Developing an integrated Scobit-based activity participation and time allocation model to explore influence of childcare on women's time use behavior*

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1. Introduction

The need for study of women's travel issues was already recognized in 1970s, especially in the American context, where the growing involvement of women in the paid labour force raised significant questions for transportation, housing and even environmental planners[1]. It is expected that a female, especially a married female, has a different role in a family and different needs from a male, and consequently leads to different travel behaviour, even though they have the same set of other socio-demographic characteristics. This study focuses on childcare, one of the most important tasks and/or responsibilities of women, which has received little attention in travel behaviour analysis. Childcare generates a feeling of happiness to both mothers and their family members, and at the same time, however, it also generates additional constraints to especially mothers when they perform daily activities as males do. In particular, such constraints may keep mothers away from participating in their own activities, and as a result, various other activities will also be affected considering the inter-activity interaction, which is in part caused by each person's available time, from the perspectives of both activity participation (i.e., whether to participate in a certain activity or not) and time allocation (i.e., how long time is allocated to the activity that is decided to perform).

Therefore, the purpose of this paper is twofold. First, we develop an integrated Scobit-based activity participation and time allocation model. Second, we apply the developed model to examine the influence of childcare on women's time use behaviour as well as other influential factors, using a national time use data collected by the Japan Ministry of Internal Affairs and Communications in 2006.

The remaining part of this paper is organized as follows. Section 2 gives a brief review of existing studies. Section 3 describes how to develop the integrated Scobit-based activity participation and time allocation model. The data used in this study will be explained in Section 4. Model estimation results will be shown and influential factors including childcare will be examined in Section 5. This study will be concluded in Section 6.

2. Review

Gender has been identified as an important predictor of travel behaviour [2)-5)]. For example, existing studies have confirmed that employed women tend to have shorter commute-to-work distances and times than employed men, women tend to spend more time in household and family support activities and make more household and family support trips, and women make fewer recreational trips[2].

Women are said to bear a greater share of the responsibility for child care. Hamilton[6] showed that presence of young children significantly reduced the annual work experience of married mothers. Hamilton[7] further revealed that the availability of good quality surrogate childcare is a key factor in enabling women to take up employment, transport options can further impact on the ability to take up a job, and as a result, women have fewer employment options than men. Rosenbloom[8] confirmed that the responsibilities of working women change as children grow older, and concluded that if women continue to bear a disproportionate share of the direct or emergency responsibility for their children, travel differences between the sexes will not disappear, regardless of other economic and occupational changes.

To date, various models have been developed/applied to describe time use behaviour in transportation as well as other research fields. To represent time use behaviour, it is important to distinguish between activity participation (whether to participate in a certain activity or not) and time allocation (how long time allocated to the activity). Up to now, activity participation has been mainly described by using the Tobit modelling technique[9)-10)] and the Logit modelling technique, where the Tobit is based on a normal distribution and the Logit model is on a Gumbel distribution. One of the problems of these two models is that they assume that individuals with initial probability 0.5 of participation or non-participation are most sensitive to changes in the introduced factors in the models than those with a clear preference for participation and non-participation. Such assumption is imposed because both Tobit and logit models are symmetric about zero. However, in reality, individuals could have any initial probability, which is unknown to analysts. Therefore it's better to specify the initial probability endogenously within the models.

The most important contribution of this study from the methodological perspective to literature is to newly develop a joint model of activity participation and time allocation by endogenously specifying the initial probability of activity (non-)participation. This is done by integrating the Scobit model[11] to represent the activity participation and the utility-maximizing model to represent the time allocation. From the perspective of empirical analysis, influences of childcare service types (i.e., social childcare with and without extended service, and without social childcare) on women's time use behaviour are examined, by using a large-scale national time use data collected by the Japanese government in 2006. Such large-scale data allows us to make some general conclusions. Even though we recognize the importance of dealing with household time use behaviour to explore the influence of childcare on women's daily life, since the main modelling target is to represent the activity participation, to simply the discussion, this study focuses on individual time use behaviour, rather than household time use behaviour.

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3. Model

To represent women's time use behaviour, here, a utility-maximizing modelling approach is first adopted based on the assumption that a woman *i* attempts to allocate her available time T_i to various activities (*j*) so that her utility u_i is maximized. Here, the utility u_i is specified using a multi-linear function.

Maximize $\quad u_i = \sum_j w_{ij} u_{ij} + \sum_j \sum_{j' \succ j} \delta_i w_{ij} w_{ij'} u_{ij} u_{ij'} \qquad (1)$

Subject to $\quad \sum_j t_{ij} = T_i, t_{ij} \geq 0 \qquad (2)$

where,

$$\sum_j w_{ij} = 1, w_{ij} \geq 0 \qquad (3)$$

$$u_{ij} = \rho_{ij} \ln(t_{ij}) \qquad (4)$$

$$\rho_{ij} = \exp\left(\sum_k \beta_k x_{ijk} + \xi_{ij}\right) \qquad (5)$$

u_{ij} ,utility of activity j; w_{ij} ,*a* weight parameter of activity *j* to indicate the relative interest (or importance) of the activity ; δ_i , an inter-activity interaction parameter ; t_{ij} , time allocated to activity *j*; ρ_{ij} ,baseline preference for activity *j*; x_{ijk} , the *k* th explanatory variable to describe the preference ρ_{ij} for activity *j*; β_k ,the parameter of x_{ijk} , and ξ_{ij} ,an unobserved factor (error term) affecting the preference ρ_{ij} .

Since time is limited to each person, the longer the time allocated to an activity, the shorter the times to the other activities, resulting in some interactions among activities. Here, the multi-linear utility function is adopted to represent the inter-activity interaction in a multiplicative form, where only binary interactions are modelled. Note that it is straightforward to extend the binary form to a multinomial form. To simplify the discussion, here, only the binary interactions are considered.

Maximizing equation (1) subject to equation (2) results in the following time function.

$$t_{ij} = \frac{w_{ij}\rho_{ij}(1 + \Sigma_{j' \neq j}\delta_i w_{ij'}\rho_{ij'} \ln(t_{ij}))}{\Sigma_{j'}(w_{ij'}\rho_{ij'}(1 + \Sigma_{j'' \neq j'}\delta_i w_{ij''}\rho_{ij''} \ln(t_{ij'})))} T_i = \kappa_{ij} T_i \qquad (6)$$

Here, it should be mentioned that the error term ξ_{ij} is included in ρ_{ij} in equation (4), which reflects the influence of unobserved factors on activity decision. For ease of model estimation, equation (6) is transformed as follows

$$t_{ij} = \tilde{\kappa}_{ij} T_i + \eta_{ij} \qquad (7)$$

where, η_{ij} is a new error term reflecting the influence of the original error term ξ_{ij} , and η_{ij} is assumed to follow a normal distribution: $\eta_{ij} \sim N(0, \sigma_{ij}^2)$. And, $\tilde{\kappa}_{ij}$ is a new term excluding the influence of the original error term ξ_{ij} .

As shown in equation (2), activity time t_{ij} could be zero or positive. This means that activity participation should be properly represented. Since choice of participating in an activity is a binary phenomenon, the utility of participation U_{ij} can be described as follows:

$$U_{ij} = V_{ij} - \varepsilon_{ij} = \sum_s \gamma_{js} Z_{ijs} - \varepsilon_{ij} \qquad (8)$$

$$Y_{ij} = \begin{cases} 1 & U_{ij} \geq 0 \\ 0 & otherwise \end{cases} \qquad (9)$$

where, Y_{ij} , outcome of participation decision (1: participation; 0: non-participation); V_{ij} ,the deterministic term; Z_{ijs} ,the *s*th explanatory variable; γ_{js} ,the parameter of the *s*th explanatory variable; and ε_{ij} , an error term (note that "- ε_{ij} " is introduced for the sake of model specification).

As seen above, activity time t_{ij} is not observed unless $U_{ij} \geq 0$. Thus, the observed activity time t_{ij} is censored.

$$t_{ij} = \tilde{\kappa}_{ij} T_i + \eta_{ij} \text{ if and only if } V_{ij} > \varepsilon_{ij} \qquad (10)$$

$$P_{ij}(Y_{ij} = 1) = \Pr(V_{ij} > \varepsilon_{ij}) = F(V_{ij}) \qquad (11)$$

Here, $F(\bullet)$ indicates the distribution function of error term ε_{ij} . Let $f(\bullet)$ be probability density function of ε_{ij} . Then, it is straightforward that marginal effect of Z_{ijs} on the participation probability P_{ij} is given below.

$$\partial P_{ij}(Y_{ij} = 1) / \partial Z_{ijs} = f(\sum_s \gamma_{js} Z_{ijs}) \gamma_{js} \qquad (12)$$

It is obvious that the marginal effect depends on the form of $f(\bullet)$. In this sense, it becomes important how to specify the form of $f(\bullet)$. In other words, if an improper function is assumed, the measurement of marginal effects will be biased and as a result, a wrong policy decision might be induced. In existing studies, it is usually assumed that the error term ε_{ij} follows a Gumbel distribution, resulting in a logit model, or ε_{ij} follows a normal distribution, leading to a Tobit model. Such model specification means that $f(\bullet)$ will reach a maximum when ε_{ij} (or V_{ij}) is equal to zero. This implies that any given variable Z_{ijs} will have its greatest effect on those individuals with the values of V_{ij} is closest to zero, or the probability P_{ij} is closest to 0.5. However, in reality, such initial probability of 0.5 cannot be guaranteed at all because it is unknown to analysts considering the existence of heterogeneity in individual behaviour. To mitigate the bad influence of model specification, this study adopts an alternative distribution function, as shown below.

$$F(\varepsilon_{ij};\alpha)=\frac{1}{(1+\exp(-\varepsilon_{ij}))^{\alpha}} \tag{13}$$

$$P_{ij}(Y_{ij}=1)=F(V_{ij};\alpha)=\frac{1}{(1+\exp(-V_{ij}))^{\alpha}} \tag{14}$$

$$P_{ij}(Y_{ij}=0)=1-\frac{1}{(1+\exp(-V_{ij}))^{\alpha}} \tag{15}$$

Here α is a parameter to represent the skewness of the distribution function ($\alpha>0$). Equation (13) was proposed by Burr in 1942, as one of the twelve general distribution functions (Burr, 1942). Equation (14) or (15) is called as *Scobit* model, named by Nagler (1994), who also gives an alternative name the skewed logit model. When α is equal to 1, equation (14) or (15) returns to the famous Logit model. In the Scobit model, marginal effect of Z_{ijs} on the participation probability P_{ij} is given below.

$$\partial P_{ij}(Y_{ij}=1)\big/\partial Z_{ijs}=\alpha\exp(-\textstyle\sum_{s}\gamma_{js}Z_{ijs})(1+\exp(-\sum_{s}\gamma_{js}Z_{ijs})^{-\alpha-1}\gamma_{js} \tag{16}$$

One can see that the marginal effect obtained from the Scobit model depends on the value of the skewness parameter. This makes the measurement of marginal effect more realistic.

Since the error terms ε_{i} and η_{ij} might be interrelated with each other, the models for activity participation and time allocation should be estimated simultaneously. For this purpose, in this study, we apply Lee[12)]'s transformation method to first transform the equations (7) and (8) into a standard normal distribution, respectively.

$$\varepsilon_{ij}{}^{*}=J_{1}(\varepsilon_{ij})=\varphi^{-1}(F(\varepsilon_{ij})) \tag{17}$$

$$\eta_{ij}{}^{*}=J_{1}(\eta_{ij})=\varphi^{-1}(G(\eta_{ij})) \tag{18}$$

where, φ^{-1} represents the inverse of the standard normal cumulative distribution function. Then, a bivariate distribution having the marginal distribution $F(\varepsilon_{ij})$ and $G(\eta_{ij})$ can be specified below, where μ_{ij} refers to the correlation of the above two error terms.

$$C(\varepsilon_{ij},\eta_{ij};\mu_{ij})=B(J_{1}(\varepsilon_{ij}),J_{2}(\eta_{ij});\mu_{ij})=N(0,0,1,1;\mu_{ij}) \tag{19}$$

$$J_{1}(\varepsilon_{ij})=\varphi^{-1}(F(\varepsilon_{ij}))=\varphi^{-1}(P_{ij}(Y_{ij})) \tag{20}$$

$$J_{2}(\eta_{ij})=(t_{ij}-\widetilde{\kappa}_{ij}T_{i})/\sigma_{ij} \tag{21}$$

Based on the above transformation, the joint probability of activity participation and corresponding time allocation can be expressed as follows:

$$\Pr(t_{ij}\cap(Y_{ij}=1))=\Pr(t_{ij}\cap(\varepsilon_{ij}\le J_{1}(V_{ij}))=\frac{1}{\sigma_{ij}}\phi(\frac{t_{ij}-\kappa_{ij}T_{i}}{\sigma_{ij}})\varphi(\frac{J_{1}(V_{ij})-\mu_{ij}\dfrac{t_{ij}-\kappa_{ij}T_{i}}{\sigma_{ij}}}{\sqrt{1-\mu_{ij}^{2}}}) \tag{22}$$

where, ϕ represents the standard normal probability density distribution function.

And, the probability of non-participation is given below.

$$\Pr((t_{ij}=0)\cap(Y_{ij}=0))=1-P_{ij}(Y_{ij}=1) \tag{23}$$

Therefore, the log likelihood function of the joint discrete-continuous choice model is:

$$LogL_{i}=\sum_{j}\left\{\begin{matrix}D_{ij}\left[\ln(\varphi(\dfrac{J_{1}(V_{ij})-\mu_{ij}\dfrac{t_{ij}-\kappa_{ij}T_{i}}{\sigma_{ij}}}{\sqrt{1-\mu_{ij}^{2}}}))+\ln(\phi(\dfrac{t_{ij}-\kappa_{ij}T_{i}}{\sigma_{ij}}))-\ln(\sigma_{ij})\right]\\ +(1-D_{ij})\ln(1-F(V_{ij};\alpha))\end{matrix}\right\} \tag{24}$$

Here, D_{ij} is a dummy variable that indicates the participation in activity j ("1" means participation and "0" means non-participation). To estimate equation (24), maximum likelihood estimation method is applied in this study.

4. Data

In Japan, the only available large-scale time use data has been collected by the Ministry of Internal Affairs and Communications, Japan, called "Survey on Time Use and Leisure Activities". This survey has been conducted every five years since 1976. The data used in this study only include the information from women and were selected from the survey conducted in 2006, in which the data about child under 10 years old are available. Moreover, we selected the samples aged between 20 and 50 years old. This is because that women's participation in the labor market has been mainly observed in this period, and a majority of childcare demand is observed in this period, too.

Activities are classified into four major categories as shown in Table 1: compulsory-contracted, compulsory-committed, discretionary, and maintenance activities. For travel time, in the survey only two types of travel time were distinguished: one is the commute/school travel time and the other is the remaining travel time. In this study, we grouped the commute/school time into the compulsory-contracted activity time. For the remaining travel time, it should be properly allocated to the other different activities; however, since there is no clue how to make the allocation, we arbitrarily grouped it into the discretionary activity time.

Table 1 Activity Classification

Activity type	Description
Compulsory-contracted activity	Paid work and schoolwork
Compulsory-committed activity	Housework, caring or nursing, child care, shopping, volunteer and community activities
Discretionary activity	Watching TV, listening to the radio, reading news papers or magazines, rest and relaxation, studies and researches (excluding school work), hobbies and amusements, sports and social life
Maintenance activity (used as a reference in model estimation)	Sleep, meals, personal care, medical examination or treatment participated

Table 2: Estimation Results for Two Models: Model Performance

Decision-making parameters	Logit-based Time Use Model		Scobit-based Time Use Model		
	Estimated parameter		Estimated parameter		t(1)[a)]
Inter-activity interaction	-0.215	*	-0.204	*	
Discretionary activity					
Relative importance	0.307	*	0.302	*	
Variance of error term	1.300	*	1.336	*	
Correlation coefficient	0.222	*	0.189	*	
Skewness parameter for scobit model			0.079		*
Compulsory-committed activity					
Relative importance	0.153	*	0.136	*	
Variance of error term	1.277	*	1.369	*	
Correlation coefficient	-0.726	*	-0.884	*	
Skewness parameter for scobit model			1.097	*	
Compulsory-contracted activity					
Relative importance	0.266	*	0.274	*	
Variance of error term	1.098	*	1.095	*	
Correlation coefficient	-0.327	*	-0.234	*	
Skewness parameter for scobit model			0.295	*	*
Maintenance activity (activity participation is excluded and all the parameters of explanatory variables are fixed to be zero in model estimation)					
Relative importance[e)]	0.274	-	0.289	-	
Variance of error term	1.280	*	1.281	*	
Initial log-likelihood	-1,698,073[b)]		-1,681,246[c)]		
Converged log-likelihood	-1,355,090		-1,354,280		
Number of parameters	92		95		
McFadden's Rho-squared	0.202		0.194		
Chi-square	1,620 (degree of freedom: 3) (larger than the critical value 7.81 at the 95% confidence level)				
Number of observations (persons)	66,839				

a) t(1): t-test for the null hypothesis "skewness parameter = 1" (i.e., Scobit = Logit).

b) Initial log-likelihood is calculated by assuming variances of error terms to be the estimated values.

c) Initial log-likelihood is calculated by assuming skewness parameters and variances of error terms to be the estimated values.

d) *: significant at the 95% confidence level

e) Relative importance parameter for maintenance activity = 1- sum of the parameters of other activities.

5. Model estimations and discussions

In this study, we estimated two types of models: the logit-based and Scobit-based models. Estimation results are shown in Tables 2 and 3.

(1) Model performance

Concerning the model accuracy, two types of indices are calculated. One is the McFadden's Rho-squared and the other is the Chi-square. In this study, the Rho-squared index is only used to check the goodness-of-fit of each model. To figure out whether the proposed Scobit-based model is superior to the existing Logit-based model or not, the Chi-square is adopted. Looking at the calculated Rho-squared indices, they are about 0.2 for both of the models, suggesting that the two models are acceptable as a model used for empirical analyses. The Chi-square value is 1,620, which is much larger than the critical value 11.34 (degree of freedom: 3) at the 99% confidence level, suggesting that the Scobit-based model is better than the Logit-based model. Considering that the Logit model is a special case of the Scobit model, this statistical text result is acceptable.

The correlations between activity participation and time allocation for compulsory-committed, compulsory-contracted, and discretionary activities are all statistically significant and the values range from -0.726 to 0.222. This confirms the existence of interaction between activity participation and time allocation behaviour, mainly due to the influence of unobserved factors shared by the two behavioural elements. Inter-activity interaction parameters are all negative and statistically significant, implying the competition of time allocation among different activities, i.e., increase (decrease) in the time of an activity will result in the decrease (increase) in the times of other activities. This is caused by the existence of available time for each person. Looking at the relative importance parameter for each activity, they are very close to each other in the two models: on average women attach the least importance to the compulsory-committed activity, but attach almost equal importance to the other three activities, i.e., compulsory-contracted, maintenance, and discretionary activities. This observation is quite different from, at least, the authors' expectation that women should attach the highest importance to the compulsory-committed activity including childcare.

Table 3: Estimation Results for Two Models: Explanatory Variables

Explanatory variables	Logit-based Time Use Model				Scobit-based Time Use Model			
	Activity Participation		Time Allocation		Activity Participation		Time Allocation	
	Estimated Parameter		Estimated Parameter		Estimated Parameter		Estimated Parameter	
Discretionary activity								
Constant term	3.115	*			0.387			
Household size (Number of household members)	-0.040	*	-0.015	*	-0.088	*	-0.009	*
Dummy variable for social childcare with extended service (1: Yes; 0: No)	-0.783	*	-0.103	*	-1.030	*	-0.086	*
Dummy variable for social childcar without extended service (1: Yes; 0: No)	-0.339	*	-0.061	*	-0.444	*	-0.072	*
Dummy variable for no social childcare (1: Yes; 0: No)	-0.953	*	-0.173	*	-1.248	*	-0.186	*
dummy variable for weather (1: a rainy day; 0: not a raining day)	0.294	*	-0.009	*	0.362	*	0.010	*
Number of rooms at home	0.032	*	0.000		0.047	*	0.000	
Household income level (1: low ~ 12: high)	0.036	*	0.002	*	0.040	*	0.003	*
Age	0.017	*	-0.005	*	0.019	*	-0.005	*
Education level (1: low ~ 4: high)	-0.041		-0.014	*	-0.020		-0.007	*
Dummy variable for marital status (1: married, 0: single)	-0.138	+	0.025	*	-0.100		0.036	*
Dummy variable for full-time job (1: Yes; 0: No)	-0.541	*	-0.080	*	-0.721	*	-0.068	*
Dummy variable for part-time job (1: Yes; 0: No)	-0.134	+	-0.054	*	-0.179	+	-0.033	*
Dummy variable for weekend (1: Yes; 0: No)	0.268	*	0.056	*	0.466	*	0.060	*
Compulsory-committed activity								
Constant term	-0.003				0.670	*		
Household size (Number of household members)	-0.005		0.006	*	-0.017	+	0.012	*
Dummy variable for social childcare with extended service (1: Yes; 0: No)	0.849	*	0.019	*	0.625	*	0.050	*
Dummy variable for social childcar without extended service (1: Yes; 0: No)	0.824	*	0.048	*	0.618	*	0.043	*
Dummy variable for no social childcare (1: Yes; 0: No)	1.697	*	0.129	*	1.579	*	0.127	*
dummy variable for weather (1: a rainy day; 0: not a raining day)	0.083	*	-0.032	*	0.059	+	-0.012	*
Number of rooms at home	-0.015	*	0.001	+	-0.006		0.001	
Household income level (1: low ~ 12: high)	-0.011	*	-0.003	*	-0.007	+	-0.001	*
Age	0.053	*	0.002	*	0.034	*	0.002	*
Education level (1: low ~ 4: high)	0.048	*	0.010	*	0.053	*	0.012	*
Dummy variable for marital status (1: married, 0: single)	1.371	*	0.337	*	1.452	*	0.477	*
Dummy variable for full-time job (1: Yes; 0: No)	-1.562	*	-0.123	*	-1.520	*	-0.125	*
Dummy variable for part-time job (1: Yes; 0: No)	-0.736	*	-0.059	*	-0.827	*	-0.054	*
Dummy variable for weekend (1: Yes; 0: No)	0.599	*	-0.010	*	0.611	*	-0.014	*
Compulsory-contracted activity								
Constant term	-2.365	*			-10.748	*		
Household size (Number of household members)	0.055	*	-0.003	*	0.100	*	-0.001	
Dummy variable for social childcare with extended service (1: Yes; 0: No)	-0.200	*	-0.026	*	-0.271	*	-0.032	*
Dummy variable for social childcar without extended service (1: Yes; 0: No)	-0.275	*	-0.035	*	-0.402	*	-0.045	*
Dummy variable for no social childcare (1: Yes; 0: No)	-1.094	*	-0.057	*	-2.099	*	-0.079	*
dummy variable for weather (1: a rainy day; 0: not a raining day)	-0.104	*	-0.006	*	-0.131	*	-0.004	*
Number of rooms at home	0.024	*	0.002	*	0.034	*	0.000	
Household income level (1: low ~ 12: high)	-0.049	*	0.000		-0.075	*	0.001	*
Age	0.003	*	-0.003	*	0.006	*	-0.004	*
Education level (1: low ~ 4: high)	-0.101	*	0.000		-0.143	*	0.000	
Dummy variable for marital status (1: married, 0: single)	-0.255	*	-0.028	*	-0.293	*	-0.017	*
Dummy variable for full-time job (1: Yes; 0: No)	4.525	*	0.121	*	11.734	*	0.162	*
Dummy variable for part-time job (1: Yes; 0: No)	4.129	*	0.048	*	10.857	*	0.090	*
Dummy variable for weekend (1: Yes; 0: No)	-2.103	*	-0.047	*	-3.489	*	-0.042	*

1) Education level: 1: junior high school, 2: senior high school, 3: junior college, 4: university, graduate school
2) Household income level: 1: <1, 2: 1~2, 3: 2~3, 4: 3~4, 5: 4~5, 6: 5~6, 7: 6~7, 8: 7~8, 9: 8~9, 10: 9~10, 11:10~15, 12:>15 (unit: 1 million Yen)
3) *: significant at the 95% confidence level; +: significant at the 90% level.

(2) Influential factors

As shown in Table 4, for both activity participation and time allocation, most of the parameters of the introduced explanatory variables are statistically significant at the 95% confidence level, some of the parameters are significant at the 90% level, and only a few parameters are insignificant. Except for one variable (dummy variable "rain"), all the other variables have the same signs between the two models.

First, the similarities between the two models are further examined. Note that a positive (negative) sign of a parameter means that probability of activity participation increases (decreases) with the value of relevant variable. Focusing on childcare variables (keeping in mind that the reference variable for the childcare variables is "no child"), the estimated parameters (without social childcare, with extended social childcare, and with social but not extended childcare) suggest that having a child will reduce the activity participation probability and the corresponding time allocated to the compulsory-contracted activity and discretionary activity, but increase the activity participation probability and the corresponding time allocated to the compulsory-committed activity, no matter whether social childcare is chosen or not. This implies that childcares surely impose some burdens on mothers. These results are understandable. On the other hand, for those employed women, they show the opposite preferences over activity participation and time allocation and such preferences are especially stronger for the full-time workers than the part-time workers. This is a dilemma for the working women with younger children. Comparing the parameters of the three childcare variables, it is found that the burdens on mothers will be heavier in case of "without social and/or extended childcare" than in case of receiving social and/or extended childcare services because the absolute values of parameters of "without social and/or extended childcare" are higher than those of the other two childcare variables. This means that providing social childcare services could be more helpful to partially release mothers (including the working mothers) from childcares.

In families with more members (household size), women have more chances to participate in the labour market (compulsory-contracted activity), but their working hours are shorter than those women in a smaller family. For the compulsory-committed activity, it is influenced by household size in an opposite way. The probability of women's activity participation in the compulsory-committed activity will be lower in a bigger family than that in a smaller family. This might be because members in a bigger family have more chances to share the responsibility of performing the committed activity. But the time allocated to the committed activity in a bigger family is longer than that in a smaller family. This might be because in a bigger family, women have to take care of more family members.

For the married women, they have to reduce the chances and hours of working and to be involved in more compulsory-committed activities as well as the chances to participate in discretionary activities, but their time allocated to the discretionary activities is longer than those unmarried women. Education level shows a complicated influence structure on time use behaviour. It increases the time use on discretionary activity and compulsory-committed activity, but results in the decrease of participation in the labour market, on the contrary, in case of working, the working hours of women with higher education level are longer than those with lower level. Other influential factors affecting time use behaviour include weather, day of week, and number of rooms.

6. Conclusions

Women's issues have been attracting more and more attentions in transportation from various perspectives. Different from other aspects of the women's issues, childcare, one of the most important tasks and responsibilities of women, has received little attention in travel behaviour analysis. This study has examined how childcare affects women's time use behaviour based on an integrated model of activity participation and time allocation. The proposed model to describe the activity participation is built based on a Scobit model. The Scobit model has a skewness parameter and can accordingly include the popular Logit model as a special case. As a result, the Scobit model can relax the assumption made in existing studies that individuals with equal probability of participation and non-participation are most sensitive to changes in the introduced factors into the model. The Scobit model is integrated with a utility-maximizing time allocation model within Lee's (1983) transformation framework. We conducted an empirical analysis using a large-scale Japanese national time use data (66,839 person-days) collected in 2006, where childcare is distinguished between social childcare with and without extended service. The model results show that childcare is much more influential to the discretionary activity and compulsory-committed activity than to the compulsory-contracted activity (mainly work). The influential factors affecting women's time use behaviour include marital status, employment status, and social childcare.

Childcare not only affects women's time use behaviour, but also refers to the choices of residential locations as well as car ownership and usage and other transportation planning issues. In the future, all the aforementioned unresolved issues should be considered.

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