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ACCESSIBILITY ANALYSIS TO PUBLIC TRANSPORT – A CASE STUDY OF THIRUVANANTHAPURAM CITY

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ABSTRACT
The paper describes accessibility analysis was done for the Central Business District area of Thiruvananthapuram city. The accessibility to public transport system was identified with the help of a methodology called Public Transport System Accessibility Level. Regression models were developed for measuring the accessibility by different wards. Separate models were developed for gender, different age groups and also for license holders and non license holders. The possibility of expressing the Accessibility by Hansen's index method was also explored by measuring the accessibility to employment opportunities.

1.INTRODUCTION

Public transportation system is the key component of sustainable transport system. The system can relieve congestion and provides efficient way of moving large number of people. Accessibility is concerned with the opportunity that an individual or type of person at a given location possesses to take part in a particular activity or a set of activities. Accessibility takes on board the land use-transport connection and handles trip numbers and travel time as indicators. Measurement of access to social services for each household can help in adjusting and accommodating the under-served regions. Accessibility measures seek to define the level of opportunity and choice taking account of both the existence of opportunities, and the transport options available to reach them.

The variety of accessibility measures currently known can be grouped into the following main categories;

- Infrastructure-based accessibility measures which measure the transport infrastructure

performance;

- Activity-based accessibility measures which are based on the availability of opportunities to satisfy individual needs, their spatial distribution and the impedance of travel;
- Utility-based accessibility measures that are based on utility theory and measures the benefits the individual may derive from the land use and transport system.

Scope and Objectives of the Study

The scope of the study was confined to assess and understand the accessibility to public transport by the population in the CBD area of Thiruvananthapuram city. The main objectives of were:

- Development of regression models for public transport trips;
- Calculation of public transport accessibility index using appropriate technique;

2. FINDINGS FROM LITERATURE REVIEW

Accessibility is the suitability of the transit system in helping people get to their destinations in a reasonable amount of time [5]. Accessibility measures can be grouped into five categories: travel-cost approach, gravity or opportunities approach, constraints-based approach, utility-based surplus approach and composite approach. In the gravity method or opportunity approach individuals' accessibility is calculated based on zones as a function of opportunity attractiveness, and the travel distance between other zones and the resident zone. The constraint-based approach is equivalent to time-space measures, while the utility-based surplus approach uses the utility measures with a greater focus on individual behavior and decision-making. Composite approaches attempt to combine time-space and utility indicators into a common model.

GIS-based accessibility measure was coined by Luo (2004). He developed a GIS based floating catchment method to assess areas with shortage of physicians. The same technique can be adopted for calculating the accessibility to public transportation system using the principle of the floating catchment methodology (FCM)[6]. A new method for measuring access to public transportation services was developed by Bhat et al (2005) [2]. They developed service area analysis in GIS. The population in each zone was identified for the analysis. Buffer areas were marked for every bus stop. These are done in spatial accessibility measures [3].

3.METHODOLOGY

The work starts from the selection of the study area followed by collection of primary and secondary data. In the data analysis, a public transport system accessibility index is calculated. The potential of Geographical Information System (GIS) was also used for analysis. Regression models are developed for the trips by public transport system using the software Statistical Package for Social Science (SPSS). Accessibility indices were worked out for the study region using the well-established Hansen's method as well.

4.STUDY AREA

The study area selected is Thiruvananthapuram city, the capital city of Kerala. Thiruvananthapuram is an emerging metropolitan city in the southernmost part of India. People from all over the State migrate to

Thiruvananthapuram due to the employment opportunities. The city is characterized by its undulating terrain of low coastal hills and busy commercial valleys. Thiruvananthapuram district is situated between north latitudes 8°17' and 8°54' and east longitudes 76°41' and 77°17' and has a gross area of 2192 sq. km. The corporation wards (13 nos.) encompassing the major corridors in the city namely the M G road and NH 66 section of LMS Junction to Kesavadasapuram is selected as the study area. A map of Thiruvananthapuram district showing the study area is given in Fig.1

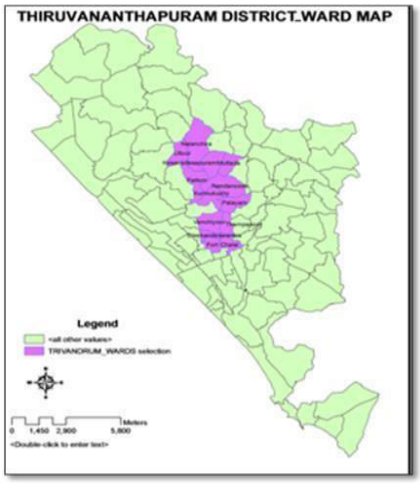

FIGURE 1 STUDY AREA

5. DATA COLLECTION

The data collection includes primary data and the secondary data. The primary data consists of the household information and trip details collected through home interviews. The secondary data collection includes the population details of the selected wards, the land use details, and the information about the public transportation system in the selected locality. The primary data is collected using a well-structured questionnaire form, comprising of:

1. Household characteristics: It consists of socio economic information about the household. The relevant questions include number of members in the house, number of employed and unemployed people in the house, their age, gender etc.

2. Personal characteristics: In this part the questions are designed to classify the household members according to age, profession, educational qualification etc.

3. Trip data: This section aims at identifying the travel characteristics. Here the origin and destination, trip purpose, mode of travel, walking distance to the bus stop and waiting time at the bus are identified.

The household data was collected from 560 houses in the selected area. Proper coding and grouping were done during the data entry process. Summary of data collection is given in Table 1.

TABLE 1 SUMMARY OF DATA COLLECTION

Ward Name	Number of houses interviewed	Number of persons interviewed in the ward
Fort	30	116
Chalai	50	148
Thampanoor	30	102
Vanchiyoor	50	106
Sreekandeswaram	50	164
Palayam	30	104
Nanthankode	30	103
Muttada	50	145
Pattom	30	97
Kesavadasapuram	30	87
Ulloor	50	169
Nalanchira	50	163
Kunnukuzhy	30	92

In all the wards, the main mode of travel is the public transport system. Nanthankode, Nalanchira and Sreeekandeswaram wards are having lower percentage of choosing the public transport system as the main mode of travel. This may be because of the accessibility problem towards the bus stops. Nalanchira ward is having highest vehicle ownership and so the percentage of choosing the public transport system as the main mode is less compared to other modes. The public transport trips are more for work and educational purposes.

6.ACCESSIBILITY TO PUBLIC TRANSPORT SYSTEM

Accessibility is an abstract concept which describes where activities are located in relation to dwellings and how convenient or difficult it is to get to these activities. From the different methods identified the Public Transport System Accessibility Level (PTAL) is a detailed and accurate measure of the accessibility of a point to the public transport network, taking into account of walk access time and service availability. So PTAL is used for calculating the public transport accessibility. But PTAL has a disadvantage that it does not takes into account where the services actually go and it excludes more distant points[3].

6.1 Public Transport System Accessibility Level

In PTAL the total access time is calculated based on two factors: walk time from the Point of Interest to the Service Access Point (SAP) and the time spent waiting at the SAP for the desired service to arrive.

Total Access Time = Walk Time + Average Waiting Time (1)

EDF=30/Total Access Time (minutes (2)

AI = EDFmax + (0.5 x All other EDFs) (3)

The total access time and the EDF are calculated based on Eqns. (1) and (2). The final Accessibility Index or the PTAL value is calculated by taking the sum of all EDF values, which is a modification of (3), to suit the field values as

$$AI = \sum EDF \qquad (4)$$

For the entire ward the directions of travel are identified. The parameters included for calculating PTAL at each ward are the walking time and the waiting time. The calculated values of PTAL for the entire wards are given in Table 2**.** The table also includes the percentage of public transport trips generated in the particular ward.

TABLE 2

CALCULATED VALUES OF PTAL

Ward name	PTAL	Percentage of Public Transport
Fort	22.00	29.09
Chalai	14.12	31.41
Thampanoor	18.37	36.30
Vanchiyoor	15.39	32.81
Sreekandeswaram	11.82	32.63
Palayam	13.70	32.39
Nanthankodu	16.12	38.33
Muttada	10.21	30.28
Pattom	15.57	27.31
Kesavadasapuram	14.01	31.32
Ulloor	16.83	29.28
Nalanchira	13.10	30.76
Kunnukuzhy	10.03	29.20

Based on the analysis a new scale for PTAL is developed for Thiruvananthapuram urban area. The accessibility levels are classified as poor, fair, good, very good and excellent based on PTAL value obtained. From this rating it is found that Fort and Thampanoor wards are with very good accessibility to public transport system. But Kunnukuzhy and Muttada wards are with PTAL value less than 12

indicating poor accessibility. This rating is used for the present study. The rating is given in Table 3.

TABLE 3
RATING OF ACCESSIBILITY LEVEL

Accessibility Level	PTAL Value
Poor	<12
Fair	12-15
Good	16-18
Very Good	19-22
Excellent	>22

Figure 2 shows the ratings of wards based on the calculated PTAL.

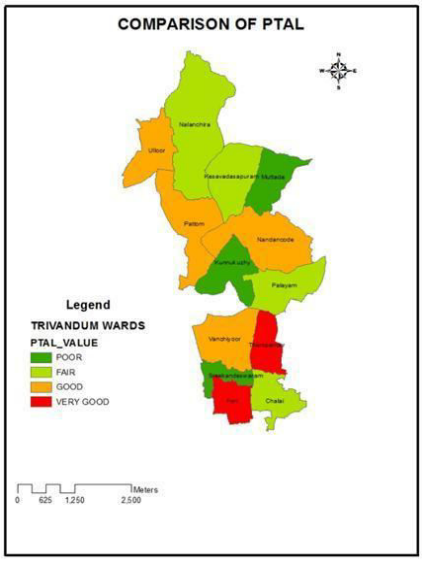

FIGURE 2. COMPARISON OF PTAL IN DIFFERENT WARDS

6.2 Regression Models

Accessibility is the main factor considered for the model formulation. The factors which affect the accessibility like the waiting time and the walking time are considered as the independent variables. The number of trips generated by each individual by the public transportation system depends on the accessibility. The number of trips by the system also increases when the accessibility to the system increases. Regression models are generated for all the 13 wards and several other models are generated based on the gender, age-wise classification and also for license holders and those without any license. The models developed for the percentage of public transport trips are given in Tables 4, 5, 6, 7.

TABLE 4 MODEL DEVELOPED FOR DIFFERENT WARDS

Ward	Model
Fort	P = 0.942–0.015xA+0.006xI–0.100x WT-0.079x WLT
Chalai	P = 1.047– 0.003x A + 0.018x I–0.111x WT- 0.097xWLT
Vanchiyoor	P = 1.238–0.013xA-0.010xI–0.004x WT- 0.229xWLT
Sreekandeswaram	P = 1.009–0.026xA-0.002xI–0.066x WT- 0.144x WLT
Thampaoor	P = 0.925– 0.004xA-0.010xI–0.121x WT -0.291x WLT
Palayam	P=1.190+0.036xA-0.025xI–0.159xWT - 0.097x WLT
Kunnukuzhy	P = 1.217 +0.022xA +0.017xI–0.113x WT- 0.137x WLT
Nanthankodu	P= 0.949-0.024xA-0.003xI–0.048xWT - 0.124x WLT
Pattom	P = 0.996-0.011xI– 0.043xWT-0.158x WLT
Muttada	P = 1.056-0.035xA –0.011xI–0.043x WT-0.158x WLT
Ulloor	P = 0.917-0.036xA–0.012xI–0.040x WT- 0.127x WLT
Kesavadasapuram	P=0.994-0.008xA-0.001xI–0.117xWT- 0.0.083x WLT
Nalanchira	P=1.072-0.005xI–0.151xWT-0.0.055x WLT
All Wards	P=.974 - 0.011xA + 0.012xI–0.078x WT- 0.109x WLT

TABLE 5 MODEL DEVELOPED FOR GENDER

Gender	Model
Male	P=0.921-0.072WT-0.106WLT
Female	P=0.996-0.045WT-0.149WLT

TABLE 6
MODEL DEVELOPED FOR DIFFERENT AGE

Age	Model
0-15	P=0.821+0.009xWT-0.167xWLT
16-23	P=0.933-0.011I-0.047WT0.128WLT
24-60	P=0.984-0.075xWT-0.115xWLT
>60	P=0.970-0.066xWT-0.125xWLT

TABLE 7
MODEL DEVELOPED BASED ON DRIVING LICENSE

Criteria	Model
Having License	P=0.921-0.072xWT-0.106xWLT
No License	P=0.892+0.013I-0.065xWT 0.107xWLT

P is the percentage of public transport trips made by a person A is the age of the person I is the monthly income by a person WT is the waiting time at the bus stop WLT is the walking time to the bus stop 20% of the data is kept for the model validation. The relation between observed and expected values is identified with the help of T test. Two tailed test is done with null hypothesis that there is no significant difference between the expected and observed values. For all the models the tabled value is higher than that of the calculated value. The calculated t values are given in table8.

TABLE 8 VALIDATION OF RESULTS

Sl. No	Model	Degrees of Freedom	Calculated Value	Tabled Value
1	Fort	22	2.020	2.074
2	Chalai	19	1.960	2.090
3	Thampanoor	20	1.370	2.086
4	Vanchiyoor	21	2.020	2.080
5	Sreekandeswaram	30	1.840	2.040
6	Palayam	21	1.990	2.080
7	Nanthankodu	19	1.980	2.090
8	Muttada	23	2.040	2.070
9	Kunnukuzhy	15	2.070	2.145
10	Pattom	19	2.060	2.090
11	Kesavadasapuram	16	1.930	2.130
12	Ulloor	30	2.000	2.040
13	Nalanchira	30	1.180	2.040
14	Gender(Male)	30	1.980	2.040
15	Gender(Female)	24	0.834	2.045
16	Age(0-15)	19	1.987	2.093
17	Age(16-23)	23	1.930	2.069
18	Age(24-60)	19	0.587	2.093
19	Age(>60)	29	0.979	2.045
20	License	30	2.010	2.042
21	No License	30	1.670	2.042

6.3 Findings from the Formulated Models

By analyzing the models for all the thirteen wards, it is found that the trips by the public transport system mainly depends on the walking time to the bus stop and waiting time at the bus stop. In all the wards, it is clear that the Age and the Income have very less significance compared with walking time and waiting time. The coefficient of waiting time is more for males and the walking time coefficient is more for female, which means that males are more willing to wait than females. But females are willing to walk more compared with males. When comparing the age groups, the coefficient of walking time is more for children. The coefficient of waiting time is more for 24 to 60 age group. The number of public transport trips and the coefficient of waiting time is less for the people having driving license.

6.4 Accessibility to Employment Opportunities

The accessibility to employment opportunities was found out using the basic H ansens Index. The primary analysis on the trips produced in the study area showed that the work trips constitute higher percentage compared to other purposes. So it is very essential to identify the accessibility to the employment opportunities. Hansens Index is the basic index used for finding the accessibility to particular locations. The index is the sum of the activity of each zone in the destination zone set weighted by a function of cost or distance between the given Origin-Zone pair [1].

$$Ai=\sum O_i f(C_{ij}) \qquad (5) \qquad (5)$$

(5)Ai is accessibility at location *i*,

Oj the number of opportunities at *j*

$f(Ci,j)$ is a function of the generalized travel cost from *i* to *j* . Usually a negative exponential function of distance

(or time) is frequently used as the cost function:

$$f(Cij)=e^{(-\gamma d)} \qquad (6)$$

di j is the distance from location *i* to destination *j*,

γ- Accessibility coefficient, which is an empirically determined parameter measuring the effect of distance on interaction with the destinations.

The value of γ depends on the impedance factor. A value of 0.5 is taken as the value of γ[4].

The Hansens Index for all the wards is calculated based on the centroidal distance and the employment opportunities in each ward. The centroidal distances are calculated from the ArcGIS software and are represented in Fig 3. The employment opportunities are obtained from secondary data collection. The values of Hansens Index for all the wards are given in Table 9. The representation of Hansens Index is done in ArcGIS software. The representation of the same is given in Fig 3.

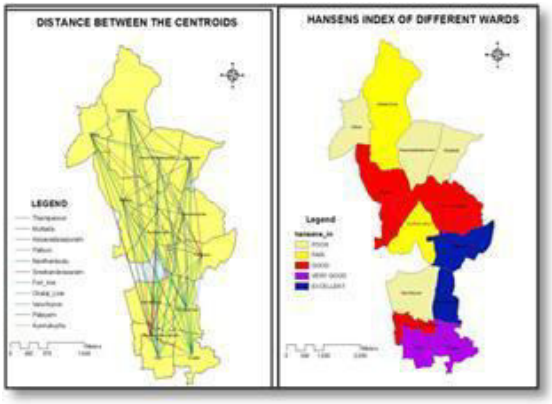

FIGURE 3. CENTROIDAL DISTACE AND REPRESENTATION OF HANSENS INDEX

TABLE 9
HANSENS INDEX OF DIFFERENT WARDS

Ward	Employment Opportunities	Hansens Index
Pattom	3535	12877
Kesavadasapuram	2041	7423
Muttada	1275	4230
Nanthankodu	3475	14648
Kunnukuzhy	2279	9819
Vanchiyoor	1452	6105
Palayam	14453	56728
Thampanoor	18392	75340
Sreekandeswaram	3871	14812
Fort	8640	29239
Chalai	9926	25536
Nalanchira	3534	7688
Ulloor	1423	2824

Based on the value obtained for the Hansens index, the accessibility is classified as poor, fair, good, very good and excellent. The accessibility index for employment opportunities is found to be excellent for Palayam and Thampanoor wards with the index value of 56728 and 75340 respectively. Ulloor and Muttada wards are having lower values of 2824 and 4320. These values indicate that the accessibility to employment opportunities is very poor for Ullor and Muttada wards. The accessibility to other opportunities like shopping, education, recreation etc can also be calculated based on Hansens Index.

7. RESULTS AND DISCUSSIONS

The study focused on the importance of accessibility measures in the transportation planning. Accessibility index for all the wards to the public transport system is calculated based on the PTAL methodology. The wards with higher PTAL value have higher accessibility to public transport system and vice versa. The PTAL values are represented in ArcGIS software.

Several regression models are generated to identify the effect of accessibility on the public transport trips. For this, the regression models are developed with public transport trips as the dependent variable and age, monthly income, walking time and waiting time of each individual as the independent variable. The regression models were developed for all the 13 wards separately to identify the effect of public transport trips in this area. Other models were also developed for public transport trips based on gender, age and also for license holders and non license holders.

The accessibility analysis for employment opportunities was done based on the Hansens Index. The index is calculated for all the selected wards. Thampanoor and Palayam wards are with higher accessibility with the index values as 75340 and 56728 for the two wards respectively. The representation of Hansens Index is done in ArcGIS software.

The work can be summed up as follows:

1. Formulated a new scale for Public transport accessibility level for Thiruvananthapuram Urban area.
2. Based on the new scale the variations in accessibility to public transport system by the different wards are calculated.
3. Linear regression models are developed for the percentage of public transport trips with walking time and waiting time as the independent variables.
4. The accessibility to employment opportunities are identified with the help of Hansen's
5. Index.

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