URBAN TRANSPORT JOURNAL
Vol. 11 No. 1, Aug. 2012

TIME - USE ANALYSIS OF WARANGAL CITY - AN ACTIVITY BASED APPROACH

Karthikeya Pavan Kumar Pisipati*, C.S.R.K. Prasad**

Abstract

The activity based modelling approach offers greater insights into how and why people travel at individual and micro level. An attempt is made in this paper to understand the temporal aspects of activities of people of Warangal city and correlate them with their trip making behaviour through the application of time - use concept. A complete analysis of individual activity travel patterns was made which highlighted the importance of household socio-economics in travel decision making of the individual. Travel duration was regressed against activity duration and activity frequency and thereby travel duration models were developed for different alternate formulations. The effect of demographic and socio-economic characteristics on allocation of time to various activities was studied. The share of time within a day budget allocated to several primary activities was examined.

Keywords: Travel pattern, Activity frequency, Travel duration, Time and space

1.0 INTRODUCTION

It is widely recognized that strategies to manage demand will be more critical to transportation planning than to increase capacity of facilities. The trip-based, four-step procedure continues to be an effective demand forecasting procedure for certain types of problems. Yet, current policy contexts call for alternative models. The time dimension was entirely omitted in the four step procedures when the main preoccupation of urban transportation planning congestion has to do with the concentration of demand in space and time.

An interest in when and where trips are made leads remorselessly to the realization that travel cannot be understood in isolation from the activities that induce it. Travel and activity are two sides of the same coin, activities must be pursued in space and over time, and space must be traversed in time to engage in activities. Activity based travel model is a richer framework in which travel behaviour is analyzed as a daily or multi-day patterns of behaviour, related to, and derived from the differences in lifestyle and activity participations among the population. Pas (1984) finds demographic factors such as employment status, gender and presence of children to have significant effects on the choice of the activity and travel pattern. People make trips because they want to participate in activities. Also people make modal choices in order to suit the activities in which they want to participate. So, in other words activities are primary and travel secondary. Activity based modelling of travel demand treats travel as being derived from the demand for activity participation, and also travel is of activity scheduling in time and space.

The Time-Use concept focuses on sequences or patterns of activity behaviour, with the whole day or longer periods of time as the unit of analysis. A fundamental difference between the trip-based approach and the activity-based approach is the way time is conceptualized and represented in the two approaches (Pas 1996; Pas and Harvey 1997). In the trip-based approach, time is reduced to being simply a

* PGET, L&T Ramboll Consulting Engineers Ltd., Chennai - 600035, India, e-mail : keyacrl@gmail.com
** Professor, National Institute of Technology, Warangal - 500016, India

"cost" of making a trip. The activity-based approach treats time as an all-encompassing continuous entity within which individuals make activity/travel participation decisions (Kurani and Lee-Gosselin 1996). Thus, the central basis of the activity-based approach is that individuals' activity-travel patterns are a result of their time-use decisions. Individuals have 24 hours in a day (or multiples of 24 hours for longer periods of time) and decide how to use that time among activities and travel (and with whom) subject to their schedule, socio-demographic, location and other contextual constraints.

2.0 METHODOLOGY ADOPTED

This section represents a brief discussion on various steps proposed to be undertaken as a part of the methodology for achieving the goal.

2.1 Segmentation

The analysis of the activity choice selection and allocation of time to various activities considers socio-economic and demographic factors. The various socio-economic characteristics include household income, work status etc. Gender, age and life stage are some of the demographic variables which have time-use behaviour. The whole population is segmented into four income groups based on monthly family income i.e. Low Income(LI) (<10000 `), Lower Middle Income(LMI) (10001 ` - 20000 `), Higher Middle Income(HMI) (20001 `- 40000 `) and High Income groups (HI) (>40000 `). Six individual types considered in this study include Head of the household, Wife, Child (>15yrs), Child (<15yrs), Older male and Older female. From the Home interview Survey (HIS) data, various activities pursued by the individuals in a day are examined. The activities considered are Work, Education, Recreation, Home, and Others.

2.2 Activity Travel Pattern Analysis

The study made in this research is based on a conceptual framework which considers that individual activity-travel patterns are affected by household access needs. Three levels of analysis carried out are:

a) Accessibility analysis of various population income groups.

b) Analysis of household access needs and resulting activity demands.

c) Analysis of activity-travel patterns of household individuals.

2.3 Travel Duration Model

Activity duration and frequency along with socio-economic characteristics of individual's influence travel durations. In this study, it is proposed to investigate the influence of these factors on travel durations. Travel time duration for the activity is taken as the dependent variable and the independent variables are frequency of activity and activity duration. Six model forms have been considered, which are described below:

(i) ***Simple Linear Model:*** $T_i = \hat{a}_0 + \hat{a}_1 F_i + \hat{a}_2 D_i$ (1)

(ii) ***Logarithmic Form Model:*** $T_i = \hat{a}_0 + \hat{a}_1 \log_{10}(F_i) + \hat{a}_2 \log_{10}(D_i)$ (2)

(iii) ***Square Root Form Model:*** $T_i = \hat{a}_0 + \hat{a}_1 \sqrt{F_i} + \hat{a}_2 D_i$ (3)

(iv) ***Power Form Model:*** $T_i = \hat{a}_0 F_i^{\hat{a}_1} D_i^{\hat{a}_2}$ (4)

(v) ***Polynomial Form Model:*** $T_i = \hat{a}_0 + \hat{a}_1 F_i + \hat{a}_2 D_i^2$ (5)

(vi) ***Exponential Form Model:*** $T_i = \hat{a}_0 + \hat{a}_1 \exp(F_i) + \hat{a}_2 \exp(D_i)$ (6)

Where,

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

F_i = daily activity frequency for activity 'i'(no. of times activity 'i'appears as destination)

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

$\hat{a}_0$, $\hat{a}_1$, $\hat{a}_2$ = coefficients

For each activity, *viz.*, Work, Education, Home, Recreation, and Other, the above models are developed.

3.0 ACTIVITY TRAVEL PATTERN ANALYSIS

Warangalcity comprising of Warangal, Hanamkonda and Kazipetareas is chosen as study area. It has a population of nearly 11 lakhs including Hanamkonda and Kazipet. The entire study carried out is based on a conceptual framework which considers that individual activity-travel patterns are affected by household access needs. To this effect, household level surveys were carried out. The data was collected on household demographics, income, house ownership, vehicle availability, location and all trips made on the survey day for about 120 households which were selected on the basis of a simple random technique.

3.1 Effect of Variables on Time Allocations

Figure 1show how the use of time varies with "age" for male workers (MW), male non-workers (MNW), female workers (FW) and female non-workers (FNW).In the figure, 'A' shows the variation of time spent at 'home', 'B' at 'work', 'C' at 'education', 'D' at 'recreation', 'E' at 'other' and 'F' in 'travel' respectively.

Time spent at home rises sharply with age for non-workers. For workers, it is saucer-shaped, declining from the teen years to the early twenties, flat through the middle years, but rising as men enter their fifties and women their late forties. The rise in time at home in the later years is statistically significant for all groups. In contrast with time at home, time spent at work is hump shaped. Work duration peaks in the middle years for men and women. Women show a dip from the late twenties to their thirties, which can possibly be ascribed to leaving the full-time workforce for childcare. Time spent on education increase in the age range of eleven to twenty. It is also observed that females tend to spent more time compared to males.

Time spent at shopping reflects high variability among non- workers. Among workers, time spent at recreation rises with age. For women recreation peaks in the middle years, when family size is the largest, for men recreation increases into the fifties and sixties, perhaps explainable by the same reasons that they spend less time at work. Generally non-workers spend more time at recreation than workers across age levels. This value drops almost monotonically with age. The trend in workers may be seen as the shift of their career from school/college to work activities. The same trend in Non Workers may be seen as the shift of their career from school/college to home activities. Teenage girls travel more than their male counterparts, but roles reverse by the late twenties. There is a slight peak in driving towards middle age for male workers and female non workers between 46 and 50, though female workers peak in their twenties and female non-workers actually drive more in their teenage.

The time allocated to various activities like home, work, education, recreation and others stratified by "gender" and "work status" is also studied in brief. The difference in activity duration between genders is found to be smaller than between individuals with different work/ non-work status. Females participate more in the recreation than men and female workers even participate more than male non-workers. Women spend more time at home than men and non-workers spend more time at home than workers. The difference between working women and non-working women on time spent for recreation is 20 minutes. Among workers, time at the other activities for men and women holds steady averaging 160 minutes for all men and 150 minutes for all women. Non-workers spend more time than workers at other activities due to the extra minutes staying at the home. Travel duration is more for male worker than female worker. For the male worker and non-worker, the time spent at travel is found to be almost the same i.e. 75 minutes.

3.2 Frequency of Activities

The travel frequency for various activities explains the fulfillment of certain household needs by means of these activities. Data was

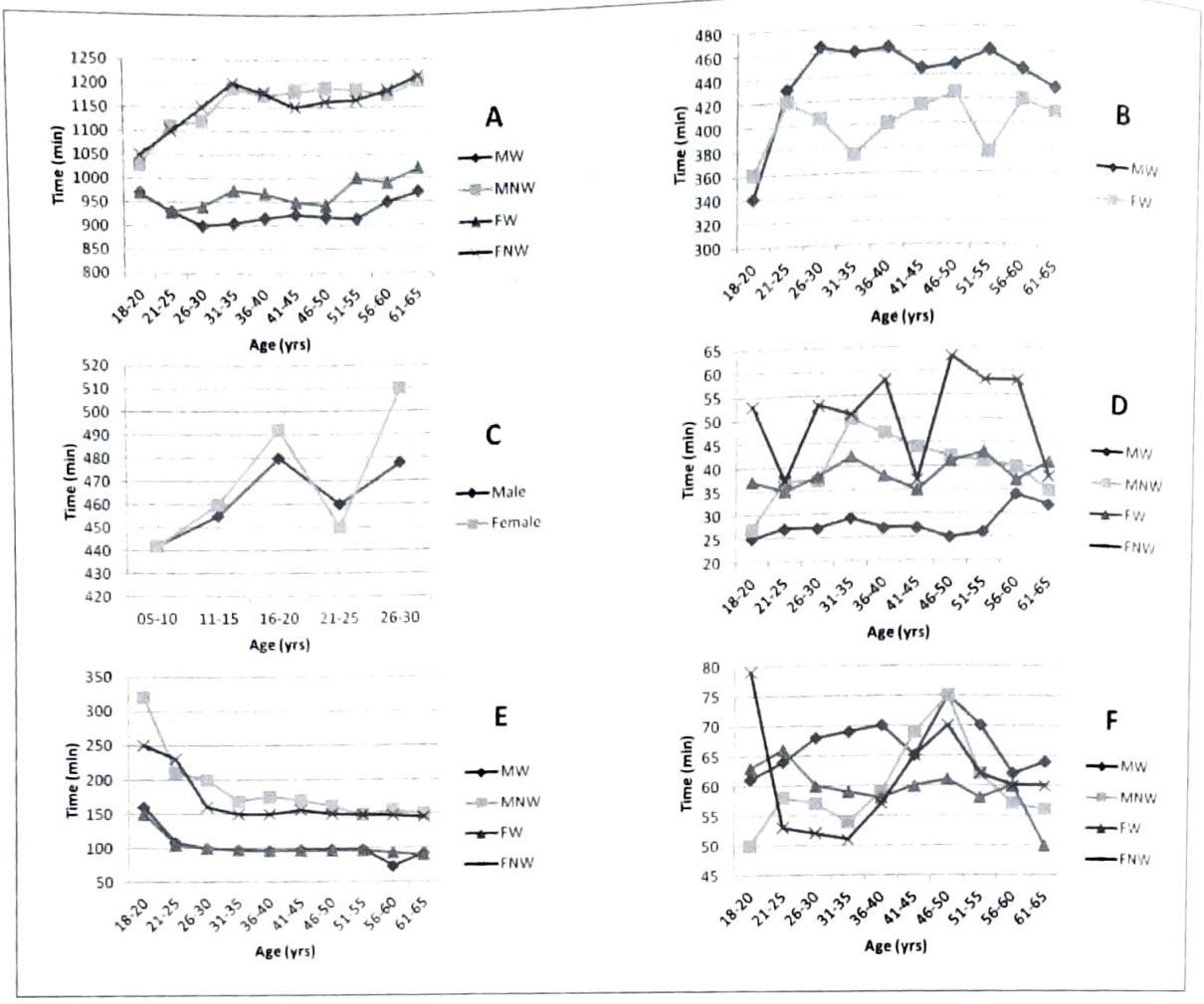

Figure 1 : Time spent in various activities

collected on the frequency of various activities for each household. The frequency types considered are "1-daily", "2-weekly", "3-monthly" and"4-occasionally". Table 1 provides the data for Kazipet, Hanamkonda and Warangal on the distribution of activities within the frequency type and the distribution of each frequency type within the four income groups.

The rows marked as 'Total %' in **Table 1** give the distribution of frequency type for the given activity at overall population level. The distribution of frequency type of an activity indicates the position of the activity within the household activity-travel priorities. There is a clear trend in how the households perform various activities. From Table 1 it can be deduced that 'work' and 'education' can be considered as daily activities where as 'recreation' and 'other' activities form weekly and monthly activities respectively for Kazipet, Hanamkonda and Warangal. While 'other' activities can be considered as occasional for Hanamkonda and Warangal, 'recreation' becomes occasional activity for Kazipet. A comparison of the three study areas provided information, at the outset, on variation in the overall activities prevalent in those areas. It can be noticed that majority of the daily work and education trips (92.5% & 100% respectively) originate from Hanamkonda which shows an existence of good accessibility to 'work' and 'education' for the people living in Hanamkonda. It is quite interesting that maximum number of daily 'recreation' trips (50%) originate from Warangal than Hanamkonda, which the latter is usually thought to be the highest 'recreation' trips originating zone as it is the major shopping zone. This may be because of the existence of good number of recreation centres in Warangal.

Table 1 : Frequency of activities for different income groups

Activity	Pop Income Groups	Kazipet Frequency Type				Hanamkonda Frequency Type				Warangal Frequency Type			
		1	2	3	4	1	2	3	4	1	2	3	4
Work	LI	12	0	0	0	14	0	0	0	10	0	0	0
	LMI	6	0	0	0	12	0	1	0	9	0	0	0
	HMI	10	2	1	0	7	1	0	0	11	0	1	0
	HI	5	2	2	0	4	1	0	0	7	1	1	0
TOTAL (%)		82.5	10	7.5	0	92.5	5	2.5	0	92.5	2.5	5	0
Education	LI	13	0	0	0	14	0	0	0	12	0	0	0
	LMI	12	0	0	0	10	0	0	0	10	0	0	0
	HMI	10	0	0	0	7	0	0	0	12	0	0	0
	HI	5	0	0	0	9	0	0	0	6	0	0	0
TOTAL (%)		100	0	0	0	100	0	0	0	100	0	0	0
Recreation	LI	2	6	0	0	3	5	0	0	4	5	1	0
	LMI	2	5	0	0	6	7	0	0	5	6	0	0
	HMI	4	7	1	1	2	4	2	0	5	5	0	0
	HI	3	7	1	1	2	7	1	1	4	4	1	0
TOTAL (%)		27.5	62.5	5	5	32.5	57.5	7.5	2.5	45	50	5	0
Other	LI	4	7	1	0	3	5	6	0	3	3	4	0
	LMI	5	3	4	0	0	1	1	1	2	4	5	0
	HMI	4	5	2	0	6	3	3	1	1	5	2	1
	HI	1	1	2	1	2	4	3	1	1	6	2	1
TOTAL (%)		35	40	22.5	2.5	27.5	32.5	32.5	7.5	17.5	45	32.5	5

Table 2 : Effect of activity duration and distance on frequency to various activities

Effect of activity duration on frequency to various activities

Activity Duration	Frequency Types (RECREATION)				Activity Duration	Frequency Types (OTHER)				Activity Duration	Frequency Types (WORK)				Activity Duration	Frequency Types (EDUCATION)			
	1	2	3	4		1	2	3	4		1	2	3	4		1	2	3	4
< 60 min	13	33	2	0	< 60 min	17	31	1	0	< 420 min	41	1	0	0	< 420 min	53	0	0	0
60 - 120 min	11	22	1	2	60 - 120 min	14	24	2	0	420 - 480 min	18	3	1	0	420 - 480 min	42	0	0	0
> 120 min	8	19	2	1	> 120 min	3	17	2	3	> 480 min	29	5	4	0	> 480 min	25	0	0	0

Effect of distance on frequency to various activities

Distance to Activity	Frequency Types (RECREATION)				Distance to Activity	Frequency Types (OTHER)				Distance to Activity	Frequency Types (WORK)				Distance to Activity	Frequency Types (EDUCATION)			
	1	2	3	4		1	2	3	4		1	2	3	4		1	2	3	4
< 5 km	40	19	9	2	< 5 km	40	23	2	9	< 5 km	68	0	1	0	< 5 km	57	0	0	0
5 - 10 km	20	10	3	1	5 - 10 km	13	4	0	6	5 - 10 km	38	5	2	0	5 - 10 km	40	0	0	0
> 10 km	11	4	1	0	> 10 km	2	2	2	7	> 10 km	23	2	2	0	> 10 km	28	0	0	0

3.3 Activity Duration and Distance

The activities considered are classified based on frequency type as described earlier. The amount of time that households actually spend on completing various activities is also a major determinant of household accessibility to these activities. It can be deduced from **Table 2** that irrespective of the activity duration, 'work' and 'education' activities are carried out daily. As the duration increases, all type of frequencies for the 'recreation' and 'other' activities decrease. It is interesting to note that as time spent for 'recreation' and 'other' activities increase, people prefer to carry out those activities weekly instead of daily. Distance is a major determinant of the accessibility of activities. Analysis was carried out to study how distance to activities affects household activity participation. The distances were grouped in three bands i.e., less than 5 km, 5-10 km and more than 10 km. It can be deduced from **Table 2** that irrespective of the distance, 'work' and 'education' activities are carried out daily. As the distance increases, all type of frequencies for the 'recreation' and 'other' activities decrease except for the occasional frequency of 'other' activity. People tend to carry out the 'other' activities occasionally irrespective of the increase in their distances.

3.4 Individual Activity Travel Pattern Analysis

The activity-travel pattern of an individual is a function of the individual type and the activity type. The daily activity variation of all the people along time of the day is shown in Figure 2. Each of the individual type has a discrete activity-travel pattern. In the figure, 'A' shows the activity travel pattern for household head, 'B' for wife, 'C' for male child(>15yrs), 'D' for male child (<15yrs), 'E' for female child(>15yrs), 'F' for female child (<15yrs), 'G' for older male and 'H' for older female respectively.

From **Figure 2**, it was deduced that most of the household heads leave the home around 08:00. The return journeys are spread between 13:00 to 21:00. The presence of these individuals at home is almost negligible within the working hours, i.e. from 09:00 to 13:00. A peak for return journeys was formed around 13:00. The state of home-based activities approaches 100% near the two ends of the day (around 06:00 and above 21:00), when most of the individuals are at home. In the mid-day period most individuals are at 'non-home' locations, (except for a few individual types). The average percentage travelling was around 71% explaining the role of travel in accessing daily activities. On the aggregate basis, the male and female childs (>15yrs) have involved in 'non-home' activities for a longer part of the day, in comparison to any other individual type. The 'recreation' and 'other' activity travel patterns of the household wife and the female childs are found to be similar. This explains the cultural effects on access to activities. It is seen that female individuals (>15 yrs and <15 yrs) tend to spend their 'recreation' and 'other' activities along with their mothers. A small percentage of older males and older females are involved in travelling.

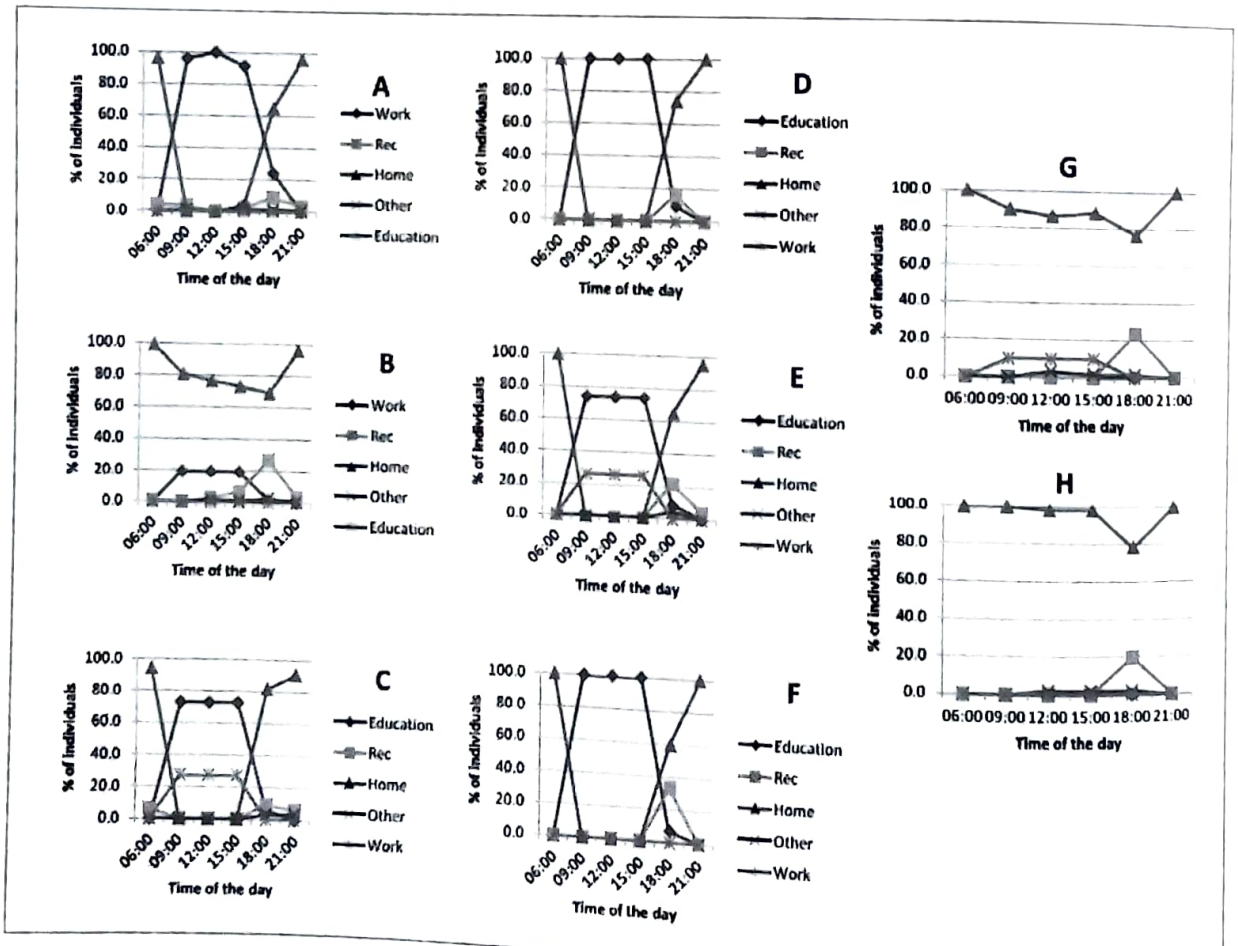

Figure 2 : Individual activity travel patterns

3.5 Time-Space Prism

The transportation, temporal and spatial constraints binding upon individuals define their time-space prism (TSP). The TSP's of individuals provide information on the extent of the activities they can perform, and gives necessary leads to seek ways to improve them. The analysis of work trips has been carried out to define the TSPs of individuals, their extents and various factors related to the households and the activity location. The distance and time of travel to work may be used to define the individual time-space prism (TSP). The slopes of the prism sides are defined on the basis of maximum speed of travel by the individual. The extent of the TSP depends both on the slopes of prism sides as well as the total daily time budget.

The slope of TSP is calculated using the following relationship:

$$\ddot{o} = \text{Tan}^{-1}\left(\frac{\text{Time}}{\text{Distance}}\right) \qquad (7)$$

Where,

ö = slope of the prism boundaries,
time = travel time and
distance = distance to the activity.

In **Table 3**, the shaded values in the diagonals of the matrix are the values of basic TSP and the shaded values in the 'all modes' row are the corresponding values of improved TSP of all the individuals surveyed. The analysis of **Table 3** indicates how individuals tend to improve their TSP, as well as accessibility to 'work', using the available transport modes. The households with no transport vehicle ownership, for example, have the basic TSP having slope of 86.18 degrees (~15 min/km), while they improve it up to 84.04 degrees (~9.58 min/km). Similarly, households with ownership of a two wheeler tend to improve their TSP from 79.41 degrees to 69.66 degrees. To generalize, it may be said that, all the individuals (belonging to any vehicle ownership category) would either tend to improve their TSP or would at least remain at their basic TSP. However in the case of households with 'car/jeep' as vehicle ownership, the ö2 value is slightly more than the ö1 value which means that there is no need for them to further improve their basic TSP.

4.0 MODEL DEVELOPMENT

This chapter presents various models developed for activity travel duration, activity choice and time allocation for all the individuals. Travel duration models are developed by

Table 3 : Basic and improved values of slope of TSP

Work Travel Mode	Angle PHI (degrees)						
	Transport Vehicle Ownership						
	0	1	2	3	4	5	6
0	86.18		75.9	82.87	51.7	-	-
1	-	-	-	-	-	-	-
2	-	75.1	79.41	67.3	-	-	-
3	-	75.86	62.36	66.68	-	-	-
4	-	70.97	64.32	-	-	-	-
5	76.51	-	66.03	69.32	-	-	-
6	-	-	-	-	-	-	
All Modes	84.04	-	68.66	67.79	-	-	-

0 = walk, 1 = cycle, 2 = two wheeler, 3 = car/jeep/taxi, 4 = auto, 5 = bus, 6 = other

regression analysis by taking the activity travel time as the dependent variable and activity frequency and activity duration as independent variables.

4.1 Travel Time Duration Models

An activity and its associated travel are economic components - one cannot be undertaken without the other. Daily travel duration for an activity depends on that activity's duration and frequency. An attempt is made to develop the relationship between them using different functional forms.

Models are developed for Home, Work, Education, Recreation and Other activities. The **Table 4** below shows the example of travel duration model of various functional forms developed for 'work' activity. Such kinds of models are developed for all other activities considered in the study. The model formulation can be extended with consideration of more complex functional forms and additional variables. However the prediction of time in travel for any given individual is notoriously hard and is a function of many factors which cannot be readily captured.

5.0 SUMMARY AND CONCLUSION

Travel duration models developed for different activities are as given below:

For Home: $T_H = 49.479 - 1.455\ F_H + 0.410\ D_H$

For Work: $T_W = -1.188 - 2.288\ F_W + 4.247\ D_W$

For Education: $T_E = -0.668 + 6.87\ F_E + 1.954\ D_E$

For Recreation: $T_R = 0.064 + 1.738\ F_R + 1.190\ D_R$

For Others: $T_O = -2.992 - 11.225\ F_O + 1.298\ D_O$

Table 4 : Descriptive statistics and travel duration models for WORK

Variables	DESCRIPTIVE STATISTICS					
	Linear	Polynomial	Logarithmic	Exponential	Power	Square Root
Travel Duration						
Mean	11.029	15.267	9.96	56.531	10.289	11.005
Std. dev	11.834	21.478	10.276	155.803	12.016	11.337
Activity Frequency						
Mean	1.34	8.267	-1.10E-15	5.20E+00	1.90E+00	5.10E+00
Std. dev	0.782	2.911	1.20E-15	2.60E+00	1.00E+00	9.20E-01
Activity Duration						
Mean	507.37	10.091	7.96	44.225	2.093	19.788
Std. dev	75.69	19.795	10.276	154.969	1.739	10.698
Model (Dep = Travel Duration)						
COEFFICIENTS						
Constant (β_0)	-1.188	6.737	4.16	-2.279	5.33	-12.471
Activity Frequency (β_1)	2.288	0.369	-7.264	2.999	0.178	-1.903
(t-stat)	11	11	-3.5	7.865 7	.225	-21.607
Activity Duration (β_2)	4.247	0.369	19.801	0.742	0.883	19.253
(t-stat)	3.332	1.974	3	1.105	4.661	7.164
Sample Size (N)	318	318	318	318	318	318
R-Square	0.93	0.925	0.881	0.764	0.926	0.913

The present study suggests that activity travel duration depends on activity's duration and activity frequency. Both these variables are found to be significant for all functional forms proposed. The R-square values of a simple linear model are slightly better than that of other functional forms.Activity duration depends on socio-economic and demographic factors. The amount of time spent at any activity is influenced by Gender, Age and Marital status. The variation in the use of time is explained by the life stage the individual undergoes and his behaviour.The present study is dealt in the analysis of the time-use concept. The models developed can be employed for the micro-simulation of daily activity-travel patterns of the individuals which in turn facilitates in the forecasting of activity based travel demand models for the future.

References

1. Bhat, C. R. and Koppelman, F. S. (1999) Retrospective and prospective survey of time use research, Transportation Research Part A: Policy and Practice, Vol. 26, No. 2, 119–139.
2. Bowman, J. (1998) The Day Activity Schedule Approach to Travel Demand Analysis, Ph.D. Thesis, MIT, USA.
3. David Levinson, M. (1999) Space, money, life-stage and the allocation of time, Transportation Research Part B: Methodoligal,Vol. 26, 141-171.
4. Nepal, K. P., Fukuda, D. and Yai, T. (2005) Microeconomic models of Intra-household activity time allocation Journal of Eastern Asia Society for Transportation Studies, Vol. 6, 1637-1650.
5. Ryuichi Kitamura, P. (1984)A model of daily time allocation to discretionary out of home activities and trips,Transportation Research Record: Journal of the Transportation Research Board, Vol. 26, 193-209.
6. Ryuichi Kitamura, P. and Koppleman, J. (1988)An evaluation of activity-based travel analysis,Transportation Research Part A: Policy and Practice,Vol. 15, No. 1, 9-34.
7. Wang, D. and Cheng, T. (2001)Aspatio-temporal data model for activity-based transportation demand modeling,International Journal of Geographical Information Science, Vol. 15, No. 6, 561-585.
8. Wen, C. H. and Koppelman, F. S. (2000)A Conceptual and Methodological Framework for the Generation of Activity and Travel Patterns,TransportationResearch Part A: Policy and Practice, Vol. 27, No. 1, 5-23.