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Activity based travel demand modeling of Thiruvananthapuram urban area

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Abstract

An efficient transportation system and infrastructure is necessary for the growth and development of economy of a nation. Transportation planning plays a vital role in improving the transportation system, which includes identifying the travel demand and implementing plans accordingly. Trip based approach and tour based modeling were the methods used for travel demand modeling. Activity based modeling is the latest trend in travel demand forecasting which considers activity based tour chains as the individual unit of analysis. This study attempts to develop an activity based travel demand model for Thiruvananthapuram urban area, taking into consideration the socio-economic characteristics and travel pattern. The model includes a single activity based tour generation model and mode choice model. The multinomial logit model was adopted for generating the models.

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Keywords: Activity; single activity tour; mode choice; multinomial logit model

1. Background

1.1. Introduction

Transportation is very much related to the growth and economy of a nation. Hence there should be an efficient transportation system and infrastructure serving the nation. Transportation planning is becoming significant in the

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present scenario of fast growing population and travel demand. Planning is highly related with demand modeling. Travel demand modeling is a mathematical relationship between travel demand and traveler and system characteristics (Cascetta, 2009). Travel demand modeling had trip based four-step modeling as its pioneer. Later on new generation models such as tour based and activity based modeling emerged covering most of the drawbacks of conventional method. The tour based approach considers chain of trips starting and ending at same location as the individual unit of analysis whereas activity based travel demand model considers travel as a derived demand to satisfy the need of the individual.

This paper explains the development of an activity based travel demand model for Thiruvananthapuram, the capital of Kerala, an Indian state, taking into consideration of the socio-economic factors and travel pattern, validating the generated model and suggesting how it can be made beneficial in the planning process. It includes a tour generation model for single activities and mode choice model.

2. Study area

One of the major steps in the transportation planning process is the selection of the study area. Being a medium sized developing city, Thiruvananthapuram, capital of Kerala, the largest and the most populous city of the state, was selected as the study area. The study area covered a total of 15 municipal corporation wards covering the CBD region. The travel demand of the district is increasing greatly, as the legislative assembly, info-parks, other business centers etc. are located here. The major cause of transportation problems in the city is congestion, lack of parking spaces, encroachment and the increased use of personal modes. The reason for this is the failure in developing a well framed public transportation system and infrastructure.

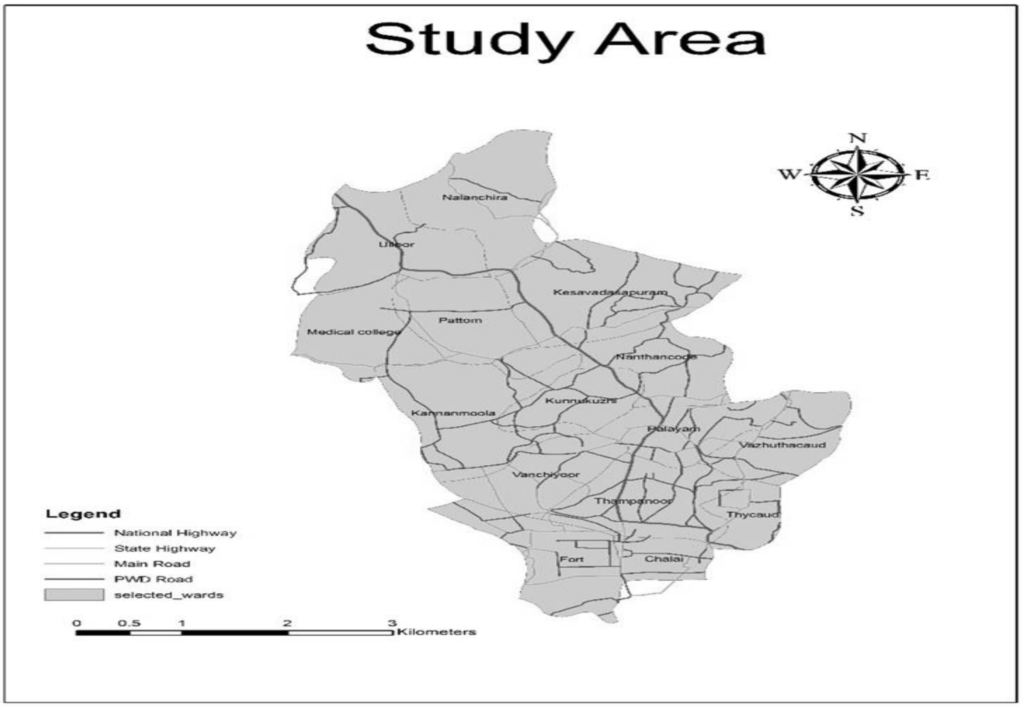

Fig. 1: Map of Study Area

3. Methodology

The study area selected was the urban region of Thiruvananthapuram Corporation, with 15 wards which were selected as the 15 traffic analysis zones. The primary data, i.e. socio-economic and travel characteristics were collected using household survey done using questionnaires. The secondary data, i.e. population data was obtained from the Corporation and NATPAC, Thiruvananthapuram. After compiling, sorting and coding, the tour generation and mode choice models were developed using SPSS software package.

4. Data collection

Data to be collected can be divided into primary data and secondary data. Primary data is the data obtained from household survey, which include travel data and socio economic data. On the other hand secondary data includes population data. The study area was divided into traffic analysis zones and the sample size was estimated for each zones. Household survey was done as it gives data on individual basis. A questionnaire was prepared for primary data collection by household survey, in which enquiries regarding the household characteristics and socio economic characteristics and travel characteristics were included.

4.1 Preliminary analysis

The primary data collected from the household questionnaire survey is sorted and coded as different group of similar characteristics. These coded data is later used as the variables for model generation. The data were sorted and coded for age groups (1 for individuals falling in the age 3 to 20, age group 2 for individuals of age 21-55 and 3 for individuals of age above 55), gender (1 for male and 2 for female), occupational status (1 for working, 2 for non-working and 3 for students), income (1 for individuals with monthly income 0-10000, 2 for individuals with monthly income 10000-25000 and 3 for individuals with monthly income above 25000), vehicle available for exclusive use (1 if yes and 2 if not available), license ownership (1 for license holders and 2 for non-holders), single activities (1 for HWH activity chain, 2 for HEH activity chain, 3 for HSH activity chains and 4 for HOH chains), mode of travel (1 for Bus, 2 for Intermediate public transport, 3 for Two wheeler and 4 for walk,5 for cars and 6 for others), Time of day (1 if both the time of start and time of destination of activity tour is in the peak period, i.e., from 8hrs to 11hrs and 16hrs to 19hrs, 2 if both fall on the off peak period and 3 for the tours for which either the time of start falls in peak and time of reaching destination falls in off peak or vice versa). Also distance, cost and time of travel were sorted for analysis.

The descriptive analysis of the variables included in the study is given in Table 1.

Table 1: Descriptive analysis of the variables

Variable		Classification	Frequency	Percentage
Age	1	3-20	464	20.18
	2	21-55	1112	48.37
	3	>55	723	31.45
Gender	1	Male	1276	55.50
	2	Female	1023	44.50
Occupation	1	Working	967	42.06
	2	Non-working	780	33.93
	3	Student	552	24.01
Income	1	0-10000	1220	53.07
	2	10000-25000	509	22.14
	3	>25000	570	24.79
Vehicle ownership	1	Yes	863	37.54
	2	No	1436	62.46
License	1	Yes	1245	54.15
	2	No	1054	45.85

Activity	1	HWH	807	35.10
	2	HEH	521	22.66
	3	HSH	516	22.44
	4	HOH	455	19.79
Mode	1	Bus	449	19.53
	2	IPT	311	13.53
	3	Two wheeler	528	22.97
	4	Walk	423	18.40
	5	Car	355	15.44
	6	Others	233	10.13
Time of day	1	Peak	1600	69.60
	2	Off peak	401	17.44
	3	Others	298	12.96

5. Model interpretation

5.1 General introduction

The modelling was done using SPSS statistical software package. The utility maximisation theory described by Multinomial logit model is used as the modelling approach. According to the point of view of Utility maximization theory, the individual's activity-travel decisions are made such as to derive maximum utility from their choices. Let U_i be the utility function for an activity or a mode by and individual 'i', can be represented as a function of observed utility and an error part. (C R Bhatt, 2003).

$$U_i = V_i + \Sigma\varepsilon_i \quad (1)$$

Where, Vi is the systematic component (observed utility) and $\Sigma\varepsilon_i$ is the random component (error).
In the case of travel demand modelling, the objective of the individual will be to select such an activity or mode from the available alternatives so that the utility will be maximized.

Discrete choice models (Multinomial logit and Nested logit) are employed in utility maximization technique. Discrete choice models statistically relate the choice made by each person to the attributes of the person and the attributes of the alternatives available to the person. Multinomial logistic (MNL) regression, which is the simplest model, is used to predict categorical placement or the probability of category membership on a dependent variable based on multiple independent variables. The independent variables can be either dichotomous (i.e., binary) or continuous (i.e., interval or ratio in scale), (Starkweather et al, 2011). The multinomial logit model is based on the following assumptions:

- Each independent variable has a single value for each case.
- Dependent variable cannot be perfectly predicted from the independent variable in any case.
- Relies on assumption of Independence of Irrelevant Alternatives.

The MNL identifies how the independent variables are related to the dependent variable and express in terms of utility. The probability of alternatives based on a reference category can be obtained based on the utility function for various alternatives considered.

5.2 Single activity tour generation model

The single activity choices, home based work (HWH), home based education (HEH), home based shopping (HSH) and home based other tours (HOH), were selected as the alternatives. After conducting trials of regression, the independent variables to be included for generating the utility function were selected on the basis of goodness of fit for each trial.

The overall test of relationship among the independent variables and dependent variables is given by the likelihood ratio test. Here the chi- square value (2355.546) of model with independent variables has a significance of 0.000 which is less than the level of significance 0.05. Hence we can conclude that the dependent variables are related with independent variables.

Table 2. Model fitting information of activity tour generation model

Model Fitting Information				
Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	3884.756			
Final	1529.210	2355.546	18	.000

Table 3. Model interpretation of tour generation model

Activity tour chain	Variables	Log of odds	Significance range < 0.05	Remarks
HEH	Distance	0.052	0.003	Significant
	[Age=1.0]	23.078	0.000	Significant
	[Age=2.0]	17.572		
	[Age=3.0]	0		
	[Income=1.0]	22.291	0.992	Not significant
	[Income=2.0]	16.417	0.994	Not significant
	[Income=3.0]	0		
	[License=1.0]	0.035	0.906	Not significant
	[License=2.0]	0		
HSH	Distance	-0.234	0.000	Significant
	[Age=1.0]	-1.176	0.102	Not significant
	[Age=2.0]	-1.968	0.000	Significant
	[Age=3.0]	0		
	[Income=1.0]	2.536	0.000	Significant
	[Income=2.0]	.637	0.003	Significant
	[Income=3.0]	0		
	[License=1.0]	-0.737	0.000	Significant
	[License=2.0]	0		
HOH	Distance	-0.004	0.666	Not significant
	[Age=1.0]	-0.740	0.277	Not significant
	[Age=2.0]	-2.355	0.000	Significant
	[Age=3.0]	0		
	[Income=1.0]	2.428	0.000	Significant
	[Income=2.0]	0.819	0.000	Significant
	[Income=3.0]	0		
	[License=1.0]	-0.561	0.002	Significant
	[License=2.0]	0		

5.3 Inferences

The following inferences have been drawn from the model;

- The characteristic variables such as distance, age, income and license were identified as significant in the single activity tour generation model.
- The age group between 3 and 20 have positive effect on educational trips.
- For unit increase in distance, the probability for shopping tours reduces by 0.234 times compared to work tours.
- Population with age 21 to 55 has a negative significance on shopping trips over work trips.
- Population with income up to 25000 are more likely to choose shopping tours compared to population with income above 25000.
- As far as leisure and religious tours are concerned, it has been found that income is having a positive impact as expected.

5.4 Mode choice model

The mode choice model predicts the choice of mode of travel by the population. The alternatives considered for the model were; Public transport, Intermediate public transport, Two wheeler, Walk, Car and others which included school bus, office bus etc. The independent variables considered were age, gender, occupation, income, vehicle ownership, license availability, travel time, cost, distance and time of day chosen for travel. The variables in the model with highest accuracy were selected as the final time of day mode choice model.

The difference between the log likelihood of the null hypothesis and final model, i.e. Chi-square value, is 3765.724 with a degree of freedom of 40 and significance of 0. Hence it supports the model with independent variable.

Table 4.Model fitting information for mode choice model

Model Fitting Information				
Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	7542.779			
Final	3777.055	3765.724	40	.000

Table 5. Model interpretation of mode choice model

Mode	Variables	Parameter	Significance	Remarks
Bus	Cost	-0.092	0.000	Significant
	[Age=1.0]	1.407	0.000	Significant
	[Age=2.0]	0.294	0.108	Non-significant
	[Age=3.0]	0		
	[Income=1.0]	-0.027	0.897	Non-significant
	[Income=2.0]	0.103	0.629	Non-significant
	[Income=3.0]	0		
	[Veh own=1.0]	-1.618	0.000	Significant
	[Veh own=2.0]	0		
	[Time of day=1.0]	-0.849	0.000	Significant
	[Time of day=2.0]	-1.308	0.000	Significant
	[Time of day=3.0]	0		
IPT	Cost	0.055	0.000	Significant
	[Age=1.0]	-0.366	0.202	Non-significant
	[Age=2.0]	-1.217	0.000	Significant
	[Age=3.0]	0		
	[Income=1.0]	0.604	0.011	Significant
	[Income=2.0]	0.191	0.451	Non-significant
	[Income=3.0]	0		

	[Veh own=1.0]	-2.002	0.000	Significant
	[Veh own=2.0]	0		
	[Time of day=1.0]	0.054	0.838	Non-significant
	[Time of day=2.0]	0.264	0.390	Non-significant
	[Time of day=3.0]	0		
Car	Cost	0.057	0.000	Significant
	[Age=1.0]	-1.963	0.000	Significant
	[Age=2.0]	-1.571	0.000	Significant
	[Age=3.0]	0		
	[Income=1.0]	-0.838	0.000	Significant
	[Income=2.0]	-0.747	0.000	Significant
	[Income=3.0]	0		
	[Veh own=1.0]	-0.048	0.792	Non-significant
	[Veh own=2.0]	0		
	[Time of day=1.0]	0.032	0.903	Non-significant
	[Time of day=2.0]	0.278	0.363	Non-significant
	[Time of day=3.0]	0		
Others	Cost	-0.014	0.068	Non-significant
	[Age=1.0]	3.629	0.000	Significant
	[Age=2.0]	0.749	0.027	Significant
	[Age=3.0]	0		
	[Income=1.0]	-0.688	0.019	Significant
	[Income=2.0]	-0.736	0.026	Significant
	[Income=3.0]	0		
	[Veh own=1.0]	-1.310	0.000	Significant
	[Veh own=2.0]	0		
	[Time of day=1.0]	-1.075	0.000	Significant
	[Time of day=2.0]	-1.188	0.000	Significant
	[Time of day=3.0]	0		

5.5 Inferences

The inferences obtained from the model were;

- The characteristic variables such as age, income, vehicle ownership, time of day and cost of travel were the significant variables in the model.
- For unit increase in cost, users preferring bus will be less by 0.092 units.
- The population falling in the age group of 3 to 20 are more users of public transportation, while the vehicle ownership reduces the preference of bus as well intermediate public transport.
- A negative impact is seen on tours by cars with old age people as well as with low income group.
- Also, as expected, low income people are seen to prefer the use two wheelers.

6. Summary and conclusions

A single activity tour generation model and mode choice model were developed using activity based approach. Multinomial logit model was used as the modelling tool. For single activity based tour generation model, single activity tour chains were considered as the dependent variable and the characteristic variables such as age, income, license and distance were identified as the significant variables in the model. In the case of mode choice model, mode of transport for single activity tour chains was considered as the dependent variable, and the characteristic variables such as age, income, vehicle ownership, time of day and cost of travel were identified as significant variables in the model. The utility functions developed from both the models were used for generating the probability functions which predicts the occurrence of single activity tour chains and mode choice for travel. The single activity tour chains considered in the model were home based work tours, home based educational tours, home based shopping tours and home based leisure and religious tours. Also the mode of travel considered as the dependent variables in the model included bus, two wheeler, car, inter-mediate public transport, walk and other modes such as school bus, office bus etc.

The models developed can be used to predict the types of activity patterns generating and the mode preference of the population. The models can serve as a platform for predicting the number of tours generated for a given socio-economic group and accordingly transportation and land use plans can be formulated in a long term perspective.

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