CAPTURING THE LONG-TERM CHANGES IN TIME USE BEHAVIOR BASED ON TIME ALLOCATION MODEL*

by Lili XU[1], Junyi ZHANG[2], Yusuke HIZUME[3] and Akimasa FUJIWARA[4]

1. Introduction

Time use research is one of travel behavior analysis approaches. Activity time expenditure is a key determinant factor which has a lasting effect on quality of life. Easterlin (2005) argues that "the happiness of an individual can be increased by allocating his or her time to those domains and constituents of domains in which hedonic adaptation and social comparison is less important (p.54)". Each individual has only a given time to allocate among different domains, therefore different time allocation will result in the distinction in quality of life. Individuals participate in different types of activities to maximize their own "utility", "well-being", "happiness" and "quality of life". Time use research could also contribute to the understanding of travel generation mechanisms and value of time (Pentland *et al*, 1999). On the other hand, it is expected that time use behavior could change over time. Such behavior change could occur in both short-term and long-term contexts. Short-term change could include hour-to-hour, day-to-day, week-to-week and season-to-season variations while long-term change is usually observed in a year-to-year base. Unfortunately, such temporal behavior change in time use has not been examined in a satisfactory way. One of the reasons is because of the lack of available time use data.

This paper attempts to apply the Survey on Time Use and Leisure Activities collected by the Ministry of General Affairs at 5 pints in time (1976, 1986, 1991, 1996 and 2001) to capture the long-term changes in people's time use behavior based on a household time allocation model. The model explicitly incorporates various interactions and interdependences in time use behavior, including intra-household interaction, inter-activity interactions, behavioral interdependency between weekday and weekend, as well as relative influences of different household members and relative importance of different activities.

2. Model

In this paper, a multi-linear function is adopted to represent household time allocation behavior by assuming that a household allocates its time to activities such that the following household utility is maximized subject to each member's available time on weekdays and weekends.

Maximize

$$HUF = \sum_i w_i u_i + \sum_i \sum_{i' \neq i} \lambda\, w_i w_{i'}\, u_i u_{i'} \tag{1}$$

$$u_i = \sum_j r_{ij} u_{ij} + \sum_j \sum_{j' \neq j} \delta_i\, r_{ij} r_{ij'} u_{ij} u_{ij'} \tag{2}$$

$$u_{ij} = f(t_{ij}^d, t_{ij}^e) \tag{3}$$

subject to

$$\sum_j t_{ij}^m = T_i^m,\ m = d \text{ (weekday) or } e \text{ (weekend)} \tag{4}$$

where,

HUF denotes "*Household Utility Function*",

---

* Keywords: time use, household behavior, intra-household interaction,

[1] Member of JSCE, B. Eng, Graduate School for International Development and Cooperation, Hiroshima University, 1-5-1 Kagamiyama, Higashi-Hiroshima, 739-8529, Japan, TEL&FAX 082-424-6919; xulilimaya@hotmail.com

[2] Member of JSCE, Dr. Eng, Graduate School for International Development and Cooperation, Hiroshima University, 1-5-1 Kagamiyama, Higashi-Hiroshima, 739-8529, Japan, TEL&FAX 082-424-6919; zjy@hiroshima-u.ac.jp

[3] Member of JSCE, B. Eng, Kobe City Hall, 6-5-1 Kano-Cho, Chuo-Ku, Kobe, 650-8570, Japan

[4] Member of JSCE, Dr. Eng, Graduate School for International Development and Cooperation, Hiroshima University, 1-5-1 Kagamiyama, Higashi-Hiroshima, 739-8529, Japan, TEL&FAX 082-424-6919; afujiw@hiroshima-u.ac.jp

u_i is household member *i*'s utility,
w_i is household member *i*'s weight parameter, reflecting the relative influence of each member,
λ is a parameter of intra-household interaction,
u_{ij} is household member *i*'s utility for activity *j*,
r_{ij} is household member *i*'s weight (or relative interest) parameter for activity *j,* reflecting the relative importance of each activity for each member's utility,
δ_i is inter-activity dependency parameter for member *i*,
t_{ij}^d, t_{ij}^e are the times that individual *i* performs activity *j* on weekday (*d*) and weekend (*e*), respectively, and
T_{ij}^d, T_{ij}^e are household member *i*'s available times on weekday (*d*) and weekend (*e*), respectively (usually 24 hours).

This paper classifies the activity of interest into in-home activity and out-of-home activity, where the latter is further classified into independent activity (compulsory, maintenance and discretionary activity), allocated activity (mainly shopping), and shared activity. To represent the behavioral interdependency between weekdays and weekends in household time allocation, here, the utilities for different activities are defined as follows:

1) In-home activity and out-of-home independent activity (*j*)

$$u_{ij} = \rho_{ij}(\alpha_{ij}^d \ln t_{ij}^d + \alpha_{ij}^e \ln t_{ij}^e) \tag{5}$$

$$\alpha_{ij}^d + \alpha_{ij}^e = 1, \alpha_{ij}^d \geq 0, \alpha_{ij}^e \geq 0 \tag{6}$$

2) Out-of-home shopping activity (*r*: shared shopping; *k*: non-shared shopping)

$$u_{ik} = \rho_{ik}(\alpha_{ik}^d \ln t_{ik}^d + \alpha_{ir}^d \ln t_r^d + \alpha_{ik}^e \ln t_{ik}^e + \alpha_{ir}^e \ln t_r^e) \tag{7}$$

$$\alpha_{ik}^d + \alpha_{ir}^d + \alpha_{ik}^e + \alpha_{ir}^e = 1, \alpha_{ik}^d \geq 0, \alpha_{ir}^d \geq 0, \alpha_{ik}^e \geq 0, \alpha_{ir}^e \geq 0 \tag{8}$$

3) Shared non-shopping activity (*s*)

$$u_{is} = \rho_{is}(\alpha_{is}^d \ln t_s^d + \alpha_{is}^e \ln t_s^e) \tag{9}$$

$$\alpha_{is}^d + \alpha_{is}^e = 1, \alpha_{is}^d \geq 0, \alpha_{is}^e \geq 0 \tag{10}$$

where $\rho_{ij}, \rho_{ik}, \rho_{is}$ reflect the influences of individual/household attributes, travel behavior, and other observed and unobserved factors on time allocation behavior, and $\alpha_{ij}^d, \alpha_{ij}^e$ ($\alpha_{ik}^d, \alpha_{ir}^d, \alpha_{ik}^e, \alpha_{ir}^e$ or $\alpha_{is}^d, \alpha_{is}^e$) are the weight parameters for weekday and weekend.

As shown above, the utility of each activity is defined as a weighted function of the times allocated to the activity on weekdays and weekends. It is assumed that each member tries to derive the utility from performing the activity on both weekdays and weekends, rather than on a single day. Such weekday-weekend interdependency with respect to an allocated activity like shopping might be different from other activities. Shopping is usually a household task. Depending on role specification within a household, it can be conducted by a particular member, or jointly by several members on weekdays and/or weekends. This is the reason why the utility function of shopping is defined differently from that pertaining to other activities. Weight parameters $\alpha_{ik}^d, \alpha_{ir}^d, \alpha_{ik}^e, \alpha_{ir}^e$ are introduced to reflect the interdependency of shopping activities on weekdays and weekends with respect to the involved household members. In fact, how to specify the involvement of household members in the allocated activity participation is still an unsolved research issue. As shown later, this study deals with couple households and it is assumed that both husband and wife are involved in the allocated activity (i.e., shopping).

Maximization of equation (1) subject to equation (4) results in the time allocation function for each activity. Due the space limitation, these functions are not shown here. Details refer to Zhang *et al* (2007).

3. Data and Model Estimation

The time use data for this study covers 5 points in time, i.e., 1976, 1986, 1991, 1996 and 2001. Originally, the year of

1981 was also included. Since this study argues that time use model should represent weekday and weekend interdependency, but the data in 1981 only collected the time use information from one day and consequently deleted from this study. The original datasets include different sizes of households, but this study only uses the data from the households with couples. And, the established time allocation model could be used to represent the shared activities performed by two or more members. Since such information is only available in 2001, for the sake of comparison, the shared activities are regrouped into other types of activities. The resulting activities include in-home activity, out-of-home work activity, maintenance activity, discretionary activity and shopping activity for a weekday and a weekend. The seemingly unrelated regression (SUR) method is applied to estimate the model. Table 1 shows the estimation results.

Observing model accuracies, work activity time sub-model on weekday show relatively satisfactory multiple correlation coefficients, ranging from 0.596 to 0.757. Accuracies of other sub-models are low, suggesting the necessity of further improving the models. Explanatory variables introduced into the model include individual attributes (INDA), household attributes (HOUA) and infrastructure attributes (INFA) at prefecture level. To accommodate the variations across activities, INDA, HOUA and INFA are first defined as a composite variable, respectively, and then activity-specific parameters are introduced into the model. Most of the parameters are statistically significant, suggesting that model performance is acceptable. Accepting such model accuracy and performance, discussion is given below with respect to behavior changes from 1976 to 2001.

Inter-activity interaction parameters are all negative. This implies that competition of time allocation among different activities occurs at each time point for both husband and wife. Activities show stable relative importance across the five points in time: both husband and wife attach the highest importance to in-home activity, followed by out-of-home discretionary activity. Work activity is ranked at the third place for husband (with an exception in 1996). The third place for wife is occupied by maintenance activity.

Concerning the interdependence between weekday and weekend, temporal changes are observed. In 1976, both husband and wife gave much more weights to weekend activities than those on weekday. Since 1986, on average, husband attached much higher importance to weekday activities and wife showed an opposite preference. A remarkable temporal change is that 1996 and 2001 models estimate much higher weights (0.7772 in 1996 and 0.845 in 2001) of wife on weekday work activity than those in 1991, 1986 and 1976. It could be interpreted that such temporal change in wife's time allocation behavior is due to the progress of women's participation to labor market.

As for the influence of infrastructure improvement (e.g., roads, railways, urban parks, hospitals, and libraries), it is observed that marginal effects of infrastructure improvement show lower values in 1976, 1986 and 2001. Construction of expressways and national/prefecture highways shows the highest marginal effect in 1991, and building municipal roads and urban parks, hospitals and libraries shows the highest marginal effect in 1996.

4. Conclusion

Applying a household time allocation model with weekday-weekend interdependence, this paper examined the long-term change in time allocation behavior from 1976 to 2001 based on the national time use data collected every 5 years in Japan. Model estimation results confirm the change of women's time allocation behavior due to the influence of participation to labor market since 1991, and also reveal the diminishing marginal effects of infrastructure improvement over time. Further detailed analysis will be given at the time of presentation.

References

Pentland, W.E., Harvey, A.S., Lawton, M.P. and McColl, M.A.: *Time Use Research in the Social Sciences*, Kluwer Academic / Plenum Publishers, New York, 1999.

Easterlin, R.A.: Building a better theory of well-being. In L. Bruni and P.L. Porta (Eds.), *Economics & Happiness--Framing the Analysis*, New York: Oxford University Press, pp.29-64, 2005.

Zhang, J., Timmermans, H. and Fujiwara, A.: A household time allocation model with behavioral interdependency between weekday and weekend, *Proceedings of the 11th World Conference on Transport Research*, 2007 (CD-ROM).

Table 1. Model estimation results

Explanatory variable	1976 Model		1986 Model		1991 Model		1996 Model		2001 Model	
	Husband	wife	Husband	wife	Husband	wife	Husband	wife	Husband	wife
Inter-activity interaction	-0.151 **	-0.177 **	-0.045 **	-0.093	-0.164 **	-0.172 **	-0.161 **	-0.169 **	-0.165 **	-0.173 **
Relative importance of activity										
In-home activity	0.519 —	0.434 —	0.614 —	0.584 —	0.505 —	0.460 —	0.437 —	0.450 —	0.405 —	0.390 —
Work activity	0.117 **	0.026 **	0.136	0.013 **	0.191 **	0.013 **	0.301 **	0.020 **	0.197 **	0.036 **
Maintenance activity	0.004 **	0.221 **	0.012	0.096 **	0.012 **	0.125 **	0.006 **	0.142 **	0.032 **	0.212 **
Discretionary activity	0.356 **	0.275 **	0.235 **	0.294 **	0.285 **	0.374 **	0.250 **	0.337 **	0.330 **	0.289 **
Shopping activity	0.004 **	0.044 **	0.003	0.012 **	0.007 **	0.028 **	0.006 **	0.050 **	0.034 **	0.073 **
Interdependency of weekday and weekend										
Weekday										
In-home activity	0.146 **	0.315 **	0.730	0.217 +	0.895 **	0.107 **	0.919 **	0.129 **	0.415 **	0.144 **
Work activity	0.443 **	0.469 **	0.969 **	0.290 *	0.996 **	0.192 **	1.000 **	0.772 **	0.993 **	0.845 **
Maintenance activity	0.133 **	0.322 **	0.220	0.634 **	0.443 **	0.467 **	0.675 **	0.318 **	0.272 **	0.191 **
Discretionary activity	0.099 **	0.288 **	0.641	0.161 +	0.843 **	0.086 **	0.853 **	0.088 **	0.214 **	0.114 **
Shopping activity	0.122 **	0.326 **	0.463	0.325 *	0.642 **	0.189 **	0.664 **	0.104 **	0.128 **	0.100 **
Weekend										
In-home activity	0.854 —	0.685 —	0.270 —	0.783 —	0.105 —	0.893 —	0.081 —	0.871 —	0.585 —	0.856 —
Work activity	0.557 —	0.531 —	0.031 —	0.710 —	0.004 —	0.808 —	0.000 —	0.228 —	0.007 —	0.155 —
Maintenance activity	0.867 —	0.678 —	0.780 —	0.366 —	0.557 —	0.533 —	0.325 —	0.682 —	0.728 —	0.809 —
Discretionary activity	0.901 —	0.712 —	0.359 —	0.839 —	0.157 —	0.914 —	0.147 —	0.912 —	0.786 —	0.886 —
Shopping activity	0.878 —	0.674 —	0.537 —	0.675 —	0.358 —	0.811 —	0.336 —	0.896 —	0.872 —	0.900 —
Infrastructure influence parameters										
In-home activity	1.000 —	1.000 —	1.000 —	1.000 —	1.000 —	1.000 —	1.000 —	1.000 —	1.000 —	1.000 —
Work activity	0.976 **	1.109 **	0.073	0.485 +	-0.963 *	-1.804 **	9.083 +	9.357 +	0.744	-0.619
Maintenance activity	1.163 **	0.902 **	-0.163	0.636 **	1.977 **	-0.851 +	-5.736	-2.180	-1.162	3.916 **
Discretionary activity	1.073 **	0.938 **	0.848 **	0.942 **	1.977 **	2.848 **	3.103	-1.193	3.894 **	1.907 *
Shopping activity	1.132 **	0.987 **	0.055	0.415	1.897 **	1.030 *	-13.51	-9.473	1.480	3.555 **
infrastructure attributes unit: per 1000 persons										
Length of expressway	-6.316 *		1.519 *		11.404 **		1.430		-0.162	
Length of national/prefecture highway	0.025 *		-0.041 *		-0.199 +		-0.020		0.013	
Length of municipal roads	-0.027 **		0.019 **		-0.021		0.013		-0.007 *	
Number of Hospitals	-6.559 **		-0.084		-12.698 **		5.561 +		-0.213	
Number of libraries	-32.552 **		0.787		-41.706 **		-10.449		2.877 *	
Number of companies	-0.100		-0.001		-0.002		0.005		-0.002 +	
Number of supermarkets	2.330		1.202 *		-18.248 **		-0.312		0.124	
Number of restaurants	-0.360		0.109 **		0.260 **		0.078		0.008	
Number of parks	-0.165 **		0.007		0.142 **		-0.014		0.002 +	
Individual influence parameters										
In-home activity	1.000 —		1.000 —		1.000		1.000 —		1.000 —	
Work activity	-0.752 **		-0.480		-7.628 **		-2.209 **		-5.314 **	
Maintenance activity	1.349 **		1.492 **		3.304 **		2.563 **		2.976 **	
Discretionary activity	1.214 **		1.453 **		2.698 **		1.202 **		2.847 **	
Shopping activity	1.180 **		1.185 **		2.691 **		3.526 **		1.644 **	
Individual attributes										
Age(years old)	0.005 **		-0.006 **		-0.002		-0.015 **		-0.004 **	
Dummy varible for nursing (Yes, 1; No, 0)	— —		-1.239 **		-0.182		0.215		0.022 +	
Dummy varible for office worker (Yes, 1; No, 0)	-2.392 **		-3.016 **		-7.924 **		-11.168 **		-0.436 **	
Dummy varible for the self-employed (Yes, 1; No, 0)	-2.406 **		-3.155 **		-8.440 **		-11.038 **		-0.413 **	
Dummy varible for housewife (Yes, 1; No, 0)	-0.146 **		-0.646 **		-1.729 **		-2.142 **		-0.076 **	
Dummy varible for student (Yes, 1; No, 0)	-2.231 **		-1.099 *		-11.510 **		-4.821 *		0.000 *	
Dummy varible for owning mobliephone (Yes, 1; No, 0)	— —		— —		— —		— —		-0.031 **	
Dummy varible for owning computer (Yes, 1; No, 0)	— —		— —		— —		— —		0.000	
Household influence parameters										
In-home activity	1.000 —	1.000 —	1.000 -	1.000 -	1.000 —	1.000 —	1.000 —	1.000 —	1.000 —	1.000 —
Work activity	-1.607	-2.799	1.346 **	1.301 **	3.766 **	4.567 **	2.244	15.06 *	0.084	0.198
Maintenance activity	1.472 *	2.810	0.773 **	1.709 **	-0.603	4.790 **	27.09 *	-16.65 *	1.782 **	-4.470 **
Discretionary activity	1.180 **	0.707 +	1.020 **	1.154 **	-1.421 **	0.834 **	-10.59 *	8.045 *	-0.566	4.638 **
Shopping activity	1.844 +	5.040	0.958 **	1.254 **	-0.430	1.984 **	12.86 *	3.545 +	-0.331	-0.693
Household attributes										
Number of household members	-0.030		-0.061 *		-1.584 **		-0.017		-0.027 **	
Dummy varible for ownig house (Yes, 1; No, 0)	-0.051		-0.001 **		0.053		0.040		0.020 +	
Number of room	-0.056		-0.060 **		-0.368 **		-0.084 *		0.012 **	
Dummy varible for ownig car (Yes, 1; No, 0)	-0.020		-0.101 *		1.392 **		-0.422 *		0.016	
Income level (1, low~12, high)	-0.028		-0.003		0.028		0.032 *		-0.005 **	
Dummy varible for having child younger than age 10 (Yes, 1; No, 0)	0.012		0.521 **		2.512 **		0.056		-0.037 **	
Dummy varible for weekday weather (Rain, 1; Others, 0)	— —		0.001 **		— —		0.612 *		0.072 *	
Dummy varible for weekend weather (Rain, 1; Others, 0)	— —		-0.001 **		— —		-0.051		-0.033	
Multiple Correlation Coefficients										
Weekday										
Work activity	0.596	0.674	0.613	0.660	0.672	0.726	0.722	0.757	0.705	0.623
Maintenance activity	0.189	0.273	0.268	0.234	0.090	0.199	0.061	0.124	0.302	0.386
Discretionary activity	0.169	0.261	0.198	0.199	0.398	0.223	0.406	0.092	0.256	0.290
Shopping activity	0.042	0.138	0.136	0.075	0.062	0.063	0.054	0.035	0.570	0.005
Weekend										
Work activity	0.368	0.561	0.297	0.121	0.257	0.364	0.010	0.145	0.115	0.396
Maintenance activity	0.142	0.230	0.508	0.101	0.203	0.294	0.347	0.449	0.266	0.362
Discretionary activity	0.219	0.224	0.117	0.146	0.166	0.218	0.268	0.439	0.214	0.278
Shopping activity	0.081	0.147	0.131	0.080	0.076	0.043	0.171	0.100	0.179	0.195
Sample size (households)	2000		2000		1800		1052		1569	

Notes: ** 99% statistical significant; * 95% statistical significant; + 90% statistical significant