream of different gender group. Tests are designed, where diverse decisions of objectives are given to people on foot and their movement concentrated on, keeping in mind the end goal to see the impact contending objectives have on pedestrian movement. Five different groups of gender mix conditions of pedestrians in these experiments are introduced. Section 3.3 represents the data decoding process, which is obtained from the single file experiments.

3.1 SINGLE-FILE MOVEMENT EXPERIMENT

Normally single file experiments are done to study the impact of space between pedestrians in the direction of motion on pedestrian speed. In this section, examinations intended to develop the fundamental diagram for Indian pedestrians are introduced. It might be specified here that comparative investigations were directed before this study to build up the fundamental diagram for German pedestrians in Seyfried et al. (2005),

Chattaraj et al. (2009), and Manoj Biswal (2014) for exploratory set up and information gathering. The following subsection displays the subtle elements on test set–up, data collection and data decoding.

3.1.1 Experimental set-up for Single-File movement

The experiment corridor is encircled via chairs and ropes. The size and shape of the experiment corridor is same as said in Chattaraj et al. (2009) for similar experiment in India furthermore, Germany. A closed corridor of the size and shape as demonstrated in Figure 3.1 is developed on a cleared ground and utilized as a part of this experiment. Analyses were led in N.I.T Rourkela Community Hall which amid daytime in wonderful climate. The length of the passage, lp = 17.3 m. It might be noticed that despite the fact that walkers move along the corridor, information is gathered just in the shaded segment which is called observation section as indicated in Figure 3.1. The length of the observation segment, lo = 2 m and is built by raising two running poles at the section and way out lines of the observation section. The camera was situated at a separation of 10 m from the observation segment along the perpendicular bisector of the observation area to diminish parallax error. The width of the path in the straight area is 0.8 m; this is adequate for single file movement yet not for overtaking. In the curved section the width is expanded to a most extreme of 1.2 m through elliptic transit curve. The explanation behind expanding the width at the curved segment is that a curved part of 0.8 m width may reduce speed which is undesirable. The experiments are done on cleared ground. The subjects are consisting of NIT Rourkela students. The subjects are told not to surpass and not to push others. To acquire data at different densities, seven arrangements of experiment with number of subjects N = 1, 6, 12, 18, 24, 30, 36 are performed.

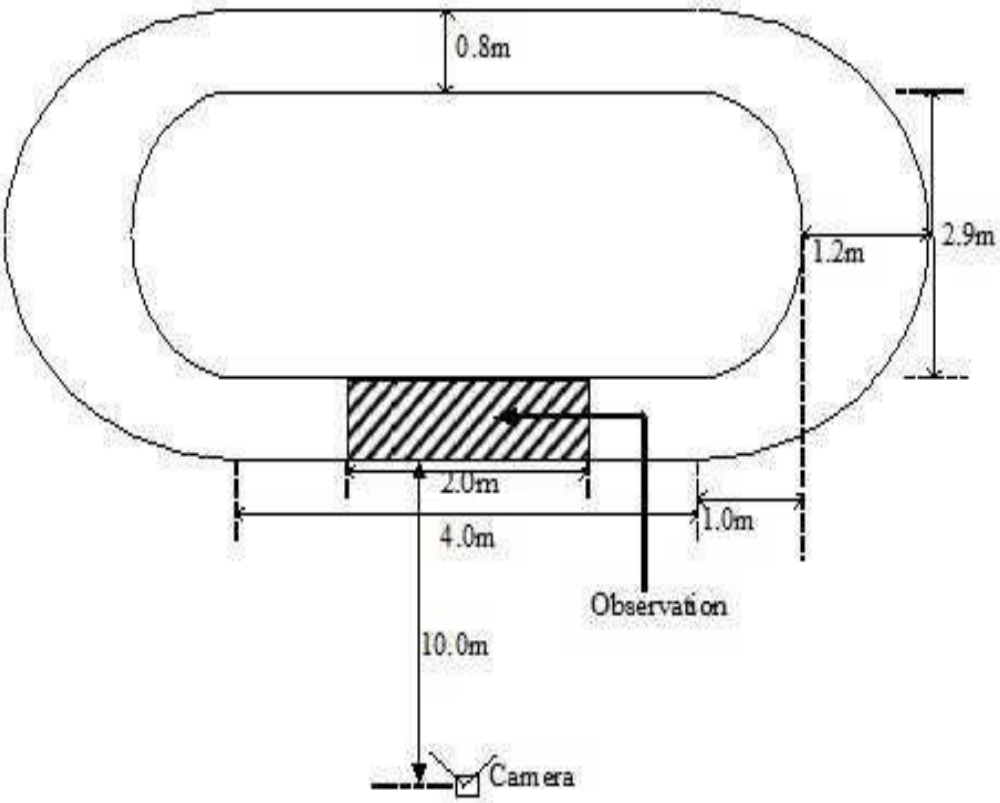

Figure 3.1: Sketch of the experimental setup for single file movement adapted from Chattaraj, Seyfried, and Chakroborty, 2009 [1]

For this experiment (with the exception of N = 1) all the subjects utilized as a part of that cycle were at first circulated consistently in the corridor in a steady progression. At that point the direction to begin was given to each subject goes around the corridor three times. After that an opening is molded in the closed corridor through which the subjects are permitted to leave and continue walking for a sufficient far separation far from the passage to avoid tailback impact. The subjects for the experiment consisted of both male and female graduate students of the N.I.T. Rourkela. The moving direction of the experiment was anticlockwise direction according to standard Indian design aspect. To show the gender and gender mix condition, the experiment was done on five different categories. The five different categories which were taken into consideration are:

1. All boys.
2. Two boys & One girl alternatively.
3. One boy & One girl alternatively.
4. One boy & two girls alternatively.
5. All girls.

Figures show the snapshots of the experiment 3.3,3.4,3.5,3.6,3.7. The experimental setup for this study is adopted from Chattaraj, Seyfried, and Chakroborty, (2009) and Chattaraj, U., Seyfried, A., Chakroborty, P., Biswal, M.K. (2013). All the shape and size of the trial setup like, length and the width of the corridor, the position and measurement of the estimation territory, the direction of the test persons, and also the estimation technique are precisely same for these tests. The moving direction is comparative however a contrast in the composition of the test subjects.

Figure 3.2: Snapshot for the run with N = 30 of N.I.T, Rourkela males

Figure 3.3: Snapshot for the run with N = 30 of N.I.T, Rourkela, Two boys & One girl Alternatively

Figure 3.4: Snapshot for the run with N = 30 of N.I.T, Rourkela, One boy & One girl alternatively

Figure 3.5: Snapshot for the run with N = 30 of N.I.T, Rourkela, One boy & two girls alternatively.

Figure 3.6: Snapshots for the run with N = 30 of N.I.T, Rourkela, All girls

3.2 DATA COLLECTION

In the first place to gather the velocity-density information, a digital video camcorder ((Mode: HXR- NX30E/NX30P, Make: Sony), Frame rate (25 frames/s) with Resolution (640 × 480) is set as indicated in figures show 3.1,3.2 recorded the movement of people on foot. In the test two ranging bars are set independently to find the rectangular measured segment indicated in fig. From the video data as indicated in fig, the snapshotof the observed section is found. To acquire the crossing time of the each person (say person p) from the rectangle area, passage time (t_p^{in}) and way out time (t_p^{out}) are noted.

Speed and density of individual person are obtained from these data sets. By these information set, speed, density for the individual person on foot is found. After acquire the density information set, the distance headway is obtained by the reciprocal of the density. As the people on foot are moving so slowly, proper accuracy was taken at the time of information gathering.

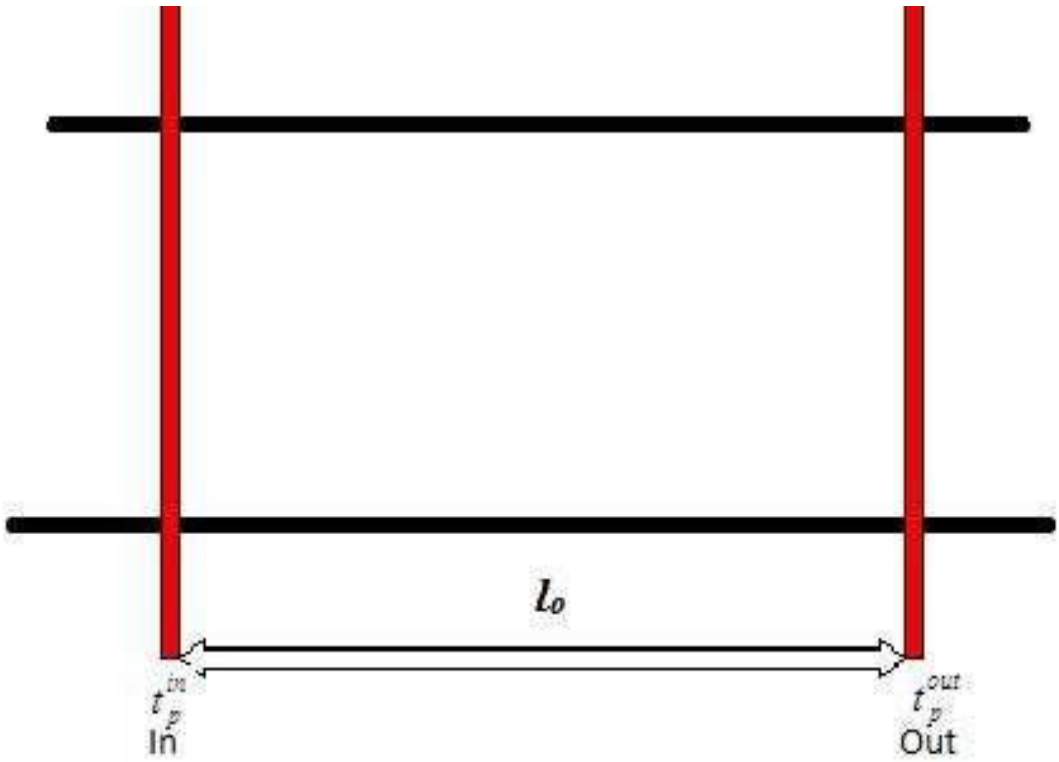

Figure 3.7: observed section for data collection

3.3 DATA DECODING

The information was decoded by playing the feature utilizing software Avidemux. For data decoding, results and discussions, Seyfried et al. (2005) was referred. As the entry time and exit time was noted from the video to obtained the speed and density data. The individual velocity is determined from the formula:

Individual velocities $= V_i^{man} = \dfrac{l_m}{t^{out} - t^{in}}$

Density = $\rho(t)^{man} = \sum_{t=1}^{N} \Theta i(t) / l_m$

$$\Theta i(t) = \begin{cases} \dfrac{t - t_i^{in}}{t_{i+1}^{in} - t_i^{in}} & t \in |t_i^{in}, t_{i+1}^{in}| \\ 1 & t \in |t_{i+1}^{in}, t_i^{out}| \\ \dfrac{t_{i+1}^{out} - t}{t_{i+1}^{out} - t_i^{out}} & t \in |t_i^{out}, t_{i+1}^{out}| \\ 0 & \text{otherwise} \end{cases}$$

Θ_i (t) gives the 'fraction' to which the space between person i and person i + 1 is inside.

(Adopted from Seyfried et al. (2005)

CHAPTER 4

ANALYSIS OF EMPIRICAL DATA AND RESULTS

In this part the data is examined and represented to show the result of gender and gendermix impacts in India. These outcomes are divided into five sections. In the first and second part results represent the fundamental relation (speed-density, distance headway-speed relation) of pedestrian flow. The third part represents the study on free flow speed of Indian pedestrian and fourth part represents the statistical analysis by hypothesis testing. In the fifth part results represent the ANOVA test to demonstrate the overall distinction exists in five unique classifications of experiment set.

4.1SPEED-DENSITY RELATIONSHIP

Figures 4.1, 4.2, 4.3, 4.4, 4.5 depict the relationship between speed and density for different categories. Speed-density relationship is the basic input to the pedestrian fundamental diagram. The speed (u)–density (k) was obtained in closed corridor condition obtained by five different categories of experiments such as

1. All boys
2. Two boys & One girl alternatively
3. One boy & One girl alternatively
4. One boy & two girls alternatively
5. All girls.

It is observed that when density is increasing, speed will be decreasing and vice versa. It is clearly noticeable from the graph that the speed-density relationship is non-linear in nature.

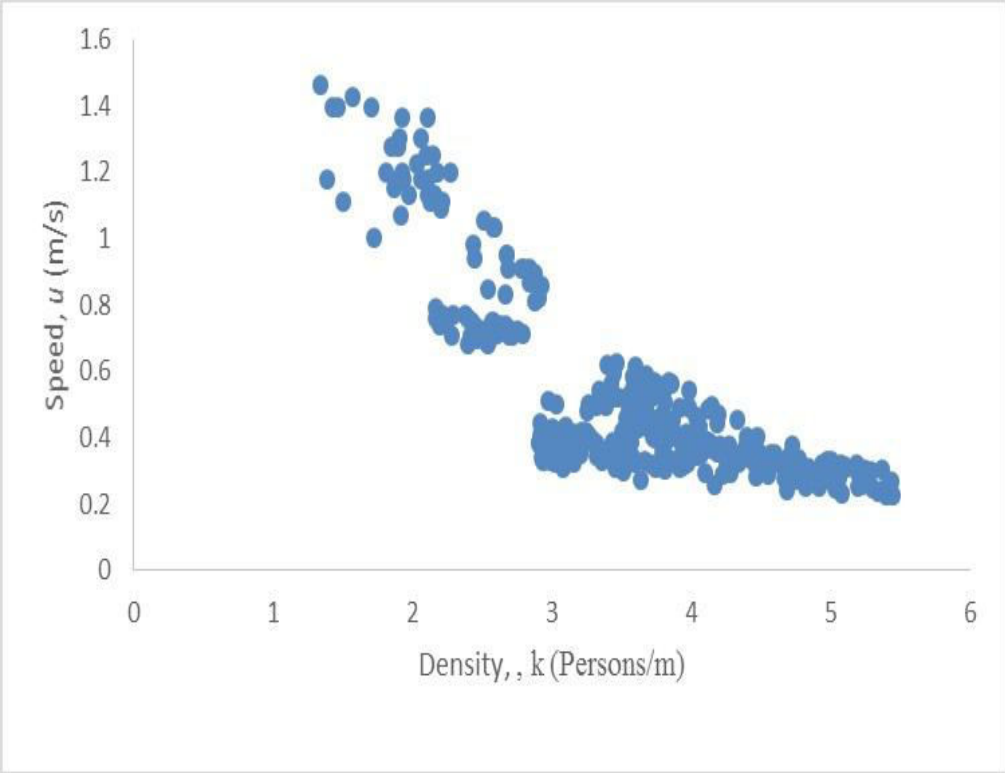

Figure 4.1: Speed-density plot for all boys

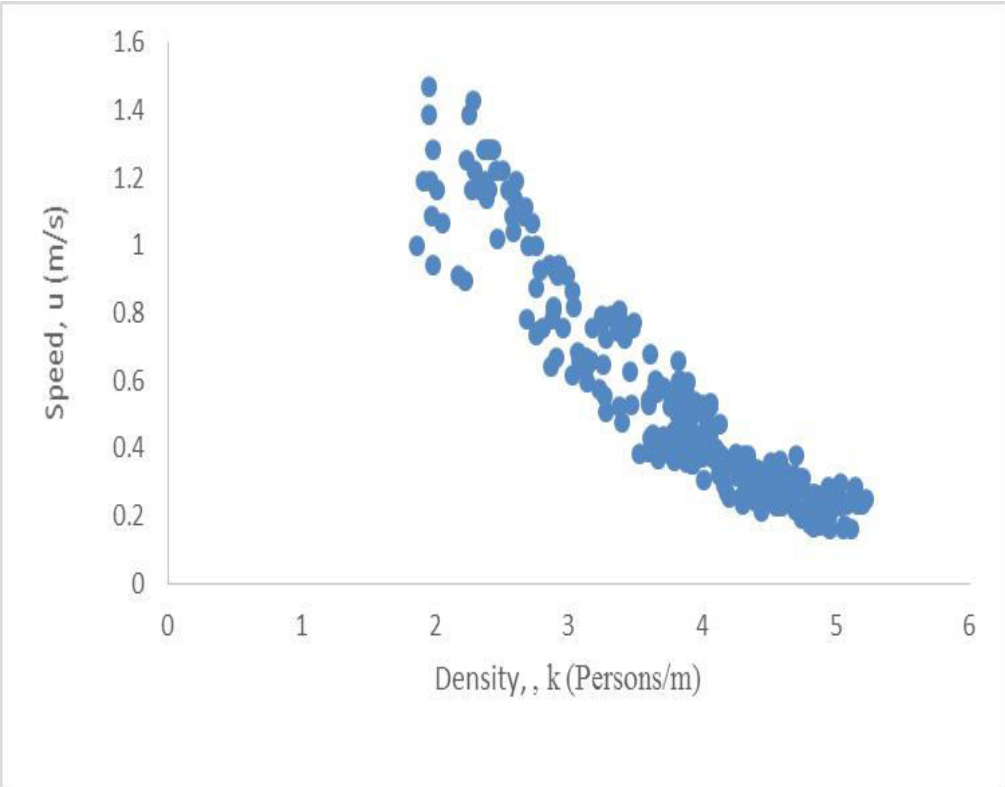

Figure 4.2: Speed-density plot for two boys and one girl alternatively

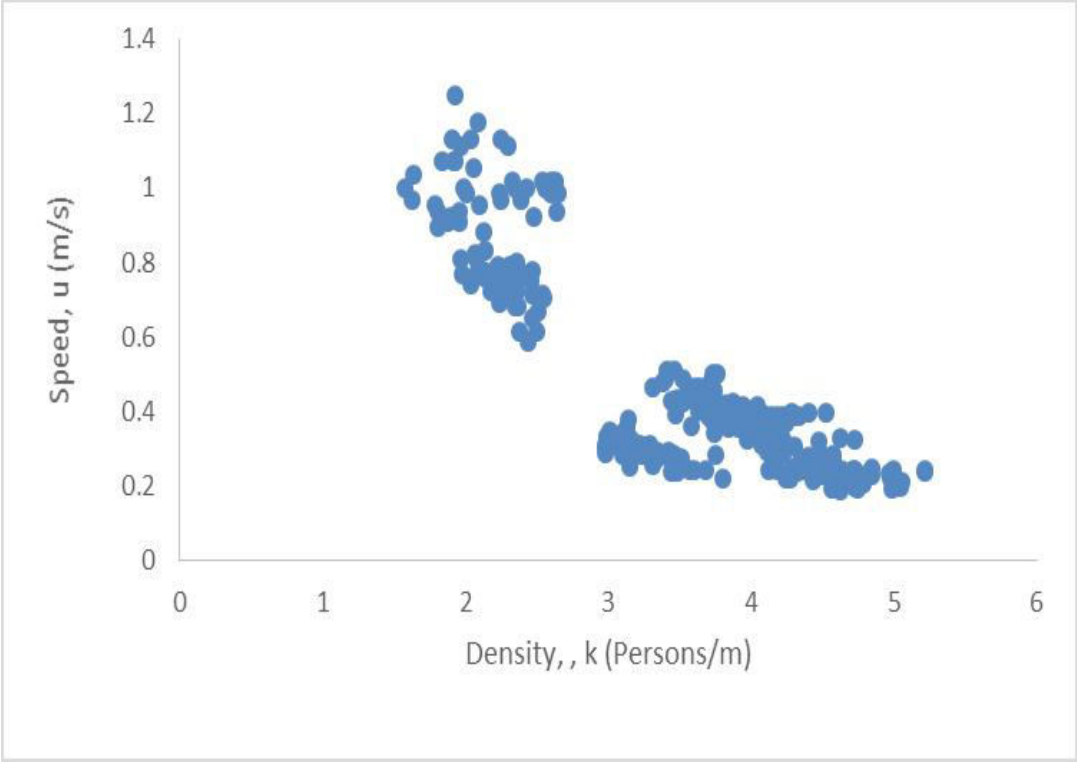

Figure 4.3: Speed-density for One boy and one girl alternatively

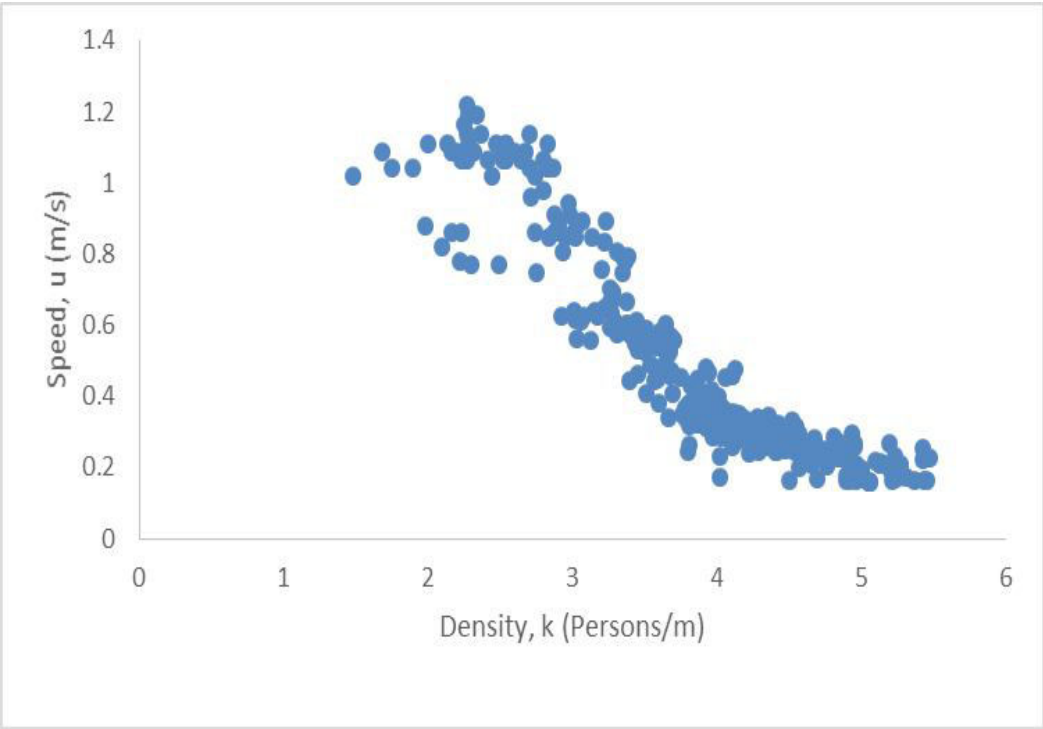

Figure 4.4: Speed-density for one boy and two girls alternatively

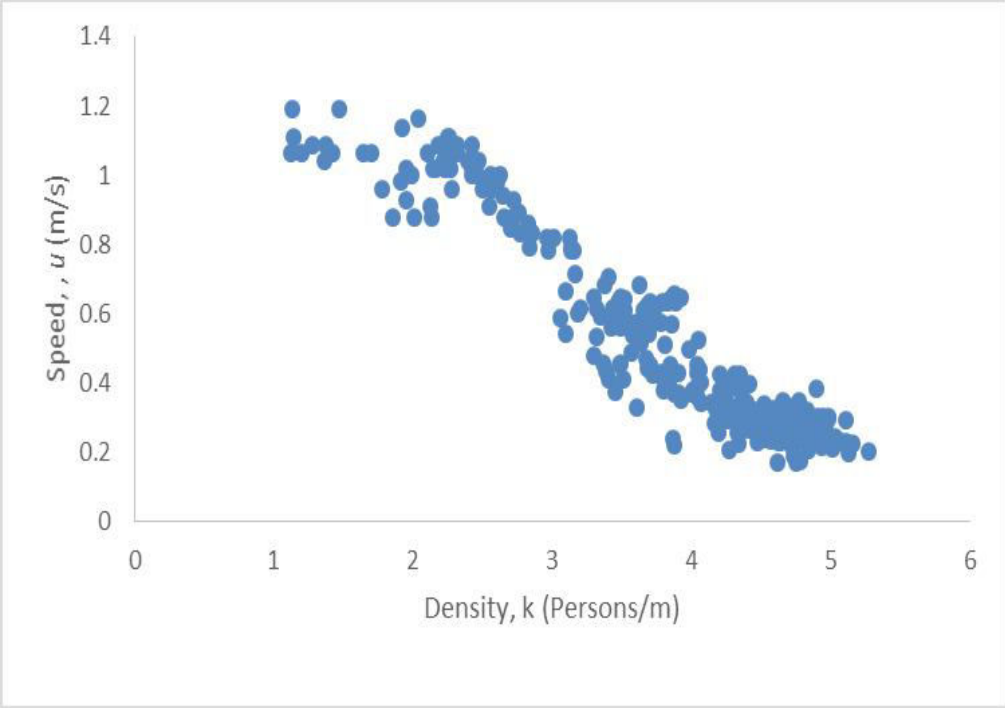

Figure 4.5: Speed-density for all girls

4.2 DISTANCE HEADWAY- SPEED RELATIONSHIP

Figures 4.6, 4.7, 4.8, 4.9, 4.10 show the relationship between the distance headway and speed. It is clearly noticeable from the speed-density graph that the speed-density relationship is non-linear in nature. So density were converted to distance headway by taking the reciprocal of speed data. For Statistical analysis it is required a linear fit curve, as the Distance headway – speed relationship is linear in nature so it is more persuadable than the speed-density relationship.

The distance headway (h)-speed (u) was obtained in closed corridor condition obtained by five different categories of experiments such as

1. All boys
2. Two boys & One girl alternatively
3. One boy & One girl alternatively
4. One boy & two girls alternatively
5. All girls.

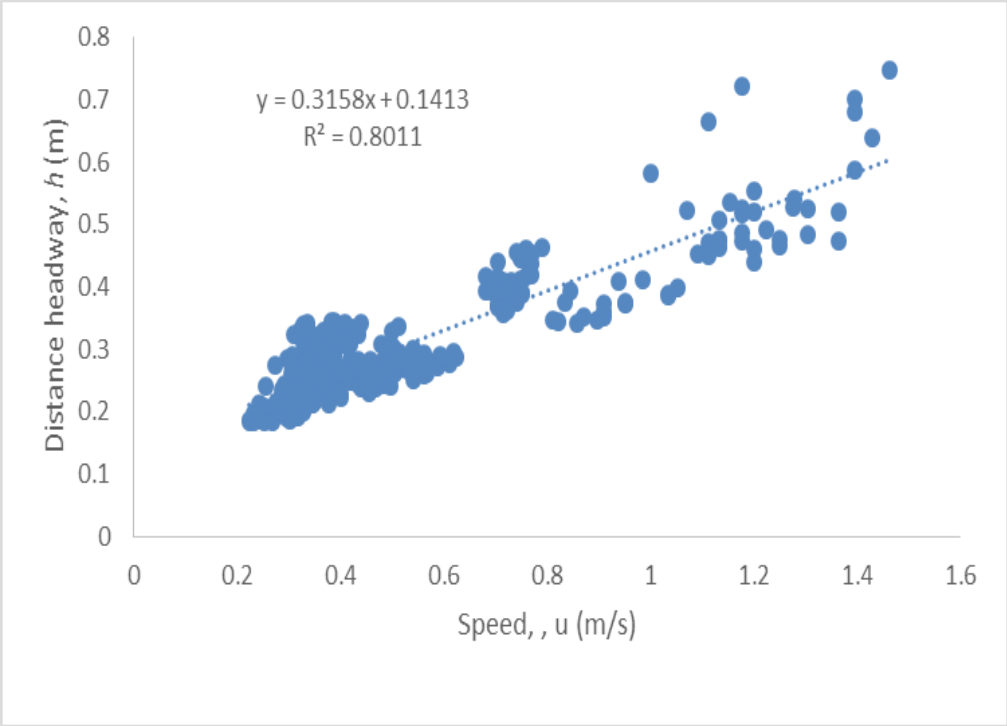

Figure 4.6: Distance headway- speed plot for all boys

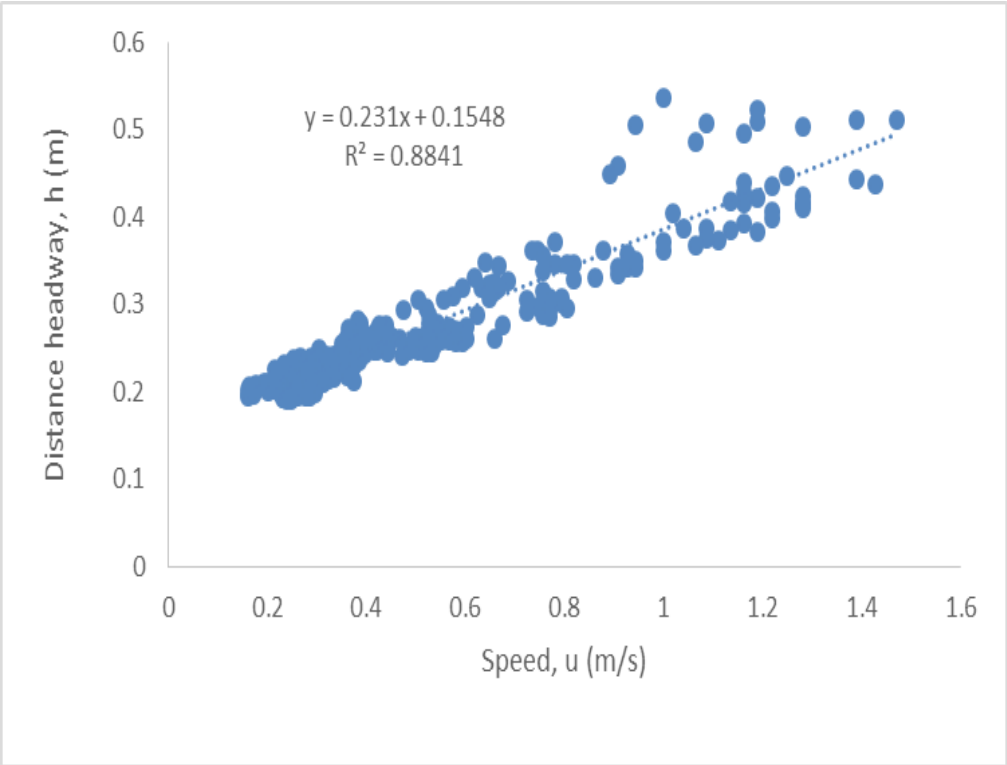

Figure 4.7: Distance headway- speed plot for two boys and one girl alternatively

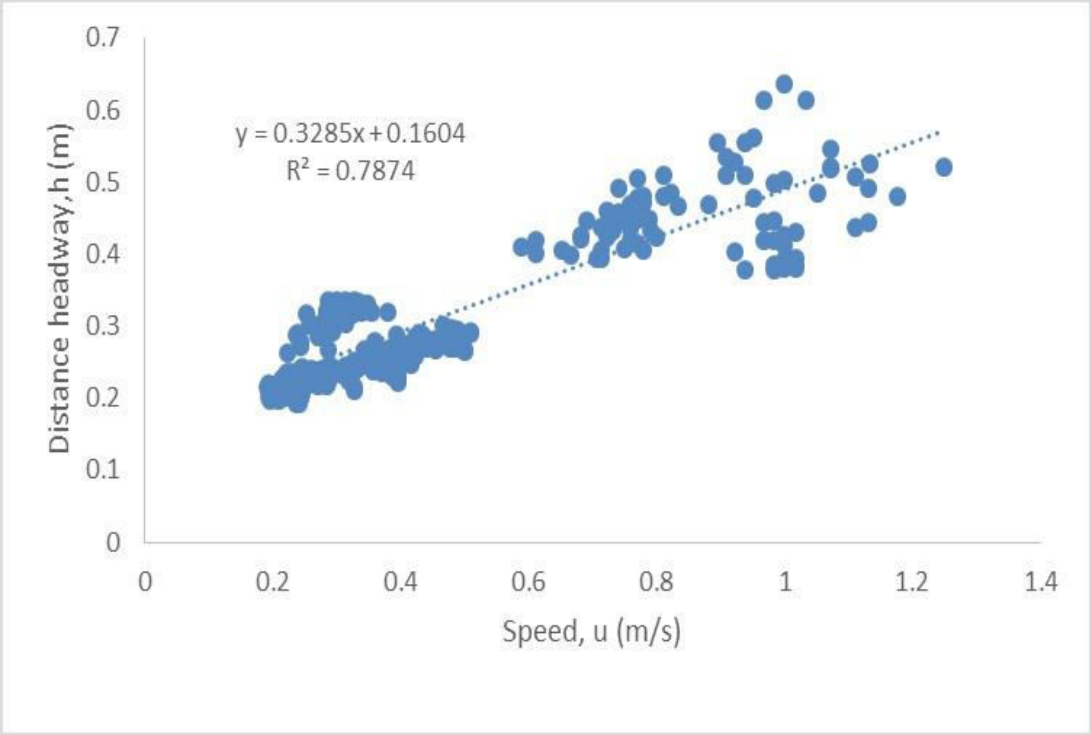

Figure 4.8: Distance headway- speed plot for one boy and one girl alternatively

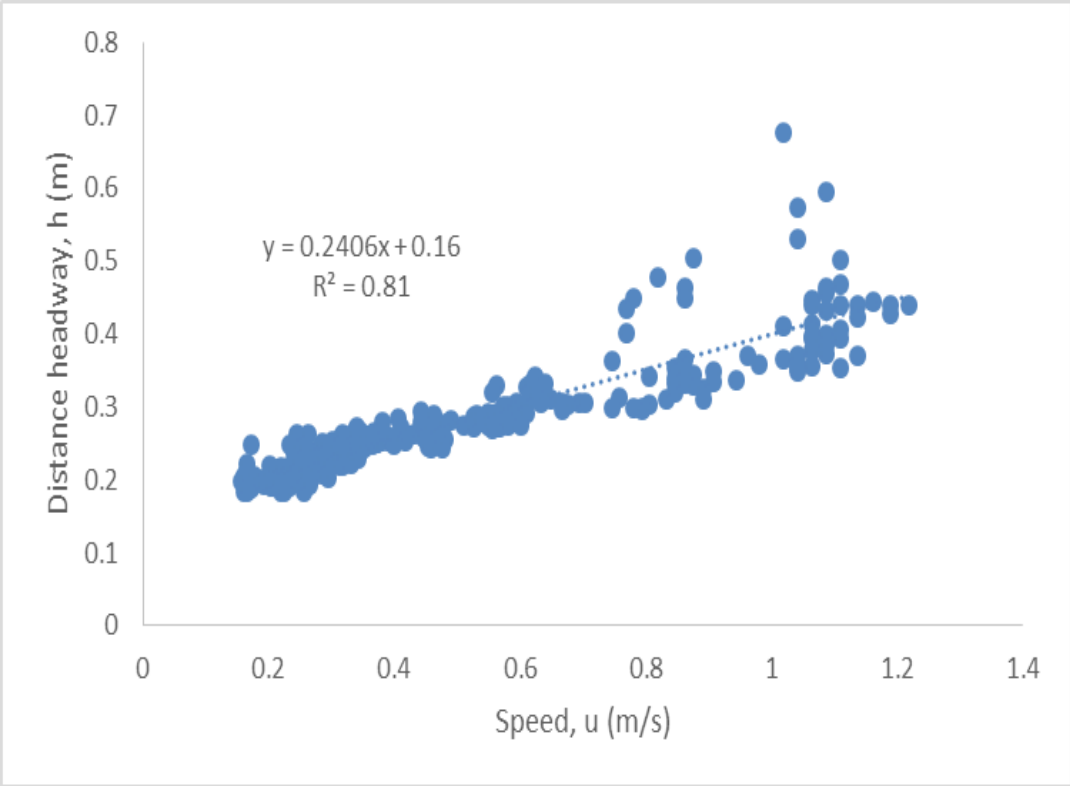

Figure 4.9: Distance headway- speed plot for one boy and two girls alternatively

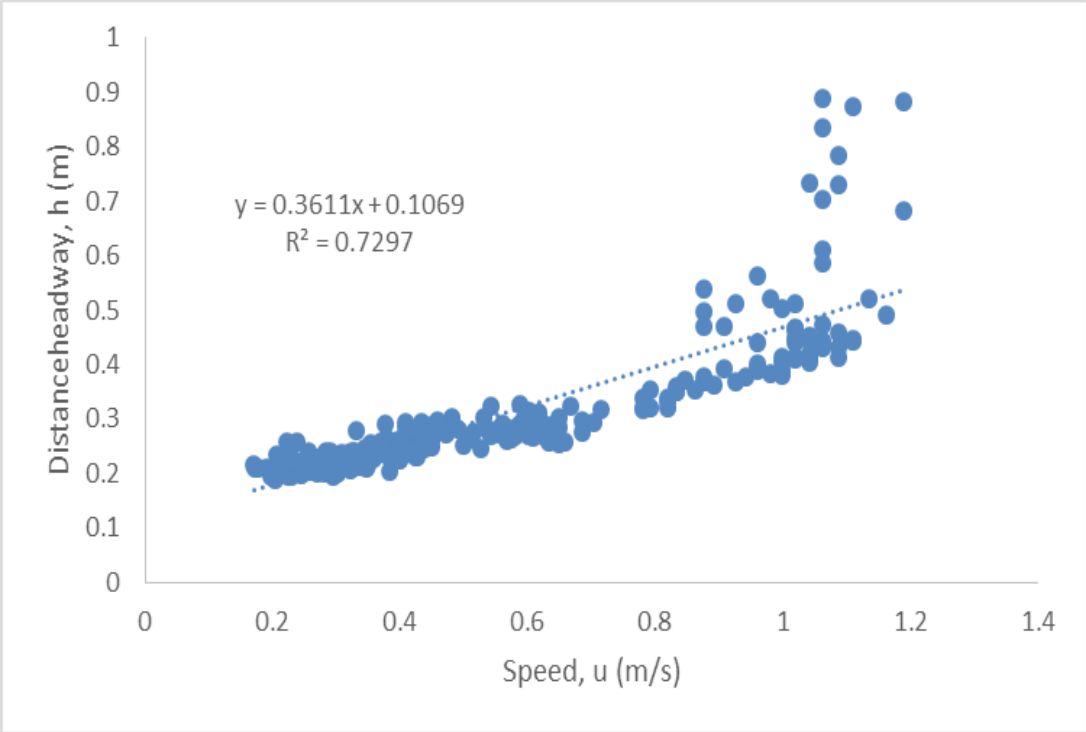

Figure 4.10: Distance headway- speed plot for all girls

4.3 STUDY ON FREE FLOW SPEED

Free-flow speed is the speed of a pedestrian when pedestrian movement is not interfered by other pedestrian or interrupted by any other conditions. The linear headway–speed (h–v) diagram of close corridor experiment can't give the free flow speed. However the information on free flow speed were gathered by making one and only individual move in the geometric corridor. From the above experiment it was found that the mean free flow speed of the boys is 1.27ms−1. Whereas the mean free flow speed of the girls are 1.24 ms−1.

4.4 STATISTICAL ANALYSIS BY HYPOTHESIS TESTING

A Z-test is a statistical test for which the distribution of the test statistic under the null hypothesis can be approximated by a normal distribution. Because of the central limit theorem, many test statistics are approximately normally distributed for large samples. For each significance level, the Z-test has a single critical value which makes it more convenient than

the Student's t-test which has separate critical values for each sample size. Therefore, many statistical tests can be conveniently performed as approximate Z-tests if the sample size is large or the population variance known. Hypothesis test was done toshow the statistical analysis.

Hypothesis test

$$z = \frac{\bar{x}_1 - \bar{x}_2 - \Delta}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

Where,
x = Standardized random variable
$\bar{x}$ = Mean of the data
σ = Population standard deviation.

Null hypothesis: H_0: $\mu_1 = \mu_2$

Or H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis: H_a : $\mu_1 \neq \mu_2$

Statistical analysis can be done by different hypothesis test but in this experiment as the number of data points is more so, z-test is conducted between two different categories of experiment out of five different categories, to show theimpacts of gender and gender mix condition. For statistical analysis by z- test, first slope and intercept of the fundamental diagram was studied. Tables 4.1, 4.2, 4.3, 4.4 shows the study of slope and intersection of fundamental diagram.

Table: 4.1 Study on intercept (a) and slope (b) of the fundamental

S. No	Data sets	Intercept (a)	Slope (b)	R^2	Data points
1	All boys	0.143	0.315	0.801	339
2	Two boys and one girl	0.154	0.231	0.884	298
3	One boy and one girl	0.16	0.328	0.787	316
4	One boy and Two	0.16	0.240	0.81	309

	girl				
5	All girls	0.107	0.361	0.729	306

Table 4.2: Z-test for intercept (a)

S. No	Data set	Z-observed	Z-critical	p-value	Result (Risk to reject null hy-pothesis)
1	(AB) and(2B and1G)	1.111	1.960	0.266	Can't R.N.H (26.65%)
2	(AB) and(1B and1G)	3.171	1.960	0.002	Reject NH (0.15%)
3	(AB) and(1B and2G)	2.016	1.960	0.044	Reject NH (4.38%)
4	(AB)and(AG)	1.079	1.960	0.281	Can't RNH (28.06%)
5	(2B and 1G) and (1B and 1G)	-1.813	1.960	0.070	Can't R.N.H (6.98%)
6	(2B and 1G) and (1B and 2G)	0.799	1.960	0.425	Can't R.N.H (42.41%)
7	(2B and 1G) and (AG)	0.081	1.960	0.935	Can't R.N.H (93.54%)
8	(1B and 1G) and (1B and 2G)	-1.026	1.960	0.305	Can't R.N.H (30.48%)
9	(1B and 1G) and (AG)	1.995	1.960	0.046	Reject NH (4.61%)
10	(1B and 1G) and AG	0.921	1.960	0.357	Can't R.N.H 35.70%

Here alpha is 5% (0.05) and the level of confidence is 95%..if alpha is more than p-value then the null hypothesis is rejected and the alternate hypothesis is accepted.

Table 4.3: Z-test for slope (b)

S. No	Data set	Z-observed	Z-critical	p-value	Result (Risk to reject null hy- pothesis)	
1	(AB) and(2B and1G)	5.384	1.960	<0.001	Reject N.H	0.01%
2	(AB) and(1B and1G)	2.423	1.960	0.032	Reject N.H	3.26%
3	(AB) and(1B and2G)	4.622	1.960	<0.0001	Reject N.H	0.01%
4	(AB)and(AG)	2.113	1.960	0.005	Reject N.H	3.46%
5	(2B and 1G) and	5.861	1.960	<0.001	Reject	0.01%

	(1B and 1G)				N.H	
6	(2B and 1G) and (1B and 2G)	-0.862	1.960	0.389	cant R.N.H	38.85%
7	(2B and 1G) and (AG)	2.357	1.960	0.018	Reject N.H	1.84%
8	(1B and 1G) and (1B and 2G)	5.097	1.960	<0.001	Reject N.H	0.01%
9	(1B and 1G) and (AG)	-2.489	1.960	0.013	Reject N.H	1.28%
10	(1B and 1G) and	1.702	1.960	0.089	Can't RNH	8.88%

Table 4.4: Final Z-test results

S. No	Data sets	Slope	Result	Interce -pt	Result	Final result
1	(AB) and (2B and	Reject N.H	Gender impact exist	R.N.H	Gender impact doesn't exist	Gender impact exist
2	(AB) and (1B and1G)	Reject N.H	Gender impact exist	Reject N.H	Gender impact exist	Gender impact exist
3	(AB) and (1B and 1G)	Reject N.H	Gender impact exist	Reject N.H	Gender Impact exist	Gender impact exist
4	(AB) and (1B and 2G)	Reject N.H	Gender impact exist	Cant R.N.H	Gender Impact doesnt exist	Gender impact exist
5	(AB) and(AG)	Reject N.H	Gender impact exist	Cant R.N.H	Gender impact doesnt exist	Gender impact exist
6	(2B and 1G) and (1B and 1G)	Can't Reject N.H	Gender impact doesnt exist	Cant R.N.H	Gender impact doesnt exist	Gender Impact doesn't exist
7	(2B and 1G) and (1B and 2G)	R.N.H	Gender impact exist	Cant R.N.H	Gender impact doesnt exist	Gender impact exist
8	(2B and 1G) and (AG)	Reject N.H	Gender impact exist	Cant R.N.H	Gender impact doesnt exist	Gender impact exist
9	(1B and 1G) and (1B and 2G)	Reject N.H	Gender impact exist	Reject N.H	Gender impact exist	Gender impact exist
10	(1B and 1G) and	Can't Reject	Gender impact	Can't R.N.H	Gender impact	Gender doesn't

	(AG)	N.H	doesn't exist		doesn't exist	impact exist

From the above z test, it was clearly noticed that the impacts of distance headway was existed in different gender mix condition where as the speed was all most equal indifferent gender mix conditions. From the z-test result, the impact of speed was noticed in three cases and these cases were

i) (All boys) and (one boy and one girl)

ii) (All boys) and (two girl and one boy)

iii) (all girl) and (1boy and one girl).

In the first case, the speed of the all boys was greater than the speed of the one boy and one girl mixcondition, because the presence of skewness in mix pedestrian condition. In one boy and one girl condition the speed was less because in this condition both girls and boys were face difficulties to walk and they were faced more challenges to walk.

In the second case, the speed of the all boys condition was greater than the two girl and one boy mix condition because in all boys condition, boys were walk freely without any psychological challenge but in two girl and one boy mix condition, the speed was less becausethe speed of the boys were less when there is double number of girls were present in the pedestrian crowd.

The third case was similar with the first case.

Here the speed of the all girls was greater than the speed of the one boy and one girl mix condition, because the presence of skewness in mix pedestrian condition. In one boy and one girl condition the speed was less because in this condition both girls and boys were face difficulties to walk and they were faced more challenges to walk. From the z-test result, it was also noticed that the impact of distance headway was existed in all the cases except

i) (two boy and one girl) and (two girl and one boy)

ii) (all girls) and (two girl and one boy).

In the first case, (two boy and one girl) and (two girl and one boy) are the exact opposite arrangement so, the space between the pedestrian were remain same in both the cases so the distance headway was not different in this case.

In second case, the distance headway between (all girls) and (two girls and one boy), does not show any difference because the distance headway between two girls were less where as boys never faced more challenges in such conditions so the impact of distance headway was not existed in this case.

4.5 ONE WAY ANOVA TEST FOR SIGNIFICANCE OF VARIANCE BETWEEN FIVE DIFFERENT CATEGORIES

One-way analysis of variance is a technique in statistics, used to compare means of three or more samples using the F distribution. This technique is used only for numerical data. It is used to find the significant relationship between various variables. Tables 4.5, 4.6 depict that the information about the ANOVA test for speed and ANOVA test for distance headway.

Table 4.5: ANOVA test for Distance headway

Test type	p-value	p-value summary	P<0.05
Brown- forsythe test	<0.0001	****	Yes
Bartlett's test	<0.0001	****	Yes

Here **** means highly significant.

Table 4.6: ANOVA test for Speed

Test type	p-value	p-value summary	P<0.05
Brown- forsythe test	0.255	NS	No
Bartlett's test	0.1316	NS	No

Here NS- not significant

4.5.1 ANOVA FOR MULTIPLE FACTORS

ANOVA sums up to the investigation of the impacts of various elements. At the point when the analysis incorporates perceptions at all mixes of levels of every component, it is termed factorial. Factorial trials are more effective than a progression of single component analyses and the effectiveness develops as the quantity of components increments. Thus, factorial experiments are vigorously utilized. The utilization of ANOVA to study the impacts of various elements has a complexity. In a 3-way ANOVA with elements x, y and z, the ANOVA model incorporates terms for the fundamental impacts (x, y, z) and terms for collaborations (xy, xz, yz, xyz). All terms requre hypothesis tests. The multiplication of cooperation terms expands the danger that a few theory test will deliver a false positive by shot. Luckily, experience says that high order interaction are rare.[verification needed] The capacity to recognize associations is a noteworthy point of preference of numerous element ANOVA. Testing one element at a time hides interactions, but produces apparently inconsistent experimental results.

Brown-Forsythe- Shows the F test from an ANOVA where the response is the absolute value of the difference of each observation and the group median (Brown and Forsythe1974).

Bartlett- Compares the weighted arithmetic average of the sample variances to the weighted geometric average of the sample variances. The geometric average is always less than or equal to the arithmetic average with equality holding only when all sample variances are equal. The more variation there is among the group variances, the more these two averages differ. A function of these two averages is created, which approximates a $q2$-distribution (or in fact, an F distribution under a certain formulation). Large values correspond to large values of the arithmetic or geometric ratio, and therefore to widely varying group variances.

From the above one-way ANOVA test, it was clearly observed that the speed was almost equal for five different categories but the distance headway was not same for the five different categories, because distance headway represented the distance between the two successive pedestrians in a group. When there was both male and female, the speed was almost same but the space between them was not same. Everyone maintained noticeable distance in mix gender condition because of the human

behavior. So the efficiency of the pedestrian movement decreases in gender mix condition as they try to maintain distance from each other.

CHAPTER 5

SUMMARY, CONCLUSION AND FUTURE SCOPE

5.1 SUMMARY

In this study, five experiments on single file pedestrian movement was directed in N.I.T., Rourkela of India to demonstrate the effects of gender impact. A test set-up was constructed to carry out the experiment as said in Chattaraj et al. (2009). Different groups of walkers was utilized for this test as a subject. At that point the direction was given to entry group of subjects to goes around the geometric corridor three times. After moving these subjects three rounds along the geometric corridor, an opening was formed in the shut passageway to keep the walkers out. In the test set-up, two running bars are set independently to find the rectangular measured area, from which video data was taken for data decoding process. Then the fundamental relation was established using the video data and by statistical and hypothesis testing the impact of gender effect was determined.

5.2 CONCLUSION

In this thesis, the experiments on pedestrian motion under closed boundary condition using the single file pedestrian motion are conducted to observe the impacts of gender and gender mix condition on fundamental diagram.The objective of this study to show the impacts of gender effect on pedestrian fundamental diagram using different hypothesis test.The results were compared statistically using z-test and ANOVA test. The following observation is found from this study: The Mean free flow speed is $1.27ms^{-1}$ for male pedestrian and it is$1.24ms^{-1}$ for female pedestrians. While walking females are more conscious about their private space than the males. Security distance is introduced to explain the private space concept. From this experiment it appears that the male group of test persons are less concerned about their personal space and thus the security distance is smaller compared to the female group. It is clearly notice that the impacts of gender is existed in pedestrian crowd flow and mostly gender condition affects the space between the pedestrians present in mix pedestrian traffic.

5.3 FUTURE WORK

From this thesis work, it is clearly observed that; fundamental diagram is significantly different for different gender mix condition.

Thus, it is expected that, in future, if gender mix condition can be compared with some other factors like age, at different time during a day and weather condition so as to find the more clarity in the pedestrian behavior.

In the present experimental work, fundamental diagram of different gender mix condition is compared. In the future, the same study can be conducted with different sample size of mixed gender pedestrians to see whether the impact is exist or not.

In the future, the same study can be conducted with different geometric size of the corridor to see whether the impact of corridor exist with the gender effect or not.

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