Activity Based Transportation Modeling for Chelakottukara ward of Thrissur District

Midhun T, Anitha Jacob

Abstract: ***An Activity-based model is the one that generally replaces the conventional trip-based model, which is usually represented to as the four-step model. With the variations in the transportation system attributes and changes in socio-demographics of the individuals, the transportation planners and engineers' need to have the ability to estimate the variations in transportation demand so as to make a well-versed transportation infrastructure planning decision possible. Activity-based models are used for this purpose; these models are used to forecast travel characteristics and usage of transport services under different socio-economic scenarios. An activity-based travel pattern model has been developed for the individuals of the study area. This activity-travel pattern model will take different input parameters such as various land-use, socio-demographic, activity system, and transportation level-of-service attributes. Thus it will provide the activity-travel pattern of each individual in the study area as the output, within the continuous time domain.***

Index Terms: Activity-Based Travel Pattern, Four-Step Model, Socio-Economic, Travel Demand.

I. INTRODUCTION

Transportation plays an important role in the growth and economy of a nation. For a country like India, transportation planning is becoming unavoidable due to the fast-growing population and travel demand. Transportation planners and engineers have to be able to forecast the response of transportation demand for the changes in the attributes of the transportation system and changes in the socio-demographics of the people using the transportation system in order to make informed transportation infrastructure planning decisions. Travel-demand models are used for this purpose. It is used to predict the travel characteristics and the use of transport services under various socioeconomic scenarios and for various transport service and land-use configurations.

The mathematical relationship between travel demand and traveler and system characteristics can be achieved with the help of travel demand modeling. Earlier travel demand modeling is done with the help of trip based four-step modeling – as the trip generation, trip distribution, mode choice and route choice. This four-step modeling is said to be conventional modeling. Later on, new generation models such as tour based and activity based models emerged overcoming most of the drawbacks of the conventional method. The tour based approach considers a chain of trips starting and ending at the 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 [1]. The objective of this paper is to develop an activity-based travel demand model for Chelakottukara, the 22nd ward of the Thrissur City of Kerala, 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 both single and complex activities.

II. LITERATURE REVIEW

A. *Trip-Based Models*

Trip-based travel models have evolved over many decades. As their name suggests, trip-based models use the individual person trip as the fundamental unit of analysis. Trip-based models are widely used in practice to support regional, sub-regional, and project-level transportation analysis and decision making. Trip-based models are often referred to as "4-step" models because they commonly include four primary components. The first trip generation components estimate the numbers of trips produced by and attracted to each zone (these zones collectively represent the geography of the modelled area). The second trip distribution step connects where trips are produced and where they are attracted to. The third mode choice step determines the travel mode, such as automobile or transit, used for each trip, while the fourth assignment step predicts the specific network facilities or routes used for each trip[8].

B. *Activity-Based Models*

Activity-based models are having some similarities to traditional 4-step models: activities are generated, destinations for the activities are identified, travel modes are determined, and the specific network facilities or routes used for each trip are predicted. However, activity-based models incorporate some remarkable advances over 4-step trip-based models, such as the clear representation of realistic constraints of time and space and the linkages among activities and travel, for an individual person as well as across multiple persons in a household. These linkages enable them to more sensibly represent the effect of travel conditions on activity and travel choices.

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Activity-based models also have the ability to integrate the influence of very detailed person-level and household-level attributes and the ability to create detailed information across a broader set of performance metrics. These abilities are possible because activity-based models work at disaggregate person-level rather than a more aggregate zone-level like most trip-based models [8], [6].

C. Econometric Modeling Approach

It involves systems of equations to capture relationships among macroscopic indicators of activity and travel, and to predict the probability of decision outcomes. These models explore how activity and travel patterns are related to land use and socio-demographic characteristics of the traveler. The main criticism of the econometric approach is that it does not explicitly model the behavioral mechanisms underlying activity engagement and travel. This limits the richness of the behavior theories that can be incorporated into the model system. Nevertheless, the family of econometric models - ranging from discrete choice models, hazard duration models and limited-dependent variable models - remains strong approach to activity-travel analysis. Its strength lies in allowing the examination of alternative hypotheses about the unconcerned relationships among behavioral indicator [9], [3].

III. Study Area

The study area selected is Chelakottukara, the 22nd ward of Thrissur Corporation which is shown in figure 1. The study area consists of total population of 5627 individuals as of 2011 census, 1599 dwelling units and 580 other building comprising a total of 2179 units.

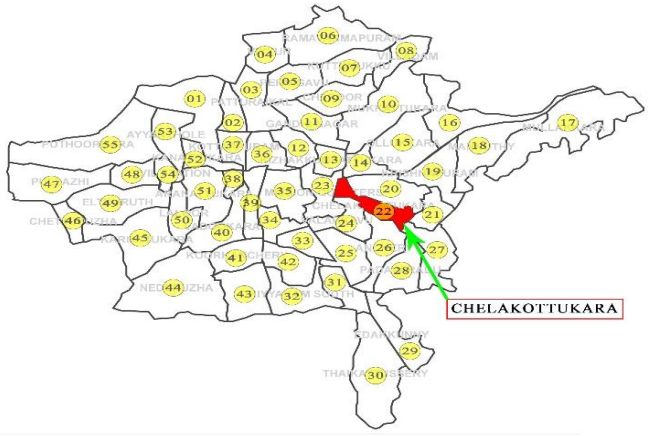

Fig. 1. Thrissur corporation map.

IV. METHODOLOGY

The study area selected was Chelakottukara, 22nd ward of Thrissur Corporation. The primary data, i.e. socio-economic and travel characteristics were collected using household questionnaire survey. The secondary data, i.e. population data were obtained from Thrissur Corporation. After compiling, sorting and coding, the activity-travel pattern model was developed using SPSS software.

A. Data Collection

Data need to be collected can be divided into two - primary data and secondary data. Primary data is the data obtained from the household questionnaire survey. For this survey, an activity travel diary is mandatory, which can incorporate personal information and travel information of whole members of the selected household. On the other hand, secondary data includes population data. The sample size of the study area is estimated with the help of current population and building details of the study area [4]. The guideline suggested by Bruton [2] is adopted and a sample size of 160 households is selected in a random manner.

B. Preliminary Analysis

The data collected from the household questionnaire survey is sorted and coded as a different group of similar characteristics. These coded data is later used as the variables for model generation. Summary of the data collected is given in table 1.

TABLE I: Summary of HouseholdSurvey Data

Details	Item	Value	(in %)
Household	Average Household size	3.55	-
	Average Household income per month (in Rs.)	29228.00	-
Trip	Average tour rate per household	2.09	-
	Average tour rate per person	0.59	-
Sample	Workers	198	35.74
	Students	128	23.10
	Homemakers	154	27.80
	Retirees	63	11.37
	Employment Seeking Group	10	1.81
Total	Female	288	51.99
	Male	266	48.01
	Individuals	554	-

1) Distribution Based on Occupation

From the chart plotted (Figure 2) based on occupation share of people, it can be identified that in the sample collected, 28% of total population are Home Makers. By conducting the preliminary study one can also find that the female percentage is slightly higher than that of the male. That would be the reason for this increase in Home Makers. Also, it can be found that by combining the working groups (government employee, private employee, self-employed and daily wages) together it is noted that about 36% (1+17+16+2) in the study area are employed. This indicates that the average income obtained from the survey is appropriate.

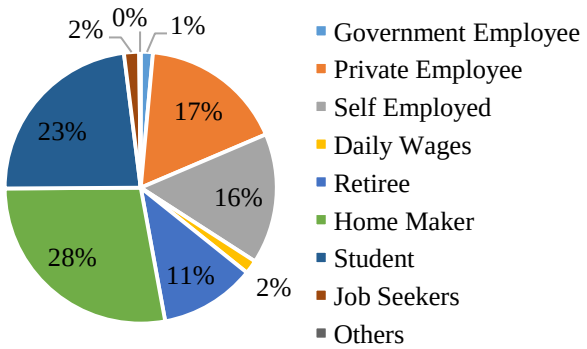

Fig. 2. Distribution of occupation.

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2) Distribution Based on Age

A chart has been generated for the distribution on age, which is given in figure 3. It can be observed that in the sample collected, there is an equal distribution of ages in all age category of people. But among them also majority of the people are in the age limit of 45 to 60 years. This implies that the age cross section of the sample is good.

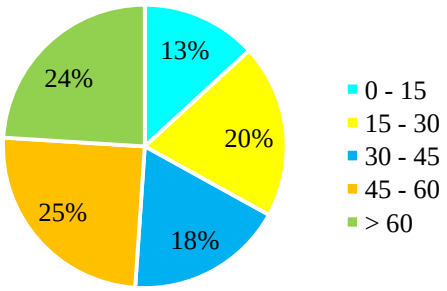

Fig. 3. Distribution of age.

3) Distribution of Household Size

A graph has been plotted with household size along the x-axis and percentage household size along the y-axis, which is shown in figure 4. From this graph, it can be identified that for a household size of 4, the percentage household size is maximum, which is 30.57%. As it is mentioned earlier that the average household size of the study area is 3.55, this graph is giving the clear picture regarding how the average household reached that value.

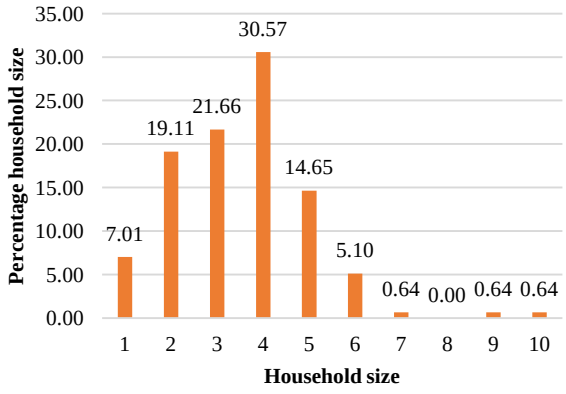

Fig. 4. Distribution of household size.

4) Distribution of Person's Education Level

Person's education level is illustrated in figure 5. It can be seen that of the sample collected, 72% of people are below graduate. That can be the reason behind the increase in self-employment and private employment compared to that of the government employment. That is also reflecting directly on their income too as it has already seen that the average income of the study area is Rs. 29288.00 per month.

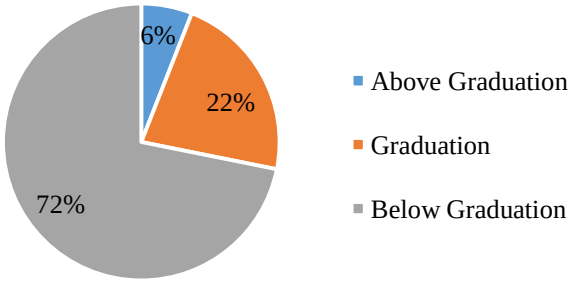

Fig. 5. Distribution of education level.

5) Distribution of vehicle Ownership

The chart (Figure 6) is plotted with the ownership of vehicles. It can be seen that for about 64% of the sample is owning one or two automobiles. This may increase the tours that can be generated.

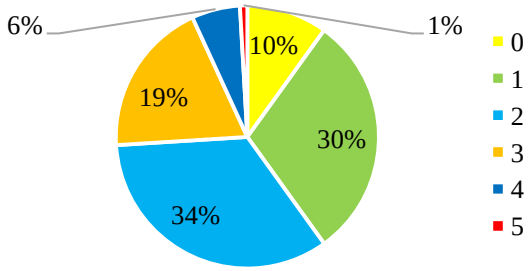

Fig. 6. Distribution of vehicle ownership.

6) Distribution of Tour Rate

In order to find a relationship between household tour rate and vehicle ownership, a graph has been plotted with the number of automobiles in a household along the x-axis with tours per household along the y-axis, as shown in figure 7. It can be seen that with the increase in the automobile ownership there is an increase in the number of tours generated per household. Hence, that it can be said that both the automobile ownership and numbers of tours made are directly proportional to each other as the automobile increases the number of tours also increases.

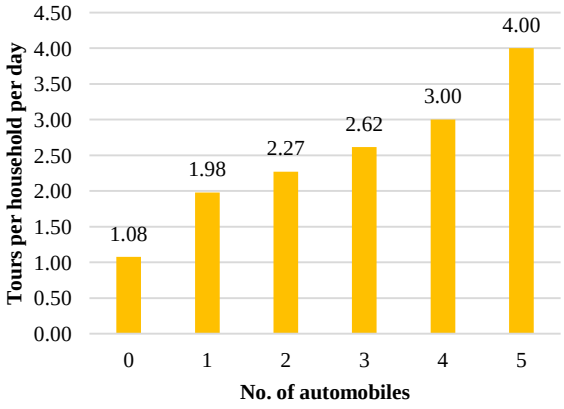

Fig. 7. Distribution of tour rates.

7) Activity-Travel Patterns

The activity-travel patterns that are identified from the sample taken are of two types, namely simple activity pattern and complex activity pattern. In simple activity pattern, there will be only two number of trips. In complex activity pattern there will be a minimum of three number of trips. The simple activity patterns obtained are, HWH (Home-Work-Home), HEH (Home-Education-Home), HSH (Home-Shop-Home) and HOH (Home-Others-Home). While the different complex activity patterns observed are HWH+ and HOH+ [5].

8) Distribution of Activities

It has been already found from figure 2 that 37% of total population are workers. Thus there is a chance of having more work activities in the study area, and from the figure 8, it can be found that 46% of total activities are of working activity.

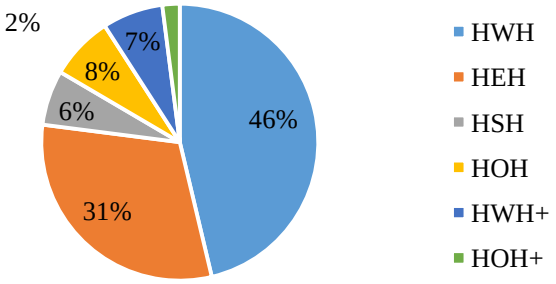

Fig. 8. Distribution of activities.

C. Modeling

The modeling was done using SPSS (Statistical Package for Social Science) statistical software package. The utility maximization theory described by multinomial logit model is used as the modeling approach.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 multipleindependent variables. The variables used for modeling the activity-travel patterns are gender, age, education, type of employment, monthly income, vehicle ownership, mode of travel, distance of travel, cost of travel, duration of travel, activity duration and time of day. Before going for the model development the first task is to find the correlation between different variables. That has been found out with the help of SPSS by using Spearman's rank correlation technique, which is given in table II.

TABLE II: CORRELATION STUDY OF ACTIVITY PATTERN

Variables	Code	Type of Correlation
Gender	G	Negative
Age	A	Positive
Education	Ed	Negative
Employment	Em	Positive
Income	I	Negative
License	Li	Negative
Vehicle	V	Negative
Mode	M	Positive
Travel Distance	TDi	Negative
Travel Cost	TC	Negative
Travel Duration	Tdu	Negative
Activity Duration	Adu	Negative
Time of Day	Ti	Positive

The final output is to generate a model and thereby estimate the total number of different activities occurring in the study area. To reach the desired output it is necessary to go through three different steps. The first step is to obtain the score of each activity by the help of equations generated. After that the next step is to calculate the probability of occurrence of each activity by the help of score of each activity pattern. Then the last step is to find the total number of activity with the help of probability of occurrence of each activity and the total population of the study area

1) Model Formulation

Multinomial logistic (MNL) regression modelis used to predict categorical placement or the probability of category membership on a dependent variable based on multiple independent variables. As an outcome of multinomial logit modeling, the different equations that can be used for predicting the utility score of various activity patterns are as given below:

$$\begin{aligned} HWH = {} & -3.693 + 0.127V - 0.025TD_i + 0.003TC + 0.003TD_u \\ & + 0.002AD_u + 0.105G_0 + 0.827A_1 \\ & + 0.241A_2 + 0.179A_3 + 0.031A_4 \\ & - 0.045Ed_0 + 2.370Em_0 + 1.516Em_1 \\ & + 1.213Em_2 + 1.827Em_3 - 0.152Em_4 \\ & + 0.073Em_5 - 1.733Em_6 + 0.332I_1 \\ & + 0.282I_2 - 0.073I_3 - 0.024Li_0 + 3.412M_0 \\ & + 3.646M_1 + 3.369M_2 + 3.584M_3 \\ & + 3.562M_4 + 3.092M_5 + 0.028Ti_1 \\ & - 0.218Ti_2 + 5.457Ti_3 \end{aligned}$$

$$\begin{aligned} HEH = {} & -3.183 - 0.036V + 0.009TD_i - 0.011TC - 0.005TD_u \\ & - 0.001AD_u - 0.156G_0 - 1.204A_1 \\ & - 0.138A_2 - 0.125A_3 + 0.070A_4 \\ & - 0.025Ed_0 - 2.231Em_0 - 1.776Em_1 \\ & - 1.715Em_2 - 2.075Em_3 - 0.649Em_4 \\ & - 0.112Em_5 + 2.813Em_6 + 0.160I_1 \\ & - 0.107I_2 + 0.638I_3 - 0.150Li_0 + 3.737M_0 \\ & + 3.549M_1 + 4.971M_2 + 4.564M_3 \\ & + 4.717M_4 + 4.953M_5 + 1.191Ti_1 \\ & + 1.374Ti_2 + 16.107Ti_3 \end{aligned}$$

$$\begin{aligned} HSH = {} & -5.424 - 0.169V + 0.030TD_i - 0.008TC - 0.014TD_u \\ & - 0.015AD_u - 0.636G_0 - 0.059A_1 \\ & - 0.504A_2 - 0.276A_3 - 0.341A_4 \\ & + 1.468Ed_0 - 2.391Em_0 + 0.543Em_1 \\ & - 0.299Em_2 + 0.242Em_3 + 1.039Em_4 \\ & - 0.219Em_5 - 1.659Em_6 + 0.526I_1 \\ & + 0.677I_2 + 0.676I_3 - 0.270Li_0 + 13.389M_0 \\ & + 14.252M_1 + 13.650M_2 + 13.024M_3 \\ & + 13.239M_4 + 13.079M_5 - 2.904Ti_1 \\ & - 1.804Ti_2 + 19.225Ti_3 \end{aligned}$$

$$\begin{aligned} HOH = {} & -4.225 - 0.087V - 0.025TD_i + 0.006TC + 0.021TD_u \\ & - 0.001AD_u + 0.727G_0 + 0.088A_1 \\ & - 1.140A_2 - 1.843A_3 - 0.636A_4 \\ & + 0.135Ed_0 - 5.986Em_0 - 3.443Em_1 \\ & - 2.895Em_2 - 3.868Em_3 - 0.144Em_4 \\ & - 0.376Em_5 - 2.642Em_6 + 1.092I_1 \\ & + 2.600I_2 + 3.047I_3 - 0.708Li_0 + 10.653M_0 \\ & + 9.465M_1 + 10.151M_2 + 10.233M_3 \\ & + 8.769M_4 + 8.999M_5 - 4.159Ti_1 \\ & - 5.096Ti_2 + 2.791Ti_3 \end{aligned}$$

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$$HWH+= -1.794 - 0.286V - 0.038TD_i + 0.071TC + 0.004TD_u + 0.002AD_u - 0.115G_0 + 0.383A_1 + 0.360A_2 - 0.290A_3 - 0.294A_4 - 0.145Ed_0 - 0.273Em_0 + 0.024Em_1 + 2.639Em_2 + 1.440Em_3 + 1.361Em_4 - 0.045Em_5 - 0.235Em_6 - 4.016I_1 - 4.663I_2 - 4.044I_3 + 1.512Li_0 + 5.532M_0 + 5.457M_1 - 0.794M_2 + 0.675M_3 + 3.825M_4 + 3.789M_5 - 2.738Ti_1 - 0.885Ti_2 + 0.024Ti_3$$

$$HOH+= -9.473 - 0.250V + 0.066TD_i + 0.017TC - 0.032TD_u - 0.001AD_u + 0.131G_0 + 3.424A_1 + 4.253A_2 + 2.803A_3 + 0.837A_4 - 1.066Ed_0 - 2.196Em_0 + 1.894Em_1 - 0.125Em_2 + 3.359Em_3 + 5.253Em_4 + 3.346Em_5 + 1.640Em_6 + 0.375I_1 + 2.219I_2 + 4.187I_3 + 0.660Li_0 + 2.489M_0 + 3.934M_1 + 0.660M_2 + 2.122M_3 - 0.652M_4 + 3.856M_5 + 2.439Ti_1 + 3.755Ti_2 + 8.863Ti_3$$

From these equations, the score of each type of activity pattern can be found out by inputting the values corresponding to each independent variables.

The probability of occurrence of each activity pattern can be calculated by using the equation (1).

$$\Pr(Y_i = 1) = \frac{e^{score(X_i,1)}}{1+\sum_{k=1}^{K-1} e^{score(X_i,k)}} \qquad (1)$$

Where Xi is the vector of explanatory variables describing observation i to k.

The total number of activity pattern can be calculated by multiplying these probabilities by the total population of the study area which is 5627.

2) Model Characteristics

The overall test of the relationship between the independent variables and dependent variables is given by the likelihood ratio test. Here the model with independent variables has a significance of 0.000 which is less than the level of significance 0.05. Hence, it is concluded that the dependent variables are related to independent variables. The significance of the model is obtained with the help of knowing the Chi-Square value of the model which is 433.94 and degrees of freedom 186. The tabled Chi-Square value is 239.428 corresponding to the same degrees of freedom. From this two Chi-Square values it can be seen that the tabled value is less than the obtained value. This means that the coefficients of independent variables have a significant role in the equations generated. Also, the significance of each independent variables is given in table III.

TABLE III: MODEL STATISTICS

Variables	Chi-Square	df	Sig.
Intercept	0.000	0	
Vehicle	2146.848	6	0.000
Travel Distance	3386.861	6	0.000
Travel Duration	7364.159	6	0.000
Gender	6.234	6	0.398
Age	8935.943	24	0.000
Education	1838.605	6	0.000
Income	26159.825	18	0.000
Mode	6248.857	30	0.000

The values for travel cost, activity duration, employment, license and time can't be estimated by SPSS.

The model that has developed is having a McFadden's coefficient of determination (R2) value of 0.409. Generally R2 values will range from 0 to 1 [7]. 0 indicates that the model explains that, there is no variability of the response data around its mean. And 1 indicates that the significant variability of the response data around its mean.

The accuracy of the model has been checked by the help of substituting one-third of the data which is not used for the model creation. As an outcome, the accuracy of the model generated is 82%, which can be considered as a good model.

V. CONCLUSIONS

An activity tour generation model was developed on six different aspects using activity-based approach. The multinomial logit model was used as the modeling tool. For every activity-based tour generation model, activity tour chains were considered as the dependent variable and different independent variables (gender, age, educational qualification, employment, income, license, vehicle ownership, mode used for travel, travel distance, travel cost, travel duration, activity duration and time of day) were identified significant in the model. The utility functions developed from the model is used for generating the probability functions which predicts the occurrence of activity tour chains. The activity tour chains considered in the model were home-based work tours, home-based educational tours, home-based shopping tours, home-based other tours, home-based complex work tours and home-based complex other tours.

The model was developed to predict the score of each activity. Using multinomial logit model, the probability of each activity was calculated. The models can serve as a platform for predicting the number of tours generated for a given socioeconomic group and accordingly transportation and land use plans can be formulated in a long-term perspective.

The extension of the study area from a single ward of the Thrissur city to entire Thrissur city can be considered as the future scope of this work. By implementing it in such a manner a decent and good model can be made that can make so many advantages to the Thrissur Corporation to analyze what will be the possible outcome by making any significant changes in that area. Also, a micro-simulation model creation can also enhance the importance of the extension of this work.

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REFERENCES

1. B. G. Hutchinson, *Principles of Urban Transport Systems Planning*, Scripta Book Company, University of Michigan, 1974, pp. 320-400.
2. M. J. Bruton, *Introduction to Transportation Planning*, Hutchinson Technical Education, London, 1971, pp. 99-150.
3. S. V. S. Saladi and K. V. Krishnarao, "Activity-Based Approach to Travel Demand Modeling: An Overview." in *TransportiEuropei*, 61th ed. vol. 6, 2016.
4. G. R. L.Amrutha, V. S. Landge and K. V. S. Sanjay, "Activity-Based Travel Demand Modeling of Thiruvananthapuram Urban Area." in *Transportation Research Procedia 17*, ELSEVIER, 2016, pp. 498-505.
5. Y. Sadayuki and M. Abolfazl, "An Activity-Based Microsimulation Model of Travel Demand in the Jakarta Metropolitan Area" in *Journal of Choice Modeling*, 3rd ed. vol. 1, 2010, 32-57.
6. G. M. Michael, "An Activity-Based Microsimulation Model for Travel Demand Forecasting," *Conference on Activity-based Approaches, Netherlands*, 1996.
7. D. Salgado, D. Jolovic, T. M. Peter and M. A. Rafael, "Traffic Microsimulation Models Assessment – A Case Study of International Land Port of Entry" *Procedia Computer Science 83, ELSEVIER*, 2016, pp. 441-448.
8. R. B. Chandra, S. Srinivasan, Y. G. Jessica and S. Aruna, "Activity-Based Travel-Demand Modeling for Metropolitan Areas in Texas." *Center for Transportation Research, The University of Texas at Austin*, 2003.
9. *Activity-Based Travel Demand Models: A Primer*, Resource Systems Group, Inc.,SHRP 2 Report S2-C46-RR-1. Transportation Research Board, Washington D.C, 2015.

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1. Anitha Jacob and Anjaneyulu M V L R, "Operating Speed of Different Classes of Vehicles at Horizontal Curves on Two-Lane Rural Highways" – Journal of Transportation Engineering, Vol. 139 (3) , March 2013, 287-294.
2. Anitha Jacob and Anjaneyulu M V L R, "Development of Crash Prediction Models For Two-lane Rural Highways Using Regression Analysis" – Highway Research Journal, Indian Roads Congress, Vol 6 No. 1, Jan-June 2013.
3. Anitha Jacob, Dhanya R and Anjaneyulu MV L R" Geometric design consistency of multiple horizontal curves on two-lane rural highways", Proceeding of the International Conference on Transportation Researchers Group of India (CTRG-2013), 12-15 December, 2013, Agra.
4. Anitha Jacob, Jinesh K. J., Jisha Akkara & Jose P. Therattil , "Effect of rural highway geometry on driver workload: A step towards safety", Procedia – Emerging trends in Engineering, Science and Technology for Society, Energy and Environment, Taylor and Francis Group, London, ISBN 978-0-8153-5760-5.

Dr. Jacob was awarded the best paper on road research by Indian Roads Congress in 2015. She is a life member in Indian Roads Congress, ISTE and Institution of Engineers.