European Transport \ Trasporti Europei (2017) Issue 65, Paper n° 6, ISSN 1825-3997

# Studies on Impacts of Gender Mix on Pedestrian Fundamental Diagram

**Ujjal Chattaraj[1*], DharitriKahali[2], Amit Kumar Das[3]**

[1]*Assistant Professor,Department of Civil Engineering,National Institute of Technology, Rourkela,India*
[2]*PG Student, Department of Civil Engineering,National Institute of Technology, Rourkela,India*
[3]*Reseach Scholar, Department of Civil Engineering,National Institute of Technology, Rourkela,India*

**Abstract**

Various approaches like field data collection, conduction of controlled tests, experimental observations and pedestrian models are used to study the pedestrian movement. These methods aim at the development of fundamental diagram. Various factors which affect the pedestrian movement need to be studied so as to give better pedestrian facilities and design spaces for human circulation. An attempt is made to study the impact of gender and gender mix condition at different densities, on the fundamental diagram. Simple system of experiment known as the movement of pedestrians along a line under closed boundary condition (single file movement) is chosen with five different gender mix condition. The mean free flow speed of male pedestrian is found to be 1.27m/s and 1.24m/s for female pedestrians. This difference in speed can be attributed to the fact that females are more concerned about their private space rather than male, while walking. Statistical hypothesis tests are conducted to quantitatively discover existence of speed difference and acclaim the gender and gender mix impact in fundamental diagram.

*Keywords:*Fundamental diagram, pedestrian facilities, gender mix, single file movement, mean free flow speed, statistical hypothesis.

## 1. Introduction

Walking is the most simple and widely used mode of transportation available to the human society. The facility of walking is utilized by almost all the person in the world. Every journey begins with walking and terminates with walking. Walking serves as a connecting link between areas utilized and mechanised travel. India being a developing nation, it needs adequate pedestrian facilities so as to provide better design spaces for human circulation and pedestrian safety. In the present study an attempt has been made to empirically study the behaviour of Indian pedestrians based on gender variation. Different types of experiments can be conducted so as to study the motion of pedestrian. Single file experiments on pedestrian movement are conducted to study the impact of space between pedestrian in the direction of motion on pedestrian speed. In order to study the effects of gender and gender mix condition on pedestrian fundamental

* Corresponding author: UjjalChattaraj (chattaraju@nitrkl.ac.in)

diagram, speed, volume and density are necessary to study as they are the basic parameters of any traffic flow and it helps to add to the knowledge of stream qualities. In the present study, pedestrian fundamental diagram is used to detect the impacts of gender and gender mix condition in pedestrian flow. Macroscopic and mesoscopic data collected from experiments are used to study the speed-density relation of pedestrian and gender effect on pedestrian fundamental diagram. Hence the pedestrian characteristics like speed, density and distance headway will be compared between different gender and gender mix conditions to study the differences which would prove useful to design different pedestrian facilities in Indian context.

## 2. Literature Survey

Hankin and Wright (1958) studied the flow of passengers in subways, including the effect of constrictions such as stairs and corners so as to contribute and set new standards for design of new facilities for pedestrians. The researchers pointed out that pedestrians move slowly on stairs as compared on subways. Stairs form bottleneck under full load condition. When subways become crowded, the pedestrian movement is slowed down unconsciously so as to avoid colliding into other pedestrians. Any further increase in volume would result in reduced speed and increased discomfort. Oeding (1963) studied the relationship of speed, flow and density for different types of pedestrians i.e. people on walk for work, sports, shopping etc. The author conducted experiment to understand the pedestrian behaviour and characteristics under mixed traffic condition. Older (1968) investigated the fundamental parameters of pedestrian flow i.e. speed and density. Movement of pedestrians on footways in shopping streets were studied. With an increase in density, the speed of fast moving pedestrians reduce as compared to slower ones, hence the range of speed available to pedestrians reduce. People are likely to move on carriageway, as the footway becomes congested. Speed-density and flow-density relations are slightly different for narrow footways and wider footways for the same density. Speeds are higher for narrow footways as compared to wider footways. Pedestrians make efficient use of narrow footways rather than wide footways. Hoel (1968) found that environmental factors like time of the day; temperature etc. affects the travel speed of pedestrians. A variation in the rate of speed was found between male and female pedestrians. Navin and Wheeler (1969) stated that two way flow reduces the capacity of a sidewalk at higher concentration. Greater is the orderly pattern of walking greater is the flow per unit width. With an increase in density of pedestrian traffic in opposite direction, the flow rate and speed of pedestrian decreases. Polus et al. (1983) studied properties and characteristics of pedestrian flow on sidewalks. Increase in pedestrian density reduced the walking speed significantly. Male pedestrians walked with higher speeds as compared to female pedestrians. Tanaboriboon et al. (1986) investigated the walking rate of Singaporean. It was found that Singaporean have lower walking rate than American people. The maximum flow rate obtained for Singaporean is higher as compare to western countries. Mori and Tsukaguchi (1987) proposed evaluating ordinary sidewalks by two different methods i.e. using pedestrian behaviour and pedestrian opinion. Level of service of sidewalks can be evaluated using density and sidewalk width as parameters. Pedestrian awareness of sidewalks can be used as another parameter to evaluate sidewalks. The first approach is used for sidewalks with heavy pedestrian traffic and the latter is used for light pedestrian traffic. Morral et al. (1991) compared the walking speed, flow and density of pedestrians in Colombo with Calgary, Canada and other Asian countries for sidewalks

of varying widths. The researchers indicated that speeds of pedestrians of Asian countries are significantly lower as compared in Calgary, Canada. These differences in pedestrian characteristics may be attributed to cultural differences. Tanaboriboon (1991), compared the walking rates of pedestrians of Bangkok and compared with those of western standards and findings of other Asian countries. Study reveals that Asian pedestrians walk slower as compared to Western counterparts. Hence separate design standards need to be developed for pedestrian facilities in Asian countries.

Alexander Mintz (1951) conducted experiment to study the non-adaptive group behaviour. The researcher concluded that under panic producing situations, cooperative behaviour is essential for success and is rewarding to individual as long as everybody cooperates. Once the cooperative pattern of behaviour is disturbed, competitive situation develops, which may lead to disaster. Hoogendoorn and Daamen (2005) conducted laboratory experiments to obtain qualitative results on pedestrian flow. Variables like free speed, walking direction, density and bottlenecks were considered. It was observed that within a bottleneck, pedestrians do not walk next to each other; rather they "zip" in an efficient way. It was also seen that when pedestrians come closer to the bottleneck, they try to reach the bottleneck more actively and prevent other pedestrians to use the available empty space to pass the bottleneck as soon as possible. Isobe et al. (2004) investigated pedestrian counter flow taking into account pattern formation and jamming transition. Experimental results were compared with simulation results. It was confirmed that the arrival time obtained from experiment is consistent with simulation and jamming transition does not occur in the experiment because of finite size effect. Seyfried et al. (2005) conducted experiment with single file movement of pedestrians. The obtained experimental results were compared with results obtained from literature for movement in a plane. The result showed a linear relation between velocity and inverse of density. Moreover, internal friction and other lateral interferences which were excluded in single file movement had no influence on the density-velocity relation for the considered density domains. Kretz et al. (2006) conducted experiments on bottleneck and represented the results in the form of total time, fluxes, specific fluxes, and time gaps. It was observed that width and specific flux are inversely proportional when one person can pass at a time and attains a steady state with increase in bottleneck width. Seyfried et al. (2009) conducted experimental study on unidirectional pedestrian flow through bottlenecks. It was confirmed from the study that the flow and width are linearly dependent on each other for different types of bottlenecks. Chattaraj et al. (2009) conducted experiment on pedestrian streams in corridors to compare the fundamental diagrams of pedestrian across culture. The researchers confirmed that speed of Indian test persons is less dependent on density than the speed of German test persons. The unordered behaviour of Indians is more effective than the ordered behaviour of Germans. This may be attributed to difference in their self-organizing behaviour.

## 3. Data collection and Data Extraction

Elements like age, sex, physical wellness, pedestrian interaction and geometry of the facility affects studies for characterising the qualities of pedestrian stream. Five similar types of experiments are conducted in this study. All the five sets of experiments are carried at NIT Rourkela to study the impact of space between pedestrian 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. Single file experiment on pedestrian movement is envisioned to understand the variety in speed and density in pedestrian's stream of different gender group. Tests are designed where decisions of objectives are given to people on foot and their movement concentrated on keeping in mind the destination to see the impact competing objectives have on pedestrian movement.

### 3.1. Experimental setup for single file movement

The experiment corridor is built up using chairs and ropes. The size and shape of the experiment corridor is same as mentioned by Seyfried et al. (2005) and Chattaraj et al. (2009).The experiment was carried at NIT Rourkela community hall during day time on a clear ground and on a fair weather. The length of the passage, $l_p$ is 17.3m. Despite the movement of the pedestrian throughout the length of the passage, information is gathered only for the shaded segment which is called observation section. The length of the observation section $l_o$ is 2.0m and is built by raising two running poles at the section and way out lines of the observation section. The camera was placed at a distance of 10m from the observation section along the perpendicular bisector so as to minimise the parallax error. The width of the path in the straight area is 0.8m and is adequate for single file movement but not for overtaking. In the curved section the width is expanded to 1.2m through elliptic transit curve. A curved part of 0.8m width may reduce the speed of the pedestrians which is undesirable. The subjects (pedestrians) consisted of male and female graduate students of NIT Rourkela. The subjects were instructed not to surpass and not to push each other. In order to obtain data at different densities, seven arrangements of experiments with number of subjects N=1, 6, 12, 18, 24, 30, 36 are performed.

For this experiment (with the exception of N=1) all the subjects were circulated consistently in the corridor in a steady progression. Each subject goes around the corridor three times. An opening is created in the closed corridor through which the subjects are allowed to leave and continue walking for a sufficient distance far away from the passage to avoid tailback effect. The direction of movement for the subjects was fixed to be 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 taken into consideration are:

a) All boys
b) Two boys and one girl alternately
c) One boy and one girl alternately
d) One boy and two girls alternately
e) All girls

Figures 1 and 2 show the snapshots of the experiment for the cases mentioned in (b) and (e), i.e., "two boys and one girl alternately" and "all girls." The experimental setup for this study is adopted from Seyfried et al. (2005) and Chattaraj et al. (2009). The shape and size of the trial setup like the length and width of the corridor, position and measurement of the observation section, the direction of the movement of the test persons and also the estimation techniques are precisely the same for these tests. The moving direction is comparative however there is a contrast in the composition of the subjects.

Figure 1: Snapshot for the run with N=30 (two boys and one girl alternately)

Figure 2: Snapshot for the run with N=30 (all girls)

### 3.2. Data Collection

In order to gather information on speed and density, a video camera (Model: HXR-NX30E/NX30P, Make: Sony), frame rate (25frames/sec) with resolution (640X480) was used. Two ranging rods were set independently to make a rectangular measured section. In order to obtain the crossing time of each person (say person p) from the rectangular area passage time $\left(t_p^{in}\right)$ and way out time $\left(t_p^{out}\right)$ are noted(Figure 3). Using the video data, speed and density of individual person are noted. Distance headway is obtained by reciprocating the density values. As the speed of the pedestrians is low, proper care was taken to maintain accuracy during information gathering.

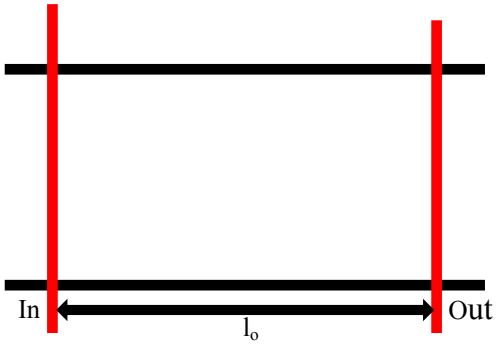


Figure 3: Observed section for data collection

### 3.3. Data Decoding

The video data was decoded using Avidemux software. References for data decoding was taken from Chattaraj et al. (2009). Entry time and exit time was noted from the video to obtain the speed and density data. Speed of individual pedestrian p in the observation section up is determined using the following formula

$$u_p = \frac{l_o}{t_p^{out} - t_p^{in}} \quad (1)$$

Density in a frame kf is calculated from the expression given below

$$k_f = \frac{N_f}{l_o} \quad (2)$$

where, Nf is the number of pedestrians in frame “f”.
kp is calculated as

$$k_p = \frac{\sum_{f=1}^{F} k_f}{F} \quad (3)$$

Where, F is the total number of frames for which kf is observed during time interval $t_p^{out} - t_p^{in}$ and can be obtained as $\Phi\left(t_p^{out} - t_p^{in}\right)$, where $\Phi$ is the frame rate of the camera (here $\Phi$=25 frames/second). Reciprocal of kp gives the average distance headway.

## 4. Results and Discussion

The data obtained is analysed and represented to show the result of gender and gender mix impacts in India.

### 4.1. Speed-Density Relation

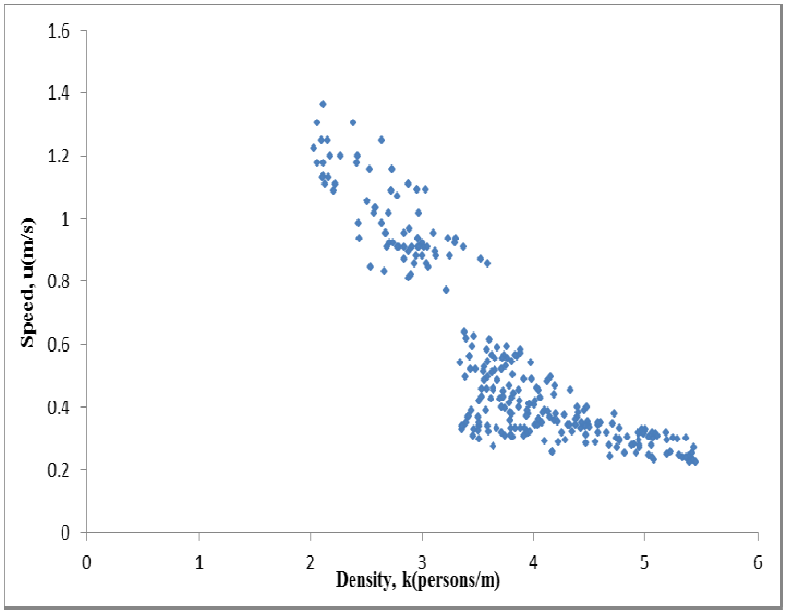


Figure4: Speed Density plot for all boys

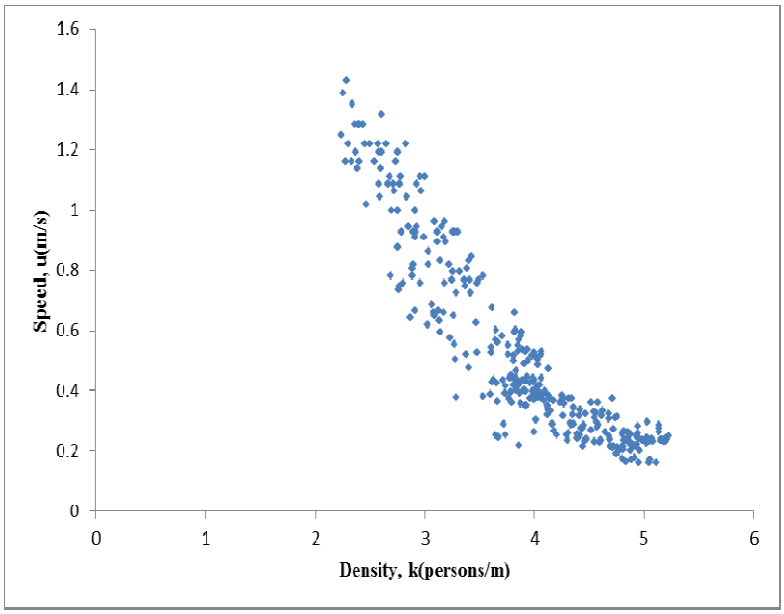

Figure5: Speed Density plot for two boys and one girl alternately

Speed-density relation is the basic input to pedestrian fundamental diagram. Figures 4 and 5 represent the relationship between speed and density for two of the cases, namely, "all boys" and "two boys and one girl alternately." It can be clearly seen from the curves that with an increase in density, speed decreases. Furthermore, the speed-density relationship obtained is found to be non-linear in nature.

### 4.2. Distance headway-speed relationship

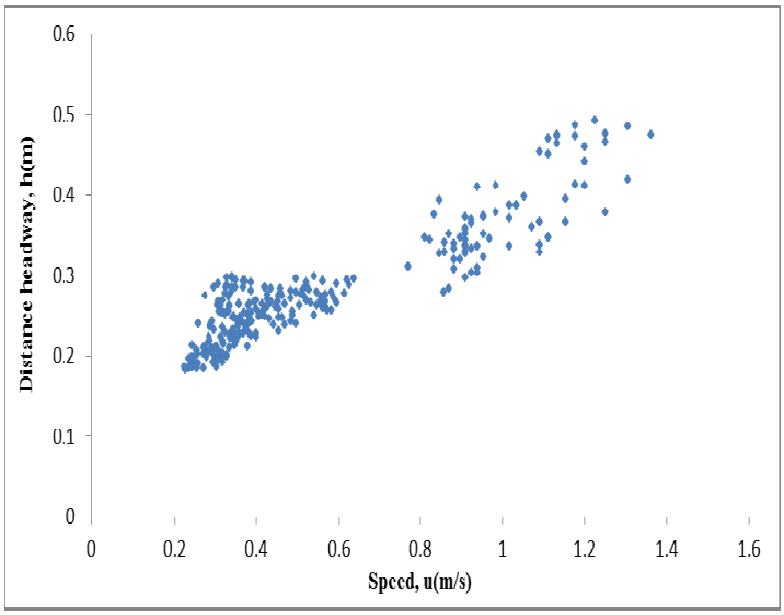


Figure6: Distance headway-Speed plot for all boys

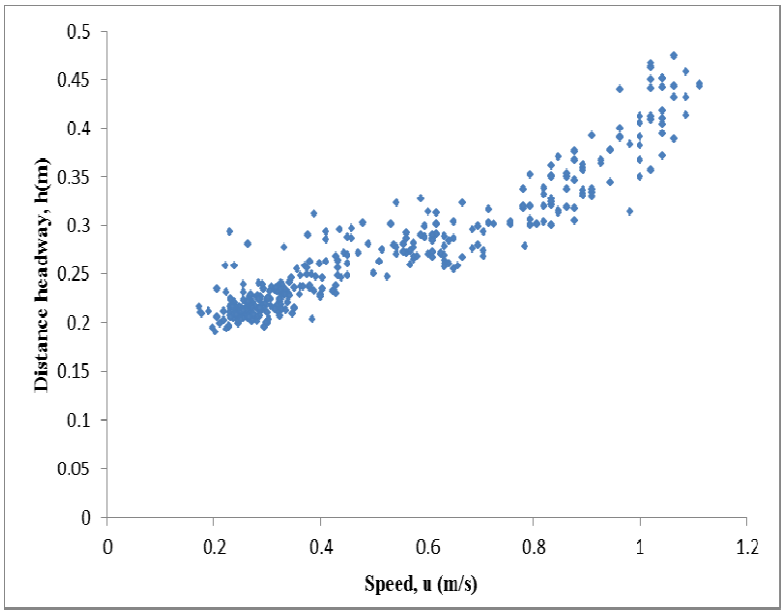


Figure7: Distance headway-Speed plot for all girls

Figures 6, 7, 8, 9 and 10show the relationship between distance headway and speed for all the five cases mentioned earlier. The density was converted to distance headway by taking the reciprocal of it. For statistical analysis, a linear fitting curve is essential. As the distance headway-speed curve is linear in nature, it is more precise than speed-density curve.

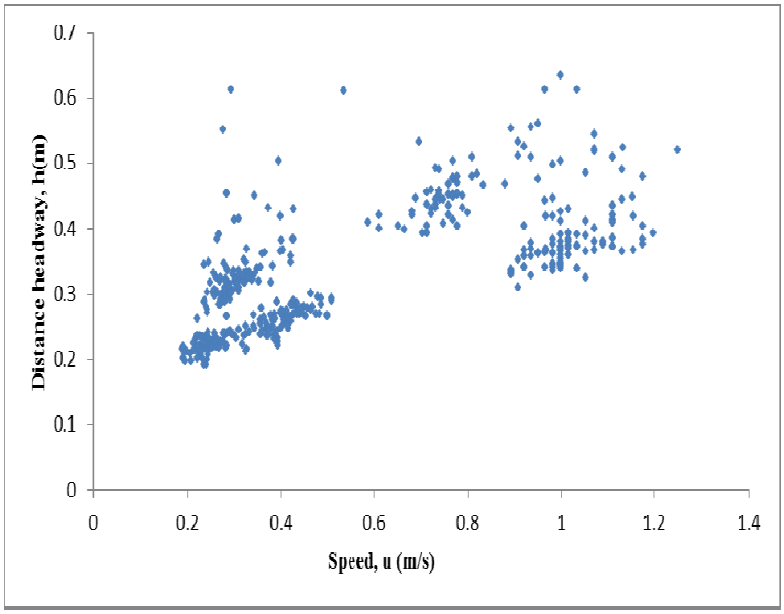


Figure8: Distance headway-Speed plot for one boy and one girl alternately

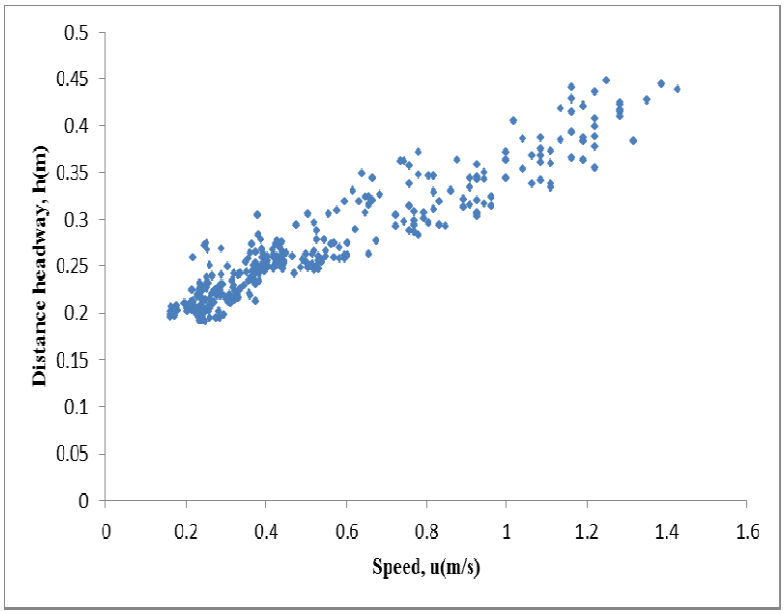


Figure9: Distance headway-Speed plot for two boys and one girl alternately

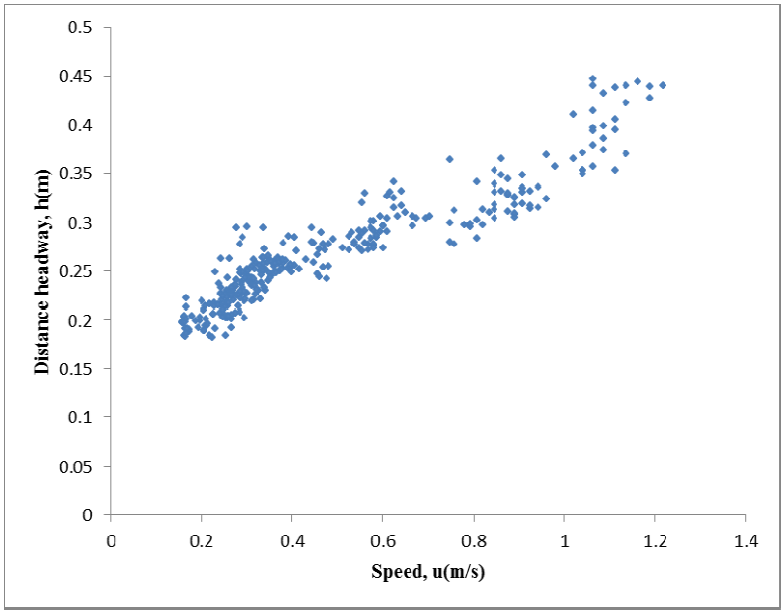


Figure10: Distance headway-Speed plot for two girls and one boy alternately

### 4.3. Study on free flow speed

Free flow speed is the speed when the pedestrian moves freely as per his/her own will without any interference from other pedestrian or any other condition. The linear distance headway-speed diagram of close corridor experiment cannot give the free flow speed. Hence the information is gathered by making one and only individual move in the geometric corridor. From the experiment it was found that the mean free flow speed for male is $1.27ms^{-1}$ whereas the mean free flow speed for female is $1.24ms^{-1}$.

### 4.4. Statistical Analysis by hypothesis testing

Z-test was conducted between two different categories of experiment out of the five different categories to show the impacts of gender and gender mix condition. The slope and intercept of the fundamental diagram was studied for statistical analysis by z-test. Tables 1, 2, 3 and 4 show the study of slope and intercept of fundamental diagram.

Table 1: Study on intercept and slope of the fundamental diagram

| *Sl No* | *Data Sets* | *Intercept(a)* | *Slope(b)* | *Data Points* |
|---|---|---|---|---|
| 1 | All boys | 0.1625 | 0.2114 | 286 |
| 2 | Two boys and one girl | 0.1719 | 0.1852 | 325 |
| 3 | One boy and one girl | 0.2367 | 0.2796 | 443 |
| 4 | One boy and two girls | 0.1759 | 0.1921 | 320 |
| 5 | All girls | 0.1541 | 0.2293 | 330 |

Table 2: Z-test for intercept

| *Sl No* | *Data Set* | *Z-observed* | *Z-critical* | *Result(risk to reject null hypothesis)* |
|---|---|---|---|---|
| 1 | (All boys) and (All girls) | 2.248 | 1.960 | Reject null hypothesis |
| 2 | (All boys) and (1boy and 1girl alternately) | 12.679 | 1.960 | Reject null hypothesis |
| 3 | (All boys) and (2boys and 1girl alternately) | 2.2211 | 1.960 | Reject null hypothesis |
| 4 | (All boys) and (1boy and 2girls alternately ) | 3.111 | 1.960 | Reject null hypothesis |
| 5 | (All girls) and (1boy and 1girl alternately) | 15.3447 | 1.960 | Reject null hypothesis |
| 6 | (All girls) and (2boys and 1girl alternately) | 4.9910 | 1.960 | Reject null hypothesis |
| 7 | (All girls) and (1boy and 2girls alternately) | 5.980 | 1.960 | Reject null hypothesis |
| 8 | (1boy and 1girl alternately) and (2boys and 1girl alternately) | 12.6925 | 1.960 | Reject null hypothesis |
| 9 | (1boy and 1girl alternately) and (1boy and 2girls alternately) | 11.7925 | 1.960 | Reject null hypothesis |
| 10 | (2boys and 1girl alternately) and (1boy and 2girls alternately) | 1.235 | 1.960 | Cannot reject null hypothesis |

Here alpha is 5% (0.05) and level of confidence is 95%. If z calculated is greater than z critical then the null hypothesis is rejected and the alternate hypothesis is accepted.

Table 3: Z-test for slope

| *Sl No* | *Data Set* | *Z-observed* | *Z-critical* | *Result(risk to reject null hypothesis)* |
|---|---|---|---|---|
| 1 | (All boys) and (All girls) | 2.414 | 1.960 | Reject null hypothesis |
| 2 | (All boys) and (1boy and 1girl alternately) | 6.312 | 1.960 | Reject null hypothesis |
| 3 | (All boys) and (2boys and 1girl alternately) | 3.885 | 1.960 | Reject null hypothesis |
| 4 | (All boys) and (1boy and 2girls alternately ) | 2.737 | 1.960 | Reject null hypothesis |
| 5 | (All girls) and (1boy and 1girl alternately) | 4.875 | 1.960 | Reject null hypothesis |
| 6 | (All girls) and (2boys and 1girl alternately) | 7.438 | 1.960 | Reject null hypothesis |
| 7 | (All girls) and (1boy and 2girls alternately) | 5.931 | 1.960 | Reject null hypothesis |
| 8 | (1boy and 1girl alternately) and (2boys and 1girl alternately) | 9.579 | 1.960 | Reject null hypothesis |
| 9 | (1boy and 1girl alternately) and (1boy and 2girls alternately) | 8.696 | 1.960 | Reject null hypothesis |
| 10 | (2boys and 1girl alternately) and (1boy and 2girls alternately) | 1.269 | 1.960 | Cannot reject null hypothesis |

Table 4: Final Z-test results

| *Sl No* | *Data Set* | *Slope* | *Result* | *Intercept* | *Result* | *Final Result* |
|---|---|---|---|---|---|---|
| 1 | (All boys) and (All girls) | Reject null hypothesis | Gender impact exist | Reject null hypothesis | Gender impact exist | Gender impact exist |
| 2 | (All boys) and (1boy and 1girl alternately) | Reject null hypothesis | Gender impact exist | Reject null hypothesis | Gender impact exist | Gender impact exist |
| 3 | (All boys) and (2boys and 1girl alternately) | Reject null hypothesis | Gender impact exist | Reject null hypothesis | Gender impact exist | Gender impact exist |
| 4 | (All boys) and (1boy and 2girls alternately ) | Reject null hypothesis | Gender impact exist | Reject null hypothesis | Gender impact exist | Gender impact exist |
| 5 | (All girls) and (1boy and 1girl alternately) | Reject null hypothesis | Gender impact exist | Reject null hypothesis | Gender impact exist | Gender impact exist |
| 6 | (All girls) and (2boys and 1girl alternately) | Reject null hypothesis | Gender impact exist | Reject null hypothesis | Gender impact exist | Gender impact exist |
| 7 | (All girls) and (1boy and 2girls alternately) | Reject null hypothesis | Gender impact exist | Reject null hypothesis | Gender impact exist | Gender impact exist |
| 8 | (1boy and 1girl alternately) and (2boys and 1girl alternately) | Reject null hypothesis | Gender impact exist | Reject null hypothesis | Gender impact exist | Gender impact exist |
| 9 | (1boy and 1girl alternately) and (1boy and 2girls alternately) | Reject null hypothesis | Gender impact exist | Reject null hypothesis | Gender impact exist | Gender impact exist |
| 10 | (2boys and 1girl alternately) and (1boy and 2girls alternately) | Cannot reject null hypothesis | Gender impact does not exist | Cannot reject null hypothesis | Gender impact does not exist | Gender impact does not exist |

The impact of distance headway was also studied from the z-test result. It was noticed that impact of distance headway existed except for the cases

a) (2boys and 1girl alternately) and (1boy and 2girls alternately)

In this case i.e. (2boys and 1girl alternately) and (2girls and 1boy alternately) the arrangements of subjects are exactly opposite. So the space between the pedestrians remains same in both the cases. Hence the distance headway was not different 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, using which the means of three or more samples can be compared using the F-distribution. Table 5 and 6 shows the ANOVA test for distance headway and speed respectively.

Table 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 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 means not significant

It can be inferred from the above one-way ANOVA test that the speed was almost equal for five different categories but the distance headway varied with the variation in the combination of subjects. Distance headway represents the distance between two successive pedestrians in a group. The speed remained the same when there were both male and female subjects, but the space between them varied. Every subject maintained a noticeable distance in a gender mix condition because of human behaviour. Hence the efficiency of pedestrian movement decreases in gender mix condition as the subjects try to maintain a safe distance from each other.

## 5. Summary and Conclusion

In the present study, experiments on pedestrian motion under closed boundary condition using single file pedestrian motion were conducted to observe the impacts of gender and gender mix condition on fundamental diagram. Hypothesis tests like z-test and ANOVA test were conducted to show the impacts of gender on pedestrian fundamental diagram. It can be inferred from the above study that the mean free flow speed for male pedestrian is $1.27ms^{-1}$ whereas for female pedestrian it is found to be $1.24ms^{-1}$. Female pedestrians are more cautious about their private space as compared to male pedestrians. The concept of security distance can be used instead of private space. In other words it can be said that the extent of psychological boundary for female pedestrians is quite higher as compared to male pedestrians, and thus the security distance of female pedestrians is more as compared to male pedestrians. It is evident from the above study that the impacts of gender exists in pedestrian crowd flow and mostly gender condition affects the space between the pedestrian present in mix pedestrian traffic.

*References*

Chattaraj, U., Seyfried, A. and Chakroborty, P. (2009). "Comparison of Pedestrian Fundamental Diagram Across Cultures",*Advances in Complex systems*, 12(3), pp. 393–
405.

Chattaraj, U., Seyfried, A., Chakroborty, P. and Biswal, M.K. (2013). "Modelling single file pedestrian motion across cultures",*Procedia-Social and Behavioral Sciences*, 104, pp.698-707.

Hankin, B.D. and Wright, R.A. (1958). Passenger flow in subways. *OR*, *9*(2), pp.81-88.

Hoel, L.A. (1968). "Pedestrian travel rates in central business districts",*Traffic Engineering*, *38*(4), pp.10-13.

Hoogendoorn, S.P. and Daamen, W. (2005). "Pedestrian behavior at bottlenecks",*Transportation science*, 39(2), pp.147-159.

Isobe, M., Adachi, T. and Nagatani, T. (2004). "Experiment and simulation of pedestrian counter flow",*Physica A: Statistical Mechanics and its Applications*, 336(3), pp.638-650.

Kretz, T., Grünebohm, A. and Schreckenberg, M. (2006). "Experimental study of pedestrian flow through a bottleneck",*Journal of Statistical Mechanics: Theory and Experiment*, 2006(10), pp.10014.

Mintz, A. (1951). "Non-adaptive group behaviour". *The Journal of abnormal and social psychology*, 46(2), pp.150.

Mōri, M. and Tsukaguchi, H. (1987). "A new method for evaluation of level of service in pedestrian facilities",*Transportation Research Part A: General*, 21(3), pp.223-234.

Morrall, J.F., Ratnayake, L.L. and Seneviratne, P.N. (1991). "Comparison of CBD Pedestrian Characteristics in Canada and Sri Lanka", *Transportation Research Record*,
1294, Transportation Research Board, National Research Council, Washington, DC, USA, pp. 57–61.

Navin, F.P. and Wheeler, R.J. (1969). "Pedestrian flow characteristics",*Traffic Engineering, Inst Traffic Engr*, 39.

Oeding, D. (1963). "Verkehrsbelastung und Dimensionierung von Gehwegen und Anderen Anlagen des Fußg¨angerverkehrs", Tech. Rep. Forschungsbericht 22, *Technische Hochschule Braunschweig*.

Older, S.J. (1968). "Movement of pedestrians on footways in shopping streets",*Traffic engineering & control*.

Polus, A., Schofer, J.L. and Ushpiz, A. (1983). "Pedestrian flow and level of service",*Journal of transportation engineering*, 109(1), pp.46-56.

Seyfried, A., Steffen, B., Klingsch, W. and Boltes, M. (2005). "The Fundamental Diagram of Pedestrian Movement Revisited",*Journal of Statistical Mechanics: Theory*
*and Experiment*, P10002.

Seyfried, A., Passon, O., Steffen, B., Boltes, M., Rupprecht, T. and Klingsch, W. (2009). "New insights into pedestrian flow through bottlenecks",*Transportation Science*, 43(3), pp.395-406.

Tanaboriboon, Y., Hwa, S.S. and Chor, C.H. (1986). "Pedestrian characteristics study in Singapore",*Journal of transportation engineering*, 112(3), pp.229-235.

Tanaboriboon, Y. and Guyano, J.A. (1991). "Analysis of pedestrian movements in Bangkok",*Transportation Research Record*, 1294.

*Acknowledgements*

We acknowledge the support of Science and Engineering Research Board, Department of Science and Technology, Government of India (Project Sanction No: SB/S3/CEE/008/2014).