PEDESTRIAN TRAVEL BEHAVIOR STUDY IN CITY OF BANGALORE

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ABSTRACT

Pedestrians have long been a neglected class in the transportation planning process of India. This has resulted in a decrease in their proportion over the years. The objective of the present study was to analyze the walking distance characteristics and determine the critical distance for trips by foot in the city of Bangalore. In the analysis part we identified certain variables which affected the trip distance by foot and studied the impact of these variables on the walking distance using statistical analysis. The variables included age, sex, purpose, occupation, level of education, and availability of driving license. The critical distance was then determined for various groups based on the results of the analysis. The study found a lack of significant difference between the trip distance characteristics by foot for certain factors including between male and female and between respondents with and without driving license. The critical walking distance was found as 1044 m for the category male and 1052 m for respondents without driving license.

Keywords: Pedestrians, Statistical Analysis, Critical Walking Distance

INTRODUCTION

Pedestrians are an important component of a transportation system. Trip using any mode will have a stage of walking whether it is to and from the bus stop or the parking lot. Walking is environmentally friendly, cheap and reasonably fast for trips up to a distance of 3.5 km, Rietveld (2000). Even with of all these advantages, walking is not given its due share in the transportation planning of many of the developing countries like India. The transportation planning policies here are motor vehicle oriented. This neglect of walking while planning is responsible for its poor infrastructure facilities which in turn are responsible for the reduced preference of people towards walking. Explanation for this neglect of walking in developing countries was given by Rahul and Verma (2012). They blamed lack of a clear understanding of the role of NMT (Non Motorized Transport) in the transportation system for its dismal state.

Planning for walking requires a clear understanding of its trip distance characteristics. These characteristics depend a lot on the land use pattern and transportation network layout in a city. A clear understanding of the walking distance characteristics along with the variables influencing it will give an idea regarding the location of infrastructure facilities for walking promotion.

Seneviratne (1984) studied the variation of critical walking distance in a CBD with respect to the various factors influencing it in the city of Calgary, Alberta, Canada based on data collected using an origin destination survey. The critical distance or acceptable distance was defined as the maximum distance by walking after which person will shift to some other alternative facility or route. The various factors used by him were trip type, trip purpose, age and sex, geographic location, time of day and cost of parking. Author found an average critical distance of 1100 meters for category trip type and, 1050 meters and 750 meters respectively for category male and female. This study helped in understanding how a change in existing pattern of travel for eg. Change in the accessibility of a bus stop affects different categories of population. A similar study was done by Arasan et al. (1994) in which the authors determined the characteristics of trips by foot and bicycle modes in Indian city. They took data about the trip length preference (in minutes) from a home interview survey done for developing a comprehensive transportation plan for the city of Tiruchirapalli. A sample of 3000 and 2000 were obtained for walking trip and bicycling trips analysis respectively. The various factors used for determining critical walking distance were the age, sex, trip purpose, occupation and time of travel for analysis. An average critical trip length of 20 minutes and 24 minutes were determined respectively for foot and bicycle which corresponded to a percentage value of 81 and 85 respectively for walking and bicycling. In another study Arasan et al. (1996) determined the variation of acceptable trip length among the commuter without vehicles based on influence of various categories of population like the employment status, sex and relationship to head of house hold. It was assumed that there were only two modes available for a commuter without any private vehicle – walking and public transit. A utility function was then developed for walking by foot. The critical distance was then determined as the distance at which the rate of change of probability of choosing walking as a mode was maximum and was found to lie between 1.3 and 2.5 kilometre. Rastogi and Rao (2003) did a study on the travel characteristics of commuter accessing transit in Mumbai on the basis of their mode use pattern, availability of access modes, satisfaction of access environment and characteristics of access leg in comparison with primary and egress legs. An acceptable distance of 910 m and 2724 m was found respectively for walking and cycling.

All these studies point to the importance of critical distance or acceptable distance in the facility promotion. In our study at first the various variable influencing the critical distance are identified after which a statistical test is done between sub groups of each variables in order to understand the influence of these variable. Lastly a critical distance is determined for each subgroups under each variable based on the result of the statistical analysis.

DATA COLLECTION AND STUDY AREA DEFINITION

The data for the study was collected from household survey done for the Comprehensive Traffic and Transportation Plan for Bangalore. A total of sample of 5063 households were used in the study. Bangalore is a plateau with roads having gentle to medium gradient.

Bangalore has a pleasant and equitable climate throughout the year. It has got a population of 8425970 (Census of India 2011). The total area of Bangalore metropolitan region is around 8000 sq km of which 2191sq km is in the urban districts (Comprehensive Traffic and Transportation Plan for Bangalore, 2007). The modal share of walking in Bangalore is 8.33%. The public transportation system in the city is run by Bangalore Metropolitan Transport Corporation (BMTC) which is a public sector company.

VARIABLES INFLUENCING TRIP DISTANCE BY FOOT

Trip distance characteristics can be assumed to be influence by various factors. For example age. A person who is young, who is in his 20's and is healthy, may walk more than a person who is old and above 50's. Similarly a person in low economic strata may walk a long distance than a person in higher economic strata because of his job profile or inability to access motorized modes. Critical distance for trips on foot gives an idea regarding the infrastructure facility location for pedestrians. But before determining it, it is necessary to understand the effect of the various variables on the walking distance. Categories which have same walking distance characteristics can be assumed to be having same critical distance. The various factors identified in our study which influenced the walking distance characteristics were age, driving license availability, level of education, occupational status, purpose and sex.

Age

Age can be thought of as an important factor which influences the trip distance characteristic. The various age groups in to which population was divided were <15, 15-30, 30-50, >50. Table1 gives the statistical characteristics of trip distance by foot of different age groups.

Driving license availability

Availability of driving license is another factor which can be thought of as influencing the trip distance characteristic. It will help us in determining the variation of trip distance by foot which exist among the vehicle owners (assuming all persons with license own a vehicle) and non vehicle owners (assuming all persons without license do not own a vehicle). The two groups considered here were, with license and without license.

Education level

The level of education was divided in to six groups which consisted of illiterate, up to Senior Secondary College (SSC), up to Higher Secondary College (HSC), diploma, graduate & above, and others.

Occupational status

Occupational status gives the various occupations in which people are employed in. It will help in identifying the walking distance variation among the categories of employed, unemployed, students etc. Occupational status had six categories - Employed (full time, part Time, self employed), Daily Wages, Students, Homemaker/Housewife, Retired, and Others.

Sex

The two groups of male and female were considered here. Figure1 shows the cumulative frequency plot for male and female. It can be observed from the data that both the plots are overlapping for majority of the portions.

Purpose

Earlier studies have shown walking characteristics to be dependent on purpose. The various categories in the purpose were work, school, shopping, personal business, and others (social, entertainment, recreation etc.). Table2 gives the statistical characteristics of trip distance by foot for different purposes.

Table 1 - Statistical characteristics of trip distance by foot of different age groups

Age groups	Percentage of total walking trips	Trip distance by foot (m)			
		mean	median	mode	Standard deviation
<15	23.3	0.97	1	0.5	0.783
15-30	31.4	1.04	1	0.5	0.928
30-50	38.4	1.09	1	0.5	0.935
>50	6.9	1.00	0.5	0.5	0.904

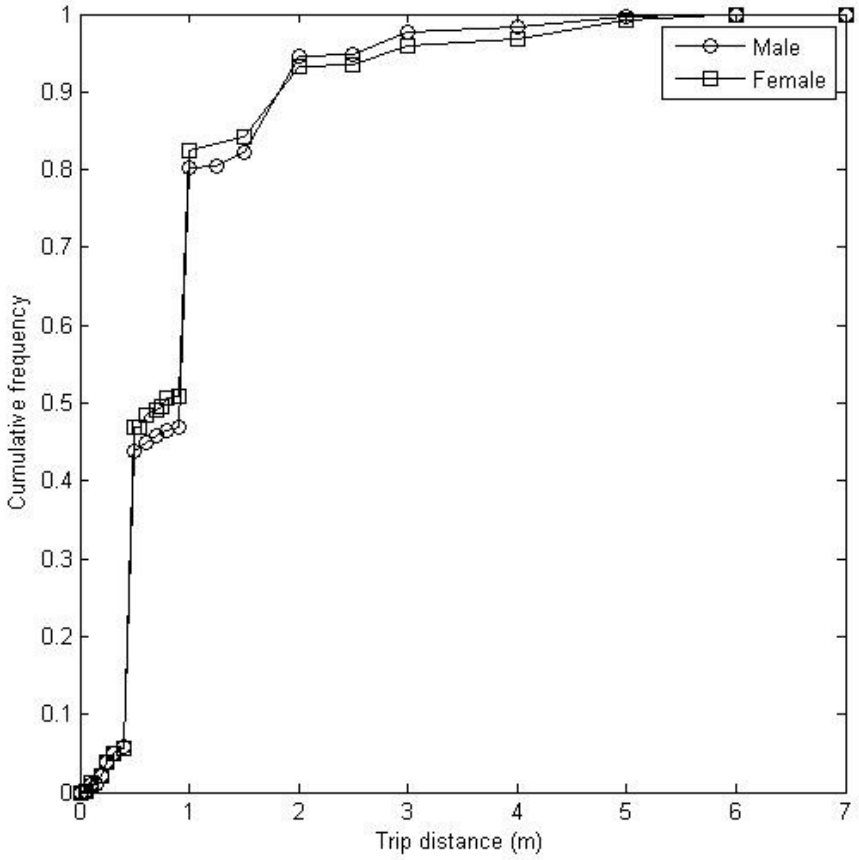

Figure 1 - Cumulative frequency plot for male and female

Table 2 - Statistical characteristics of trip distance by foot of different purposes

Purpose	Percentage of total walking trips	Trip distance by foot (m)			
		mean	median	mode	Standard deviation
Work	36.6	1.08	1	0.5	0.89
School	22.1	0.997	0.6	0.5	0.92
Shopping	0.3	0.91	1	0.5	0.57
Personal business	0.9	0.72	0.5	0.5	0.49
Others	40.1	1.05	1	0.5	0.90

METHODOLOGY

The entire methodology was divided in to two parts. In the first part a statistical analysis was done to understand the walking distance variation along subgroups of each variable and in the second part critical distance for trip distance by foot was determined for each subgroup based on the results of the statistical analysis.

Statistical analysis

The statistical analysis consisted of determination of significant difference between the mean trip distances on foot of different subgroups under each variable. A lack of significant difference between the subgroups indicated that the mean of walking distance was same. In such a case these groups were merged and the critical distance was found for the merged group. We considered only two groups at a time for analysis.
Statistical analysis for significant difference of mean checks the null hypothesis that the mean between two groups under consideration are same. The alternate hypothesis is that the two means are not same. There are three tests which could be done for checking the null hypothesis according to the sample properties. The first one is a Z-test in case the sample size is greater than 30. It is done for different variances. The second test is a modified t-test if the sample size less than 30 and the variance of both groups under consideration are significantly different. The third test is a t-test where the variances of both groups considered are assumed same. In our study according to the sample properties one of the three tests were done and hypothesis was checked. All the tests were done as two tailed tests and the level of significance was assumed as either 5% or 10%.

Critical distance determination

As defined earlier critical distance by foot is the maximum distance after which person will shift to some other alternative facility or route. In case of walking as main mode it is the distance after which a person will shift to some other mode and in case of walking as an access or egress mode to public transits it is the distance after which a person will shift to some other private modes.
For determining the critical distance in the current study a plot was made between distance travelled by the respondents along X- axis and the corresponding cumulative frequency of respondents along Y-axis. The critical distance was located at a point where the variation of slope of cumulative frequency plot was maximum. This plot was made by using a well defined distribution of either normal or the lognormal whichever was fitting the actual data from the field to better extend. In order to identify the better fit a goodness of fit test was done using the Chi-square distribution. Here we have used only two distributions but a number of other distributions can also be checked for its fit.

RESULTS AND DISCUSSION

Statistical analysis

The results of the statistical analysis for different variables are given below

Age

There was a lack of significant difference between the groups <15 years and >50, and also 15-30 and >50. It means that the average characteristics of the age groups 15 years and >50, and 15-30 and >50 are the same. Here since the z-value of the later one was lesser the critical distance by foot was determined combined for them. Table 3 shows the result of statistical test between age groups.

Driving license availability

The group with driving license available did not show any significant difference in mean with the group without driving license. It came as a surprise mainly because of the fact that these groups were expected to have a variation. The critical value observed in the z-test for a significance level of 5% was 1.96 and the observed z-statistic value was -0.18.

Table 3 - Result of statistical test between age groups

Age Group*	Critical value	|Observed value|	Remark
1 & 2	1.96	3.20	reject
1 & 3	1.96	5.40	reject
1 & 4	1.96	1.08	accept
2 & 3	1.96	2.21	reject
2 & 4	1.96	0.82	accept
3 & 4	1.96	2.10	reject

*1 <15
*2 15-30
*3 30-50
*4 >50

Level of education

The results influence of level of education on trip distance by foot is shown in table 4. The results indicated an insignificant difference of mean between the groups illiterate, up to Senior Secondary College, up to Higher Secondary College and others. After the category 'higher secondary college' the mean of walking distance was found to decrease as the level of education increased. It means that a highly educated person is willing to walk lesser distance than his lower level counterparts.

Table 4 - Result of statistical test between levels of education categories

Group*	**Critical value**	**|Observed value|**	**Remark**
1&2	1.96	1.06	accept
1&3	1.96	0.17	accept
1&4	1.96	3.08	reject
1&5	1.96	4.39	reject
1&6	1.96	0.90	accept
2&3	1.96	0.83	accept
2&4	1.96	2.59	reject
2&5	1.96	4.04	reject
2&6	1.96	1.25	accept
3&4	1.96	2.90	reject
3&5	1.96	4.14	reject
3&6	1.96	0.97	accept
4&5	1.96	0.57	accept
4&6	1.96	2.24	reject
5&6	1.96	2.57	reject

*1 - Illiterate
*2 - Senior Secondary College
*3 - Higher Secondary College
*4 - Diploma
*5 - Graduate and above
*6 - Others

Occupational status

Categories employed (full time, part time, self employed), students, homemaker/housewife and retired were found to have an insignificant difference between mean. As expected the daily wage labourer's had a higher mean as compared to other groups. It may be due to the fact that they have to walk a longer distance for access of jobs. Table 5 shows the results of the statistical test between different levels of education.

Table 5 - Result of statistical test between different levels of education

Group*	Critical value	Observed value	Remark
1&2	1.96	4.31	reject
1&3	1.96	1.69	accept
1&4	1.96	0.03	accept
1&5	1.96	0.62	accept
1&6	1.96	2.69	reject
2&3	1.96	5.04	reject
2&4	1.96	2.90	reject
2&5	1.96	1.57	accept
2&6	1.64	1.69	reject
3&4	1.96	-0.90	accept
3&5	1.96	1.19	accept
3&6	1.96	2.92	reject
4&5	1.96	0.52	accept
4&6	1.96	2.60	reject
5&6	1.96	2.26	reject

*1 - Employed (full time, part Time, self employed)
*2 - Daily Wages
*3 - Students
*4 - Homemaker/Housewife
*5 - Retired
*6 - Others

Sex

There was no significant difference between the mean walking distance of male and female. The average walking distance of male was found as 1.04 Km and of female was found as

1.05 Km. The critical value observed in the z-test for a significance level of 5% was 1.96 and the observed z-statistic value was 0.54.

Purpose

The trip distance by foot between groups work and shopping, work and others, and also school and shopping were found to have a lack of significant difference between their mean. So the categories school and shopping were combined, and groups work and others were combined. Table 6 shows results of comparison of mean walking distance for different purposes.

Table 6 - Result of statistical test between different purposes

Group*	Critical value	Observed value	Remark
1&2	1.96	2.99	reject
1&3	2.07	1.14	accept
1&4	1.96	5.97	reject
1&5	1.96	1.37	accept
2&3	2.07	0.46	accept
2&4	1.96	4.48	reject
2&5	1.64(10%)	1.89	reject
3&4	2.07	4.47	reject
3&5	2.07	5.46	reject
4&5	1.96	5.47	reject

*1 - work
*2 - school
*3 - shopping
*4 - personal business
*5 - Others

Critical distance on foot

Table *7* shows the result of the critical distance obtained for various categories. The critical distance by foot increased with increase in age group till group 30-50 and then reduced for the group >50. This show that young kids and old people walk less compared to young and middle aged men. In the variable level of education one could observe the increasing critical distance by walking with increasing education level after Higher Secondary College (HSC). The result was same as that obtained for the mean distances. Figure 2 shows the cumulative frequency plot for category male and female. It is drawn using a lognormal distribution with mean -0.205 and standard deviation 0.675 found from data.

Table7 Walking critical distance characteristics for different categories

Category		Mean	Standard deviation	Acceptable distance (m)	Sample size
Age					
	<15	965	783	815	1926
	15-30 & >50	1071	931	851	6115
	30-50	1097	935	867	3160
Driving license availability		1052	899	880	4151
Level of education					
	Up to HSC,SSC, illiterate & others	1061	916	856	5166
	Diploma	934	724	773	356
	Graduate and above	907	793	760	757
Occupational status					
	Employed, students, House wife & Retired	1019	882	854	5757
	Daily Wages	1194	997	979	812
	Others	1464	1399	905	72
Sex					
	Male & Female	1044	901	839	8586
Purpose					
	Work & others	1060	896	863	6627
	School & shopping	996	919	772	1929
	Personal business	724	491	730	78

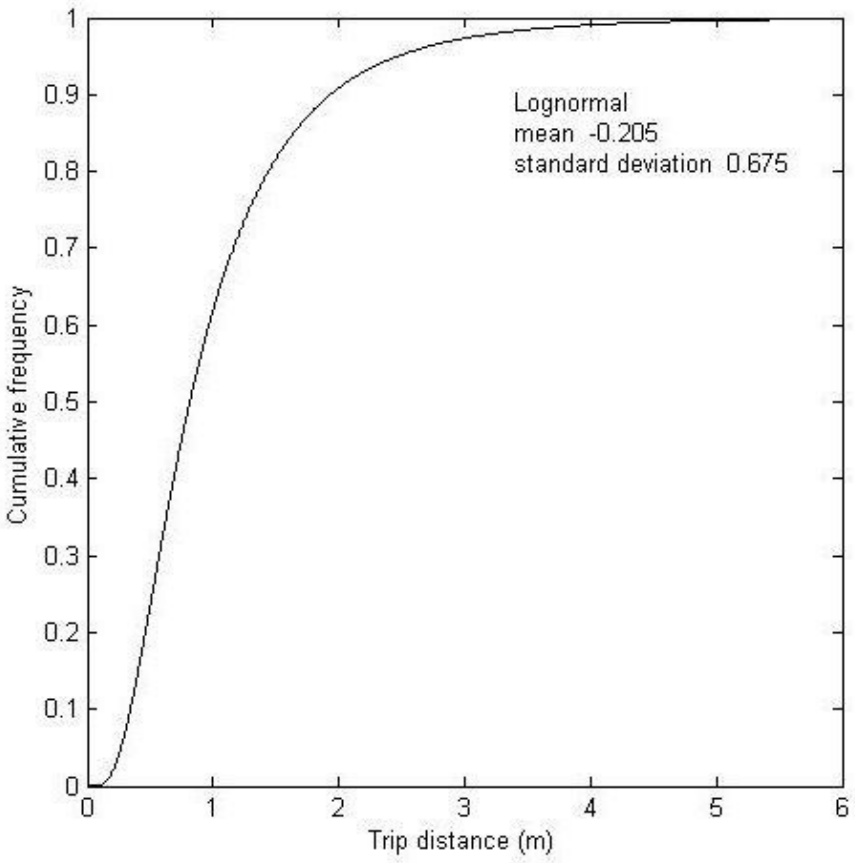

Figure 2 - Cumulative frequency plot for male and female

Comparison of walking distance characteristics of Indian cities from earlier studies

Table 8 shows a comparison of the trip distance characteristics by foot of two earlier studies done for Indian cities and the present study. The study for the city of Tiruchirapalli was done by Arasan et al(1994) and for Mumbai was done by Rastogi and Rao (2003).The mean distance of Bangalore was found to be less than the city of Tiruchirapalli but greater than city of Mumbai.

Table 8 - Comparison of walking distance characteristics of Indian cities

City	Mean distance(m)
Tiruchirapalli	1700
Mumbai	910
Bangalore	1043

CONCLUSION

The present study analyzed the influence of variables age, availability of driving license, education level, occupational status, sex and purpose on the walking distance in the city of Bangalore. It was done using the statistical method of comparison of means. The results were then use in the determination of critical distance by foot. Critical distance was defined as the maximum acceptable distance a commuter will walk in order to access a facility. Statistical analysis showed a lack of significant difference between the mean trip distance of male and female and also between respondents with driving license and without driving license. The critical distance of the combined group of males and females and of respondents with driving license and without driving license were found as 1044m and 1052 respectively. A comparison of means of walking distance of Bangalore with walking distance in Mumbai and Tiruchirapalli showed that the people of Bangalore walk more than people of Mumbai but less than people of Tiruchirapalli. The reason for Mumbai having a less walking distance may be due to the good connectivity provided by the suburban rail.

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