



A study for Commuter Walk Distance from Bus Stops to Different Destination along Routes in Delhi

Amita Johar^{1*}, S.S Jain², P.K Garg³ and P.J Gundaliya⁴

¹Ph.D. Scholar, Centre for Transportation System (CTRANS), IIT Roorkee, Roorkee 247667, Uttarakhand, India,
avamitamita@gmail.com

²Professor, Transportation Engineering Group, Department of Civil Engineering & Associate Faculty CTRANS, IIT Roorkee, Roorkee-247667, Uttarakhand, India,profssjain@gmail.com

³Professor, Geomatics Engineering Group, Department of Civil Engineering & Associate Faculty CTRANS, IIT Roorkee, Roorkee-247667, Uttarakhand, India,pkgiitr@gmail.com

⁴Associate Professor, Department of Civil Engineering, L.D College Ahmadabad, Ahmadabad-380001, Gujarat, India,
pjgundaliya@gmail.com

Abstract

Walk is an essential mode of human travel, and availability of data for this mode of travel in metropolitan city like Delhi is still in infancy. Therefore, the prime objective of this study is to analyze the appropriate distribution and found the mean and 85th percentile walking distance according to appropriate distribution that data follows. For this analysis, the data were collected through interview survey conducted at various bus stops along the Delhi Transport Cooperation (DTC) route number 832 (Janakpuri D Block to Inderlock Metro Station) and route number 817 (Kair Village to Inderlock Metro Station). Appropriate distribution for dataset is computed by fitting the data to probability distribution function using easyfit software. The travel characteristics were discussed with respect to trip purpose and personal characteristics were discussed with respect to age and income. The mean walking distance of commuters from different areas to bus stops in the present study and is compared with the values of different authors.

Keywords: Walk, Commuters, Bus Stop, Probability Distribution Function and Lognormal distribution.

* Corresponding author: Amita Johar (avamitamita@gmail.com)

1. Introduction

In metropolitan cities like Delhi, the commuters are usually dependent on mass transit facilities, like metros, bus, rapid transit etc., but commuters in such cities have access to transit facilities through various modes, such as walking, manual bicycle, rickshaw, taxis, personal motorized two-wheelers etc., and each mode has its own importance according to the distance. In such situation, there is an increase in the number of intermediate public transport and private modes at the expense of loss in utility of walk mode (Rastogi 2010). This has degraded the surroundings environmentally, socially and economically, and has increased health consciousness (Koushki 1998), accidents and congestion cost (Koushki 1998).

Most of the researchers have made an attempt to analyze the urban trips through walk. Morall and Lam (1982) have calculated mean walking distance and waiting time to bus stops by statistical analysis. Different factors were considered by them to refine the bus passenger catchment area; that is ratio of actual walking distance to airline distance. O'Sullivan and Morall (1995) developed the guidelines for pedestrians accessing the light rail transit station. They compared the walking distance estimated for bus stops and light rail transit station, and stated that commuters walk longer to reach light rail transit station. Cervero (2001) developed the regression model to predict the percentage of trips accessing to Bay Area Rapid Transit (BART) station by walking for all trips purpose.

Rastogi and Rao (2003) analyzed the travel characteristics of the commuters reaching the transit station with respect to pattern and availability of access mode. Cumulative frequency distribution was used by them to compute the acceptable walking and bicycling distance. The mean acceptable distance computed for walk and bicycle was 910 meters and 2724 meters, respectively. Wibowo and Olszewski (2005) developed a binary logit model using equivalent walking distance. Equivalent walking distance was calculated by using walking distance and characteristics of walking route, such as delay at crossing, total crossing on the route and ascending and descending steps. Yang and Diez-Roux (2012) developed a distance decay function to summarize the distribution of walking distance and duration of walking trip for different purpose and group using nationally representative data of 2009. Finally, they state that mean and median value for walking distance is 0.7 (1127 meters) and 0.5 miles (805 meters) and walking duration is 14.9 and 10 minutes. Yang *et al.* (2013) build a Kishi's Logit Price Sensitivity Meter (KLP) model to calculate the walking access distance and time to reach urban rail station. A comparative analysis of distribution features was done. They mentioned that the standard walking distance is 472 meters and the maximum walking distance is 862 meters. Park *et al.* (2014) analyze the travel, socio-economic and built environment variable using binominal logit. The model I analyze 277 walkers and auto users living within 2.4 km and model II analyze 280 bikers and auto users living within 3.2 km. Finally, they found that trip purpose, race and intersection density affect transit users' decision to walk over driving and gender and race affects their decision to bike over driving to station.

The above discussion indicates that mean walking distance is different for different cities. Acceptable walking distance is an important input for city planners and engineers in designing

urban facilities, particularly the bus stops. Therefore, the prime objective of this study was to discuss the travel and personal characteristics that influence the walking distance, and to analyze the appropriate distribution that belong to collected dataset. Appropriate distribution for walking distance is computed by fitting the dataset to probability distribution function using easyfit software (Arasan *et al.* 1994). Appropriate distribution is useful in finding the mean and 85th percentile walking distance of commuters coming from different areas to bus stops. For this analysis, the data were collected on the bus stops that lie along the selected urban routes.

2. Data collection

Data were collected through physical survey conducted at various bus stops on DTC routes number 832 and route number 817, Delhi. The urban bus route number 832 runs from Janakpuri D Block to Inderlock Metro Station via Sagarpur, Tilak Nagar, Moti Nagar and Inderlock while route number 817 runs from Kair Village to Inderlock Metro Station via kair Depot, Tuda Mandi, Kakrola Mor, Janakpuri East Bus Stop, Tilak Nagar, Inderlock. The details of both the routes are shown in Table 1. The survey was conducted on bus stops marked with dotted circle in Figure 1. The survey was conducted in the month of March, 2014. A questionnaire was designed for this purpose which provided information on commuters walking distance and parameters affecting the choice of the trip. The survey was done in the morning from 7:00 am to 11:00 am and in the evening from 4:00 pm to 7:00 pm. Trips included during the survey were work, shopping, education and recreational trips. A total of 2000 samples were obtained out of which 1748 samples were used for analysis. The details of total samples are furnished in Table 2. Table 2 depicts that 87.4% of the commuters reach to their destinations by walk, 5.4% of the commuters used shared auto and 7.2% of the commuters used rickshaw. The distance travelled from/to bus stop to all destinations is as shown in Figure 2. The distance 1069 meters is decided on the basis of 85th percentile value obtained through cumulative distribution curve. About 80.7 % of the commuters within 1069 meters reach to their destinations by walk and 6.7 % of the commuters beyond this distance reach to their destinations by walk.

The information related to commuters at the bus stops was obtained by requesting the respondents to indicate the walking distance from origin to destination, purpose of trips, age, income, travel time, cost and mode of travel. The data were analyzed using percentage of frequency for all the parameters affecting the walking distance.

Table 1: Detail of Urban Bus Route Number 832 and 817

S. No	Detail of Bus Route	Name of Urban Bus Route	
		Route No. 832	Route No.817
1.	Length	14 (Km)	28(km)
2.	Number of Bus Stops	33	53
3.	Number of Intersection	16	20

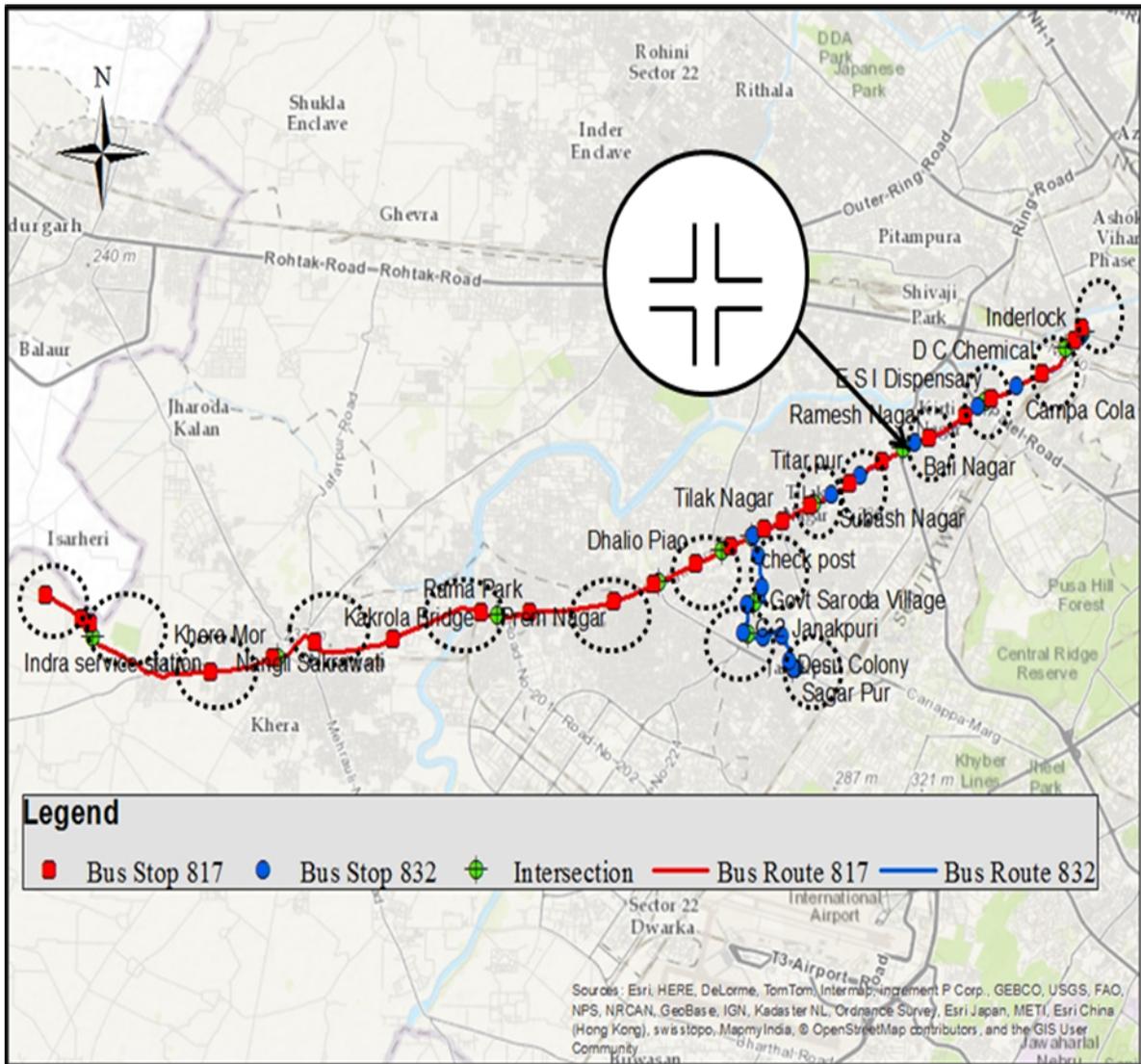


Figure 1: Urban Bus Routes of Delhi Transport Cooperation

Table 2 : Distribution of Trip According to Shared Mode

S.No.	Mode	Trips (%)		
		Up to 1069 m from Bus Stops	Beyond 1069 m from Bus Stops	Total
1.	Walk	80.7	6.7	87.4
2.	Shared Auto	3.6	3.6	5.4
3.	Rickshaw	2.8	2.6	7.2

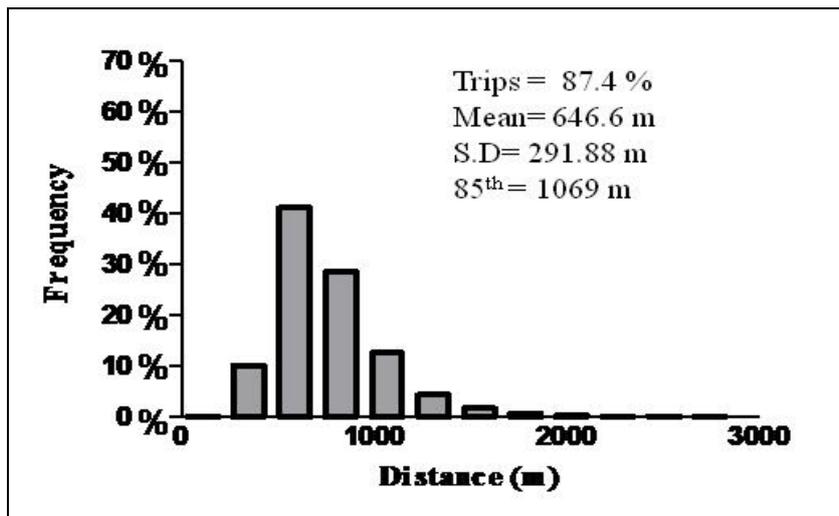


Figure 2: Distance walked from/to bus stop to all destinations.

3. Analyses of Travel and Personal Characteristics

The walking distance of commuters depends upon the travel characteristics (by trip purpose) and personal characteristics (by age and sex and by income group). The commuter's travel characteristics and personal characteristics influence the distribution of walking distance, as discussed below.

3.1 Travel Characteristics

The commuters visiting the bus stops have different purposes of trips. Therefore, the trip purposes considered for analysis were (1) Work, (2) Education, (3) Recreational and (4) Shopping. The distance walked from/to bus stops to work, education, recreational and shopping are as shown in Figure 3. Distance walked from bus stop to work places (Mean= 676.65m, 85th percentile = 1058 m), education (Mean= 659.87 m, 85th percentile = 1035 m), and recreational (Mean= 653.57 m, 85th percentile = 895 m) is less than shopping (Mean= 636.92 m, 85th percentile = 892 m). From the Figure 3 it is depicted that higher proportion of people visit to bus stops for work purpose and it is also depicted that people going for shopping trip walk more than the people going for work trip.

3.2 Personal Characteristics

3.2.1 Age and Sex

The walking distance was analyzed on the basis of sex and three different age groups (i. e 15-25 years, 26-35 years and above 35 years). The distance worked from bus stop to other places based on sex and three different age groups are as shown in the Figures 4 and 5. Figure 4 depict that the

distance walked by female from bus stop to their end destination for age group +35 (Mean = 632.23 m 85th = 865 m) is less than 15-25 (Mean = 642.67 m 85th = 870 m) and 26-35 (Mean = 644.86 m 85th = 880 m). Similarly, the Figure 5 depict that the distance walked by male from bus stop to their end destination for age group +35 (Mean = 637.99 m 85th = 885 m) is less than 15-25 (Mean = 666.83 m 85th = 905 m) and 26-35 (Mean = 654.2 m 85th = 895 m). The 85th percentile for males and females on overall data is 895 m and 871 m. Therefore, from both the figure and 85th percentile of overall data it is depicted that males has higher tendency to walk.

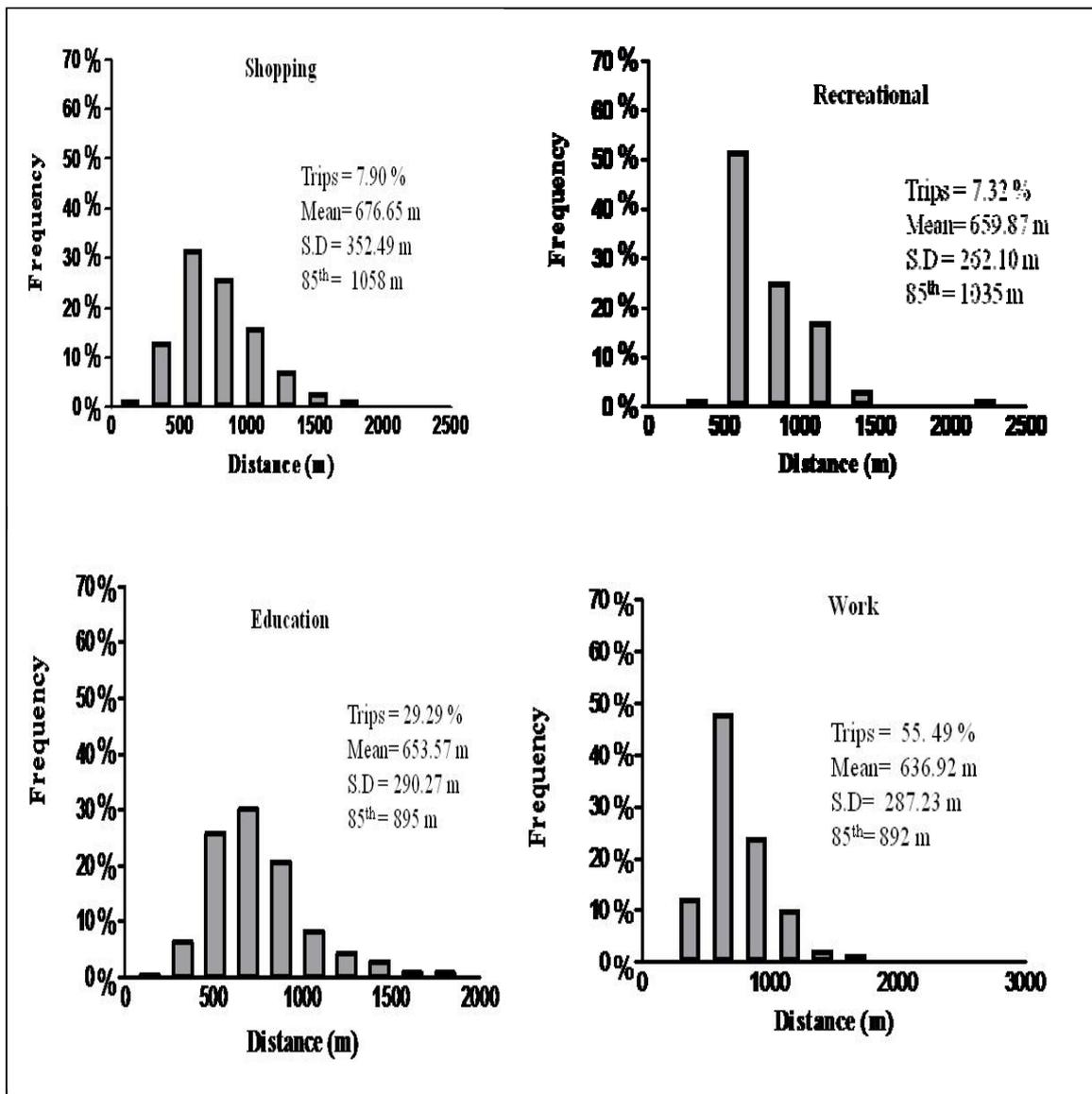


Figure 3: Distance Travel from Bus Stop to Work, Education, Shopping and Recreational

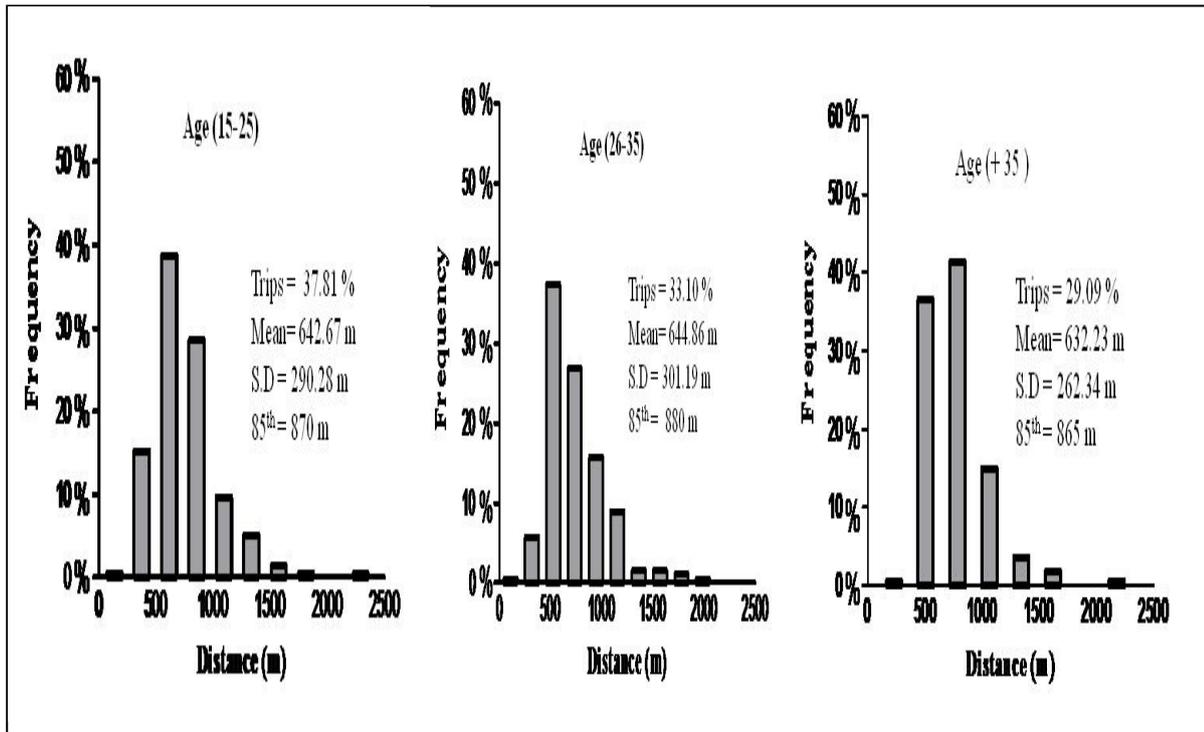


Figure 4: Distance walked from Bus Stop to their end Destination by Females

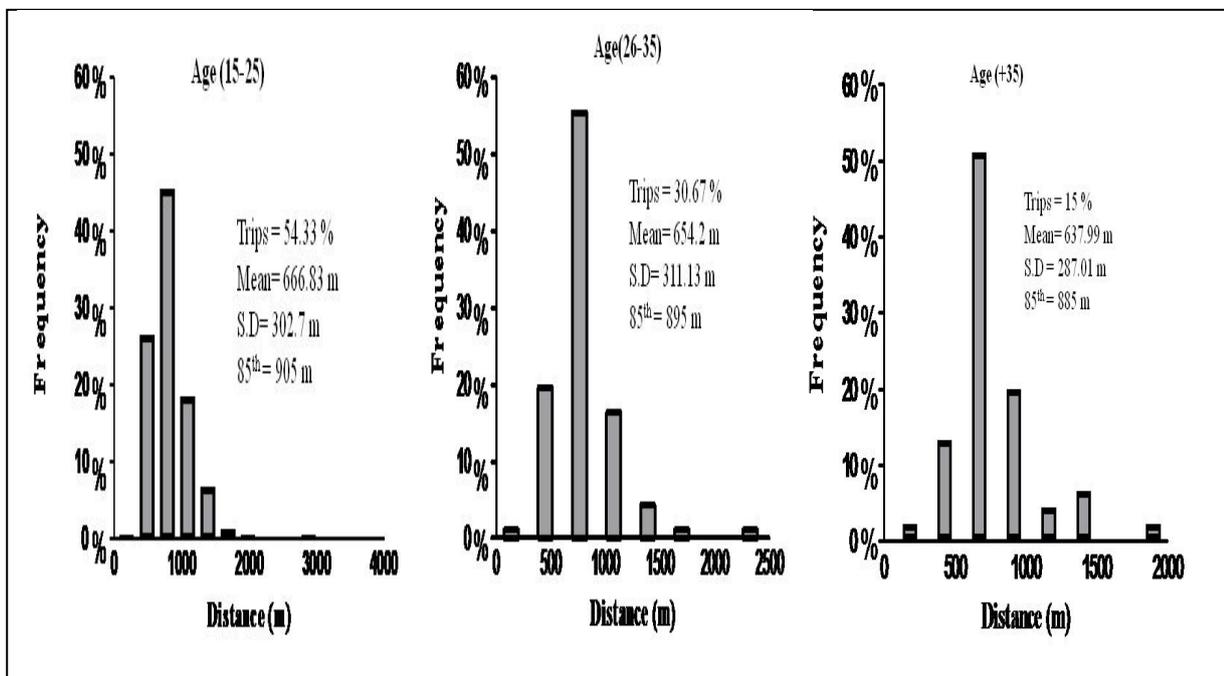


Figure 5: Distance walked from Bus Stop to their end Destination by Males

3.2.1 Incomes

Walking distance was also analyzed on the basis of income per month (i.e., household and individual) and four different sub-groups; (1) Rs 5000-15000, (2) Rs 15000-30000, (3) Rs 30000-50000 and (4) Rs >50000. The distance worked from bus stop to other places based on income and three different sub-groups are as shown in the Figures 6 and 7. Figure 6 depict that the distance walked from bus stop to their end destination based on household income. The household income with sub-groups 30,000-50,000 (Mean = 621.42 m 85th percentile = 865 m) is less than household income with subgroups 15,000- 30,000 (Mean = 640.84 m 85th percentile = 910 m) and 5000-15,000 (Mean = 665.4 m 85th percentile = 955 m). Similarly, Figure 7 depict that the distance walked from bus stop to their end destination based on individual income. The individual income with sub-groups 30,000-50,000 (Mean = 625.39 m 85th percentile = 910 m) is less than individual income with subgroups 15,000- 30,000 (Mean = 635.71 m 85th percentile = 936 m) and 5000-15,000 (Mean = 645 m 85th percentile = 945 m). Therefore, from both the figure it is depicted that people with low income (i.e 5000-15,000) has higher tendency to work. The income subgroups >50,000 is rejected because of smaller sample size.

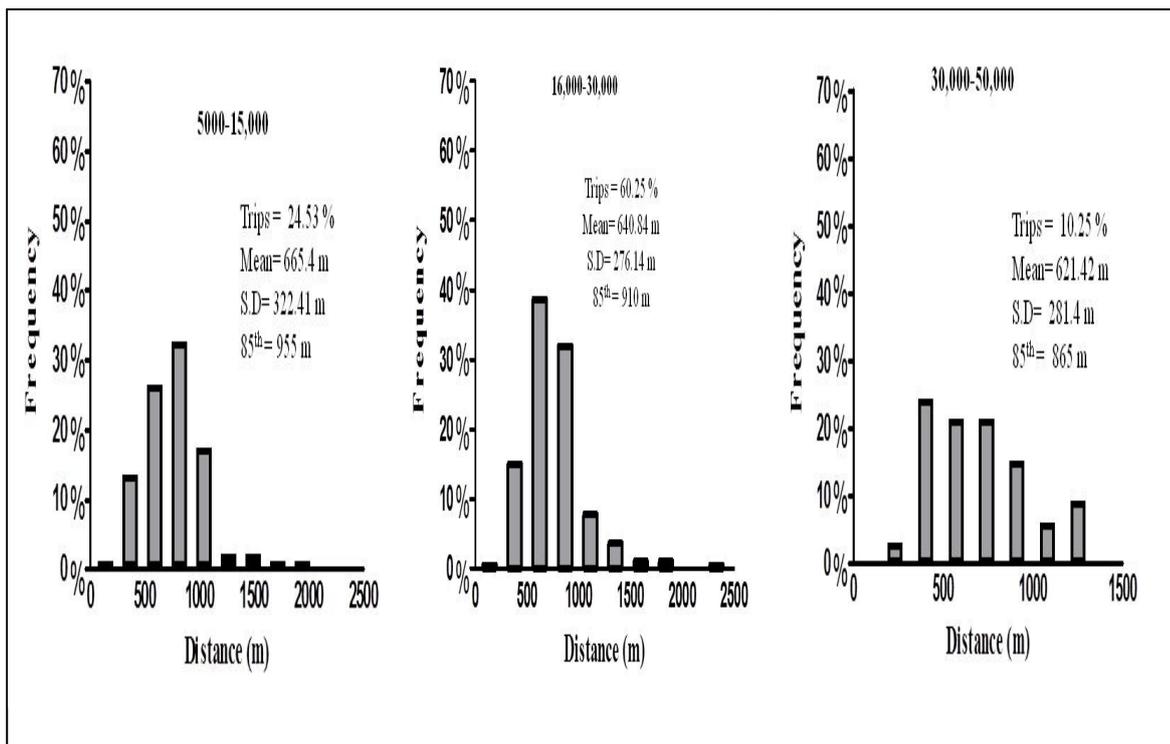


Figure 6: Distance walked from Bus Stop to their end Destination based on Household Income

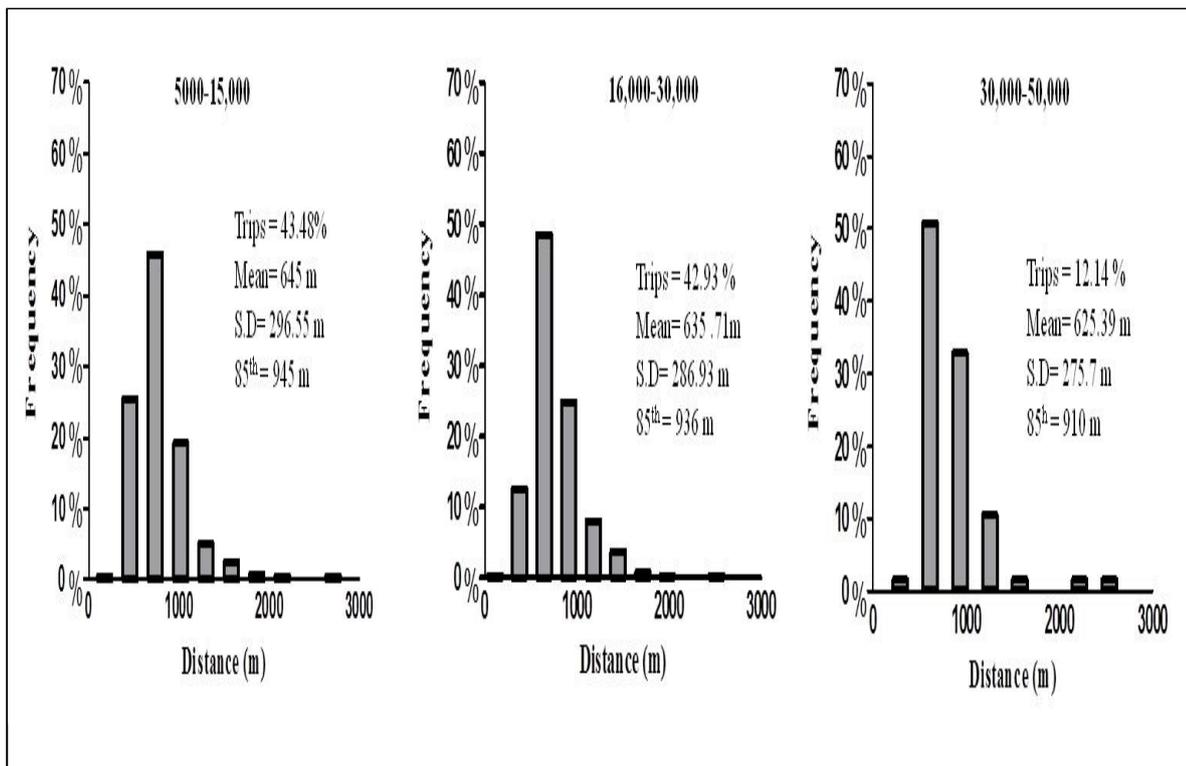


Figure 7: Distance walked from Bus Stop to their end Destination based on Individual Income

4. Data Fitting to Distribution

The appropriate walking distance distribution was determined by fitting the dataset with various probability distribution functions using EasyFit Software, which check the goodness of fit on the basis of Chi-square, Anderson Darling (A-D) and Kolmogorov Smirnov (K-S) for various distribution functions (Burke and Brown 2007). Some of the distributions that are accepted on the basis of A-D test at 0.05 confidence level are shown in the Table 3. Out of various distribution functions, the lognormal distribution function best fit with the data as identified by the statistics value which is less than other distribution function. The A-D is accepted if calculated statistics value is smaller than critical value at certain level of confidence otherwise it is rejected. The A-D test is accepted or rejected is checked at 0.05 confidence level. The A-D test examines how well the observed walking distance data are estimated by lognormal functions. The lognormal distribution function fitted to observed walking distance made from bus stops to end destination is as shown in the Figure 6. Statistical results of lognormal distribution curve for observed walking distance is shown in Table 4.

Table 3: Statistics of Distribution Fitted to Overall Data

S.No	Distribution	Parameters	Goodness of Fit	Critical Value (0.05)
1	Lognormal	$\sigma=0.43065$ $\mu=6.379$	Statistics=0.919	2.502
2	Lognormal (3P)	$\sigma=0.40383$ $\mu=6.4424$ $\gamma=-35.348$	Statistics=0.949	2.502
3	Log-Pearson 3	$\alpha=11131.0$ $\beta=-0.00408$ $\gamma=51.84$	Statistics=0.952	2.502
4	Log-Gamma	$\alpha=219.16$ $\beta=0.02911$	Statistics=0.971	2.502
5	Inv.Gaussian(3P)	$\lambda=4408.8$ $\mu=710.94$ $\gamma=-63.832$	Statistics=1.385	2.502
6	Fatigue Life(3P)	$\alpha=0.39784$ $\beta=653.54$ $\gamma=-58.103$	Statistics=1.485	2.502
7	Fatigue Life	$\alpha=0.44359$ $\beta=589.13$	Statistics=1.509	2.502
8	Gen-Gamma (4P)	$k=0.57369$ $\alpha=14.093$ $\beta=5.7632$ $\gamma=38.747$	Statistics=1.672	2.502

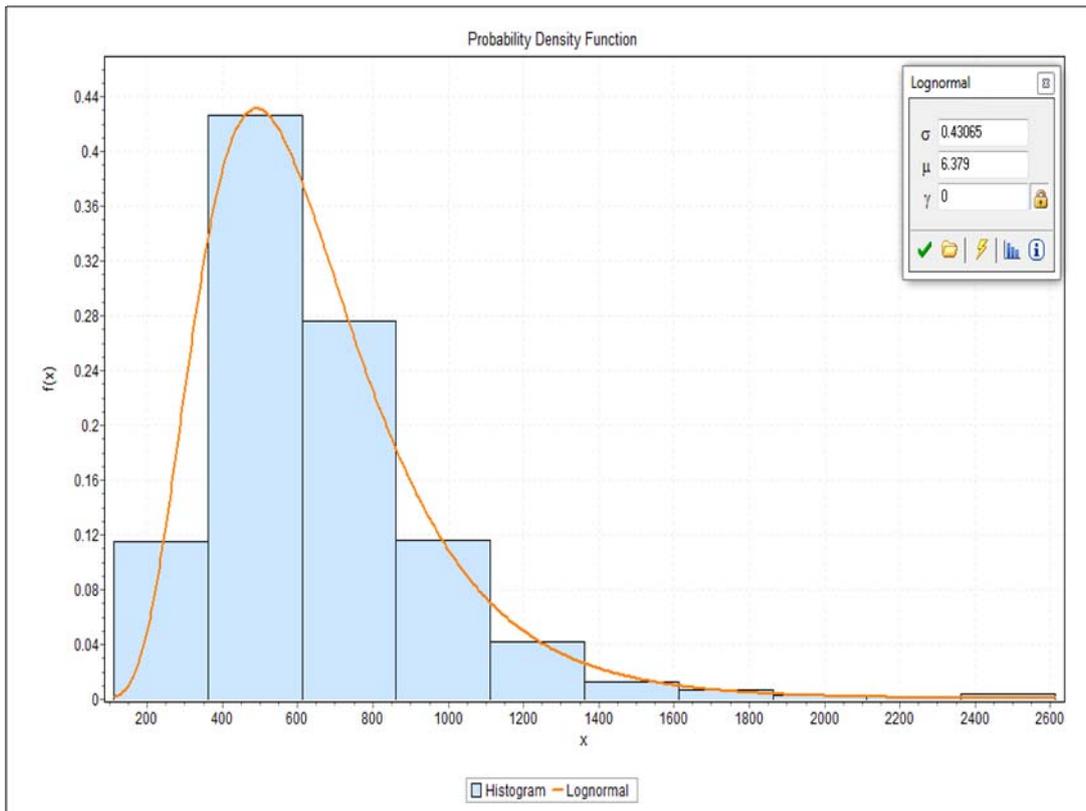


Figure 6: Lognormal Function Fitted to Observed Walking Distance from Bus Stops to all Destinations

Table 4: Statistical Results of Lognormal Distribution Function for Observed Walking Distance

Data	Statistics Properties							A-D Test Statistics	A-D Test Critical
	Mean	Mode	Variance	S.D	COV	Skewness	Kurtosis		
Observed	646.6	489.58	85195.0	291.88	0.451	1.446	3.935	0.919	0.252

S.D = Standard Deviation, COV= Coefficient of Variance

The A-D test is a nonparametric test based on the maximum distance between the observed and theoretical curves and is a modification of the Kolmogorov-Smirnov (K-S) test. The A-D test gives more weight to the tails of the distributions than the K-S test and may be considered as conservative in situations where the function parameters are estimated from the data (Stephens 1974).

Table 5 shows the statistical result for different lognormal distribution function that has been fitted to different categories (i.e. personal and travel characteristics) reported in the paper. The comparison between categories was done to identify mean and 85 th percentile walking distance and also to identify whether this measured sample of different categories follow lognormal distribution based on A-D test.

The mean and 85th percentile walking distance of commuters from different categories in Delhi city according to lognormal distribution curve is 647 m and 1069 m. The mean walking distance thus obtained is found comparable with the study done in Calagry, Canada (O' Sullivan and Morrall 1995). The mean walking distance thus obtained in the present study is compared with the walking distance values proposed by different authors, and are shown in Table 6.

5. Conclusions

Walking is an essential mode of travel to reach to nearest bus stop from major generator, such as home and offices. Therefore, bus stops must be placed at an acceptable walking distance. Appropriate distribution for dataset was computed by fitting the data set to probability distribution curve using easyfit software. Lognormal distribution function found best fit with the dataset as identified by the A-D values. The analysis on the whole data set reveals that mean walking distance of commuters in Delhi city according to lognormal distribution is 647 m.

Table 5: Statistical Results of Lognormal Distribution Function that has been Fitted to Personal and Travel Characteristics

Distribution	Mean (m)	S.D	85 th percentile (m)	Parameters		Goodness of Fit (A-D Test)	
				σ	μ	Statistics	Critical (0.05)
Distance Travel From Bus Stop							
To Education	653.57	290.27	895	0.424	6.392	0.490	2.502
To Shopping	676.65	352.49	1058	0.49	6.397	0.252	2.502
To Recreational	659.87	262.10	1035	0.383	6.419	0.560	2.502
To Work	636.92	287.23	892	0.430	6.364	1.376	2.502
Distance Travel from Bus Stop to their end destination By Females for Age Group							
15-25	642.67	290.28	870	0.431	6.372	0.265	2.502
26-35	644.86	301.19	880	0.444	6.370	0.439	2.502
+35	632.23	262.34	865	0.399	6.370	0.611	2.502
Overall	640.33	285.86	871	0.426	6.371	0.496	2.502
Distance Travel from Bus Stop to their end destination By Males for Age Group							
15-25	666.83	302.7	905	0.433	6.409	0.347	2.502
26-35	654.2	311.13	895	0.452	6.382	0.765	2.502
+35	637.99	287.01	885	0.429	6.366	0.614	2.502
Overall	658.64	303.25	895	0.439	6.394	0.719	2.502
Distance Travel from Bus Stop to their end destination Based on Household Income							
5000-15000	665.4	322.41	955	0.459	6.394	0.377	2.502
16000-30000	640.84	276.14	910	0.413	6.378	0.561	2.502
31000-50000	621.42	281.4	865	0.432	6.339	0.288	2.502
Distance Travel from Bus Stop to their end destination Based on Individual Income							
5000-15000	645	296.55	945	0.437	6.375	0.454	2.502
16000-30000	635.71	286.93	936	0.430	6.362	0.852	2.502
31000-50000	625.39	275.7	910	0.414	6.323	0.256	2.502

For all cases, statistical value is less than critical value at 0.05 confidence level and all follows lognormal distribution function.

Table 6: A Comparison of Mean Walking Distance

S.No.	Author	City/ Country	Mean Walking Distance (meters)
1.	Seneviratne (1985)	Calagry, Canada	523
2.	Kouhki (1998)	Saudi Arabia, Riyadh	859
3.	Soegijoko and Horthy (1991)	Indonesia	400
4.	Arasan et al., (1994)	Tiruchirapalli	1302m (female)
5.	O' Sullivan and Morrall (1995)	Calagry, Canada	326-649
6.	Lam <i>et al.</i> , (1995)	Hong Kong	263-493
7.	Rastogi and Rao (2003)	Mumbai, India	910
8.	Present study	Delhi, India	647

The analysis on travel characteristics and personal characteristics reveals that dataset for different trips purpose, age and income subgroups also follows lognormal distribution function. From this study, it is identified that people in Delhi city walk more for shopping trips and also identify that higher proportion of people walk to bus stops for work purpose. The mean walking distance for shopping, recreational, education and work trips according to lognormal distribution is 677 m, 660 m, 654 m and 637 m.

This study also reveals that males in Delhi city have higher tendency to walk to bus stops than females. The mean walking distance of males and females is 659 m and 640 m. It is also indentify that low income groups that is 5000-15000 have higher to work to bus stops than higher income groups. The mean walking distance for low income on the basis of household and individual income is 665 m and 645 m.

The filed data in this study was collected in month of March when the weather of Delhi, is neither too hot nor too cold and also having less rainfall. However, it has been observed that the weather such as intense heat in summers and rains do influence the walking distance. Therefore, for further study these factors should be considered for finding the acceptable walking distance for Delhi city.

The information of acceptable walking distance is useful to transportation planners and engineers in deciding the positions of new bus stops along an urban route which depend upon the travel and personal characteristics of the commuters originating in that particular zone.

List of Abbreviations

DTC= Delhi Transport Cooperation

BART= Bay Area Rapid Transit

KLP= Kishi's Logit Price Sensitivity Meter

A-D= Anderson Darling

K-S= Kolmogorov Smirnov

S.D= Standard Deviation

COV= Coefficient of Variance

References

- Arasan, V.T., Rengaraju, R. and Krishna, Rao K.V. (1994) "Characteristics of Trips by Foot and Bi-cycle Modes in Indian City", *Journal of Transportation Engineering* 120 (2), pp. 283-294.
- Burke, M. and Brown, A. L. (2007) "Distance People Walk for Transport", *Road and Transport Research* 16 (3), pp.16-29.
- Cervero, R. B. (2001) "Walk-and-Ride: Factors Influencing Pedestrian Access to Transit", *Journal of Public Transportation* 3 (4), pp.1-23.
- Koushki, P. A. (1988) "Walking Characteristics in Central Riyadh, Saudi Arabia", *Journal of Transportation Engineering* 114 (6), pp. 733-744.
- Lam, W. H. K., Morrall, J. F. and Ho, H. (1995) "Pedestrian Flow Characteristics in Hong Kong", *Transport Research Record 1487 Transportation Research Board Washington D.C*, pp. 56-61.
- Morrall, J. F. and Lam, W. (1982) "Bus Passenger Walking Distance and Waiting Times: A Summer- Winter Comparison", *Transportation Quarterly* 36 (3), pp. 407-421.
- O'Sullivan, S. and Morrall, J. (1995) "Walking Distance to and from Light-Rail Transit Station", *Transportation Research Record* 1538 (1). doi: 10.3141/1538-03.
- Park, S., Khang, J. and Choi, K. (2014) "Finding Determinants of Transit Users' Walking and Biking Access Trips to the Station: A Pilot Case Study", *KSCE Journal of Civil Engineering* 18 (2), pp. 651-658. doi: 10.1007/s12205-014-0073-6.
- Rastogi, R. and Krishna, Rao V. K. (2003) "Travel Characteristics of Commuters Accessing Transit: Case Study", *Journal of Transportation Engineering*, 129 (6), pp. 684-694. doi:10.1061/(ASCE)0733-947X(2003)129:6(684).
- Rastogi, R. (2010) "Willingness to Shift to Walking or Bicycling to Access Suburban Rail: Case study of Mumbai, India", *Journal of Urban Planning and Development* 136 (1), pp. 3-10. doi: 10.1061/ (ASCE) 0733-9488(2010)136:1(3).
- Seneviratne, P. N. (1985) "Acceptable Walking Distances in Central Areas", *Journal of Transportation Engineering* 111(4), pp. 365-376
- Soegijoko, S. T. B. and Horthy, S. I. (1991) "Role of Non-motorized Transport Modes in Indonesian Cities", *Transport Research Record 1294 Transportation Research Board Washington D C*, pp. 16-25.
- Stephens, M. (1974) "EDF Statistics for Goodness of Fit and Some Comparisons", *Journal of the American Statistical Association* 69 (347), pp.730-737
- Wibowo, S.S. and Olszewski, P. (2005) "Modeling Walking Accessibility to Public Transport Terminals: Case Study of Singapore Mass Rapid Transit", *Journal of Eastern Society for Transportation Studies* 6 , pp. 147-156

Yang, R., Yan, H., Xiong, W. and Liu, T. (2013) “The Study of Pedestrian Accessibility to Rail Transit Stations Based on KLP Model”, *Procedia-Social and Behavioral Sciences*, pp. 714-722.

Yang, Y. and Diez- Roux, A. V. (2012) “Walking Distance by Trip Purpose and Population Subgroups”, *Amercian Journal of Preventive Medicine* 43(1), pp. 11-19.

Acknowledgements

The Financial support in the form of MHRD fellowship from Indian Institute of Technology Roorkee, India, to Ms Amita Johar is gratefully acknowledged