Evaluation of Time Allocation to Travel and Other Activities Through Time-Use Analysis

A. Lakshmi and CSRK Prasad*

Centre for Transportation Engineering,
REC, Warangal – 506 004, India
e-mail: csrk@recw.ernet.in

ABSTRACT

Better understanding of urban travel behaviour would enable analysis of model as well as formulation of strategies in managing urban travel. Till date, focus has been on estimation of travel demand utilising trip as unit of analysis. The conventional trip records, which have been used to develop transportation-planning models, are not able to assess the impact of transportation planning on urban resident's quality of life. Hence, data to be used in analysis must contain information not only on trips but also on distribution of activities. An attempt has been made in this paper to understand the temporal aspects of activities and correlate them with trip making through the application of time use concept. Travel duration was regressed against activity duration and activity frequency for different segments of population. Logit models were calibrated to understand the behaviour of people in allocating time to different activities on a normal working day.

INTRODUCTION TO TIME USE CONCEPT

The context of urban transportation planning has changed dramatically since the 50's and 60's, when the travel demand methodologies that are currently in use were being developed (Kitamura and Bhat, 1999). Greater emphasis is now being placed on demand management and other transportation control measures, while relatively less consideration is given to highway construction as a solution to transportation problems. The transportation planning tools that are currently available have their limitations in their ability in evaluating the planning and policy options. The problem stems from the fact that transportation planning methods have been concerned with trips but not with why people make trips and how trips contribute to the quality of life. Travel is directly linked to activities and their characteristics such as spatial distribution, intensities and scheduling of activities. To be able to capture the full impacts of alternative planning options and assess how they contribute to urban residents well being, methodologies must be developed, whose scopes are not limited to trips but encompass the whole daily itineraries of activities and travel. These arguments motivate the collection of time use data and are used to develop models of time use behaviour and to establish procedure for activity-based evaluation of transportation planning options. Many investigators have tried to study the interaction between travel and activity (Lakshmi 2001; Bhat and Koppelman, 1999; Bhat and Misra 1999; Garling et al 1999; Levinson, 1999; Ettema and Timmermans 1997; Golob and McNally 1997; Hsu and Hsieh 1997; Kalfs and Saris 1997; Niemeier and Morita 1996; Kitamura et al 1996; Stopher et al 1996; Stopher 1992; Kitamura 1988). An attempt has been made in this paper to explore time use concept in evaluation of time allocations to travel and other activities in an Indian city.

STUDY METHODOLOGY

Time use analysis is referred as how time is allocated to various activities taking the whole day or longer periods of time as the unit of analysis. Individuals have 24 hrs in a day and they have to decide how to allocate their time for travel and other activities in a day depending on their constraints. The time spent at any activity depends on the travel time to the activity and the frequency of the activity i.e. the no

* Conference Speaker

of times the activity has occurred as the destination. It is proposed to investigate the influence of activity duration on travel duration and allocation of time for different activities in a day as presented below.

Travel Time Duration Model Formulation

It is hypothesised that travel time duration is a function of activity frequency and activity duration. The effectiveness of the relationship varies with the form of the variables. Hence, it is proposed to use the transformed variables in development of the models. The following four model formulations are envisaged for investigation.

a) Linear model – Simple Variables

$$T_i = \beta_0 + \beta_1 F_i + \beta_2 D_i \quad (1)$$

Where

T_i = daily travel duration for activity 'i' in minutes

F_i = daily activity frequency for activity i (times activity 'i' appears as Destination)

D_i = daily activity duration for activity i (in minutes)

$\beta_0, \beta_1, \beta_2$ = Coefficients

The underlying assumption of this functional form is that travel time will be composed of fixed and variable components. One component is independent of the number of trips, assuming the trip is made. A second element is linearly proportional to the number of times that activity is undertaken per day. The third part reflects the importance of that activity, measured by the minutes spent at the activity.

b) Linear Model – Logarithmic transformation of Variables

$$T_i = \beta_0 + \beta_1 \log(F_i) + \beta_2 \log(D_i) \quad (2)$$

c) Linear Model - Square root transformation of Variables

$$T_i = \beta_0 + \beta_1 \sqrt{F_i} + \beta_2 \sqrt{D_i} \quad (3)$$

d) Power model

$$T_i = \beta_0 \; F^{\beta 1} D^{\beta 2} \quad (4)$$

The terms in equations 2 to 4 have the same meaning as explained earlier. It was further hypothesised that activity and family income influence the value placed on travel time duration. However, their influence was studied by considering them as exogenous variables. Total population was segmented initially based on activity type, viz., Home, work, education and others. Travel duration models of different formulations as suggested above were considered for calibration. Further, such models would be developed for different income segments i.e. Low Income, Medium Income and High Income segments.

Time Allocation Model Formulation

Individuals choose an activity plan at the beginning of the day. This plan devotes a certain percentage of the day to specific activities like home, work, shopping, travel and other activities. The share of the day spent at any activity depends on a number of factors such as activity frequency, activity travel time, age, gender, household income etc. Share of the day implies minutes per day spent at any activity divided by total minutes in a day (1440 minutes). The individual decision-maker chooses the amount of time to spend on each activity. The population has been segmented into three groups as indicated below.

Population Segment	Activity Choice set
Work segment	Work, home, shop and other activities
Education segment	Education, home, shop and other activities
Business segment	Business, home, shop and other activities

Logit model is proposed to analyse the share of the day spent at each activity. The probability that an individual will allocate a certain percentage of the day to an activity 'i' is given by:

$$P_{in} = \frac{e^{u_{in}}}{\sum_{j=1}^{m} e^{u_{jn}}} \qquad (5)$$

Where
P_{in} = probability of allocating a certain percentage of the day to the activity 'i' by an individual 'n'.
U_{in} = utility derived for activity 'i' by an individual 'n'
U_{jn} = utility derived for alternate activity 'j' by an individual 'n'
m = number of activities

The utility expressions for work segment are as given below:

$U_w = a_1$ (Work activity frequency) + a_2 (Work activity travel time) + a_3 (gender) + a_4 (Age) + a_5 (Income)
$U_h = a_1$ (Home activity frequency) + a_2 (Home activity travel time)
$U_s = a_1$ (Shop activity frequency) + a_2 (Shop activity travel time)
$U_o = a_1$ (Other activity frequency) + a_2 (Other activity travel time)

Where
a_1 = Coefficient for activity frequency (Generic coefficient)
a_2 = Coefficient for activity travel time (Generic coefficient)
a_3 = Coefficient for gender
a_4 = Coefficient for age
a_5 = Coefficient for income

To know the probability that an individual will allocate a certain percentage of the day to an activity, the individual should plan his day before i.e. the activities he/she pursues in the day must be known in advance.

CASE STUDY

Hyderabad city, the capital of the Andhra Pradesh state, has been taken as the study area for demonstration of the time use concept. Data collected through HIS as part of HATS (1988) was used in the present study.

Travel Duration Analysis for Hyderabad City

Activities, which an individual generally does in a day, include work, education, business, social, shopping, recreation and others. Since the activities like work, education and business, cannot be performed by an individual at one time, these forms a basis for categorization. However work and education activities are time bound and regular, compared to business. Hence, the activities are categorised as work, education and others in addition to home activity. Travel time durations for different trips and their associated activity durations were extracted from the data. Travel duration for return home trips was attributed for home activity. Income has significance in the allocation of time to various activities. In order to find its influence on travel durations to different activities, population has been segmented into three groups based on their monthly family income, viz; Low Income (LI) group (Rs. 1000 or less), Medium Income (MI) group (Rs. 1000 to Rs. 3000) and High Income (HI) group (above Rs. 3000).

Initially, travel duration models were calibrated for the whole population for home, work, education and other activities. Different model formulations, as discussed earlier, were tried. The results are presented in Table 1.

Table 1: Travel duration models for the whole population

Coefficients	Linear Model	Linear Model – logarithmic transformation	Linear Model – square root transformation	Power model
Home Activity				
Constant (β_0)	44.000	51.600	51.240	02.250
Frequency (β_1)	00.910 (6.2)	18.210 (20.2)	11.290 (18.7)	00.240 (16.2)
Activity duration (β_2)	-0.020 (-25.5)	-42.42 (-29.6)	-1.190 (-29.6)	-0.740 (-32.1)
Sample size	11,935	11,935	11,935	11,935
R-square	0.040	0.050	0.050	0.050
Work Activity				
Constant (β_0)	20.040	-5.670	12.120	02.360
Frequency (β_1)	00.260 (0.1)	02.022 (0.3)	02.730 (0.4)	00.110 (1.1)
Activity duration (β_2)	00.014 (9.6)	11.480 (10.1)	00.570 (10.1)	00.180 (10.5)
Sample size	5,388	5,388	5,388	5,388
R-square	0.015	0.017	0.016	0.019
Education Activity				
Constant (β_0)	12.800	-4.080	09.200	02.050
Frequency (β_1)	05.620 (1.9)	06.220 (1.8)	06.970 (2.0)	00.660 (2.4)
Activity duration (β_2)	00.018 (8.3)	06.300 (8.6)	00.090 (4.0)	00.180 (11.4)
Sample size	4,207	4,207	4,207	4,207
R-square	0.020	0.017	0.045	0.030
Other Activity				
Constant (β_0)	17.520	-6.32	11.980	02.170
Frequency (β_1)	03.150 (0.9)	03.910 (1.5)	03.250 (0.9)	00.330 (2.1)
Activity duration (β_2)	00.021 (9.3)	12.260 (13.2)	00.715 (9.9)	00.230 (14.4)
Sample size	2,340	2,340	2,340	2,340
R-square	0.034	0.067	0.039	0.078

It is observed from the table that the activity duration coefficient for home is negative and significant implying that trips to home are coupled with trips to non-home activities, and home and non-home activities are generally substitutes. While, it is positive and significant for all other activities implying that more the activity duration, passengers are ready to spend more time on travel. Frequency coefficient is positive for all activities, which means that more the trips made for an activity, more will be the time allocated to travel. This coefficient is found be significant for home and other activities only. R-square values of all the models are very low reflecting poor explanatory power of models. Even, the transformation of variables has not improved the model's goodness of fit significantly. However, the magnitudes of all the coefficients across all the activities are not in the same order. This observation emphasises the fact that peoples' perceptions about travel time for different activities is not unique.

Since, no significant impact was found for different transformations of variables, travel duration models of linear form were further developed for different income segments to understand the influence of income on travel durations for different activities. The results are presented in Table 2. It is observed from the table that people, based on their income levels, give different weights to frequency and duration of activity. Like in previous models, R-square values of these models are much less, revealing their poor fit.

Time Allocation Analysis for Hyderabad City

The share of the day spent at any activity depends on a number of factors. To examine the share of time within a 24-hr budget allocated to the activities, a Time allocation model is to be developed. The population was segmented into three groups as mentioned earlier. Logit models were calibrated for

Table 2: Travel duration models for different income segments

Coefficients	Low Income	Medium Income	High Income
Home Activity			
Constant (β_0)	25.62	39.51	41.67
Frequency (β_1)	01.02 (1.6)	02.89 (5.5)	01.19 (0.7)
Activity duration (β_2)	-35.50 (-2.4)	-1.75 (-11.1)	-1.61 (-3.1)
Sample size	4,366	4,806	403
R-square	0.02	0.03	0.03
Work Activity			
Constant (β_0)	17.76	22.98	14.60
Frequency (β_1)	03.82 (0.3)	-2.92 (-0.6)	05.24 (0.3)
Activity duration (β_2)	00.099 (4.4)	00.015 (6.9)	0.02 (2.7)
Sample size	2,519	2,617	252
R-square	0.016	0.018	0.03
Education Activity			
Constant (β_0)	14.97	13.13	12.43
Frequency (β_1)	0.086 (0.2)	01.20 (2.6)	-1.28 (-0.9)
Activity duration (β_2)	0.0254 (2.8)	00.013 (5.6)	00.026 (3.0)
Sample size	2,262	1,780	165
R-square	0.036	0.02	0.05
Other Activity			
Constant (β_0)	16.60	12.22	14.80
Frequency (β_1)	04.07 (1.5)	08.40 (4.1)	02.21 (0.3)
Activity duration (β_2)	00.02 (6.7)	00.02 (4.8)	0.032 (3.5)
Sample size	966	1,251	123
R-square	0.05	0.04	0.09

the above three choice groups to understand the time allocations behaviour of residents of Hyderabad. WAGIT package (Prasad 1997) was used for this purpose. The results obtained are shown in Table 3.

The activity frequency coefficient was found to be having illogical sign for all the three choice sets. Travel time was found to be not significant for work group and illogical sign for the education group and business group. If these two variables are considered as alternative specific, probably, they would have given some insight to understand their influence on time allocations for different activities. The other three variables viz., gender, age and income, which were treated as alternative specific variables, are found to have logical sign and significant coefficient values.

Table 3: Time allocation model for different segments of population

Variable	Work		Education		Business	
	Coefficient	t-ratio	Coefficient	t-ratio	Coefficient	t-ratio
Frequency	-4.2200	-25.9	-6.1300	-8.2	-4.1100	-6.9
Travel time	0.0009	0.2	-0.1800	-0.4	-0.0137	-0.7
Gender	0.1661	2.2	0.1100	1.4	0.2124	1.4
Age	0.0099	4.9	0.0675	9.5	0.0195	2.9
Income	0.0001	3.1	0.0001	2.5	0.0002	2.4
R-square	0.49		0.53		0.53	

SUMMARY

An activity and its associated travel are economic complements. One cannot be undertaken without the other. Daily travel duration for an activity depends on that activity's duration and frequency. Activity travel duration models were developed for various activities to find the relationship between activity travel duration, activity frequency and activity duration. Time allocation to different activities in a normal working day was modelled using LOGIT formulation.

The present work suggests that activity travel duration depend on activity's duration and activity frequency. Time duration was found to be significant for all income segments and for all activities. Gender, age, and income influence the amount of time spent at any activity. They were found significant in the estimation of the share of day spent at any activity. Both the travel time duration models and time allocation models are for understanding the time use concept rather than prediction. Hence, findings of illogical / insignificance of variables are as important as findings of logical / significance variables.

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