Journal of the Eastern Asia Society for Transportation Studies, Vol. 6, pp. 1956 - 1970, 2005

THE EFFECTS OF A FLEXTIME SYSTEM ON ARRIVAL AND DEPARTURE TIMES TO AND FROM WORK

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Abstracts: In this paper, time choice models to and from work are developed using panel data collected during a three-year period after the introduction of a flextime system in a company. Interesting facts revealed: (1) the habitual effect of arrival time to work continues after the new system is implemented, but decreases over time, (2) household structure does not have a great effect on arrival and departure times to and from work, and (3) interdependence between the two times to and from work are significant. In light of these conditions, it is believed that the times to and from work are decided simultaneously, hence a simultaneous choice model is formulated and estimated based on the same data. The interdependence between these two times is significantly confirmed in the model.

Key Words: Flextime system, Travel behavior analysis, Simultaneous-equations model, State dependence

1. INTRODUCTION

The number of companies introducing flextime (i.e., flexible working time) systems has been increasing in recent years. As of January 1, 2001, 35.9% of large Japanese companies having 1,000 and more employees have introduced the system at least partly (Ministry of Health, Labor and Welfare, 2003). Although the system was originally introduced to make their businesses more effective, it is an interesting policy from the viewpoint of transportation planning because it can serve to avoid peak hour commuting of employees, which eventually leads to alleviating traffic congestion in cities (Institute of Transportation Engineering, 1989).

In transportation research which deals with flextime systems, the development of arrival time choice models to work and measuring the effects of the introduced systems have been important subjects. In this context, Matsui et al. (1993) developed commuting time choice models and measured abbreviating effects of road traffic using a combined model of hourly commuters distribution and traffic assignment. Sato et al. (1996) developed commuting time choice models using "person trip" data, and demonstrated qualitative effects of decreasing road congestion by combining the models with a traffic assignment method. Ieda et al. (1997) developed arrival time choice models for rail commuters which can be applied to both flextime system users and fixed start workers. These findings are all based on aggregate data for practical use. Tsukai et al. (1999) developed starting time choice models from home at the disaggregate level, considering life rhythms of commuters, and so was able to calculate their benefits in order to clarify the significance of introducing a flextime system.

On the other hand, it is true that flexible work arrangements have important linkage to travel behavior to and from work and subsequent impact on traffic mix in urban areas (Brewer, 1998). We have studied within the context of travel behavior analysis (Stopher et al., 1997) how the flextime system affects household members in their travel behaviors to work in the morning (Sugie at al., 1999), and how individual household structure is related to work arrival-time choice (Sugie at al., 2001) using actual data from a company which had just recently introduced a new flextime system. In addition, a follow-up survey has been conducted in order to check the adjustment process of commuters' travel behaviors after implementing the system (Suto et al., 1998).

The focus of this paper is to develop further the previous studies which dealt with only travel behaviors to work from home, by considering those from work in the evening simultaneously. At first the effects of a flextime system on travel behaviors to and from work over a three-year period will be analyzed, and then the effects of commuting time behavior before introducing the system in comparison to after the introduction (i.e., habitual effects) will be examined by building arrival and departure time choice models to and from work separately based on four sets of time-point panel data collected from the same company. Since it is anticipated by this model analysis that arrival time to work is affected by departure time from work and, conversely, the latter time is also affected by the former time, a simultaneous choice model will be proposed which represents explicitly the interdependence between these two times.

2. THE FLEXTIME SYSTEM AND QUESTIONNAIRE SURVEY

2.1 Changes in a Working System by the Introduction of a Flextime System

For our study, we analyzed a large construction consultant company in Hiroshima, Japan which introduced a flextime system in August, 1996. This company abolished a fixed work starting time (8:40) with the introduction of the system, and adopted a system in which employees are allowed to go to the office any time before beginning a core time (10:00). Furthermore, required hours were reduced to seven hours and a half, that is, decreased by 20 minutes. The change in the working system before and after introduction of the flextime is depicted in Figure 1.

2.2 Outline of the Questionnaire Survey

To gauge the effects on the employees, four time-point questionnaire surveys were carried out; before introduction of the system (September, 1996), after one month (November, 1996), after one year (August, 1997) and after three years (August, 1999). Survey items in each survey entailed personal attributes (i.e., arrival and departure times to and from work, travel modes, activities on the way to and from work, etc.), and household structure (i.e., the existence of preschool children or senior citizen, spouse's employment status, etc.). By making the forms of questionnaire sheets almost equivalent at each point in time, temporal comparisons and panel analyses could be easily made. Since cooperation of the company was obtained for distributing and collection of the questionnaire sheets, a very high collection ratio, 90% (i.e., about 300 sheets), of the distributed ones were obtained at all four time points. Consequently, the number of panel data, which were identified by the ID numbers of employees, was 161. These panel data will be specifically used for the following study.

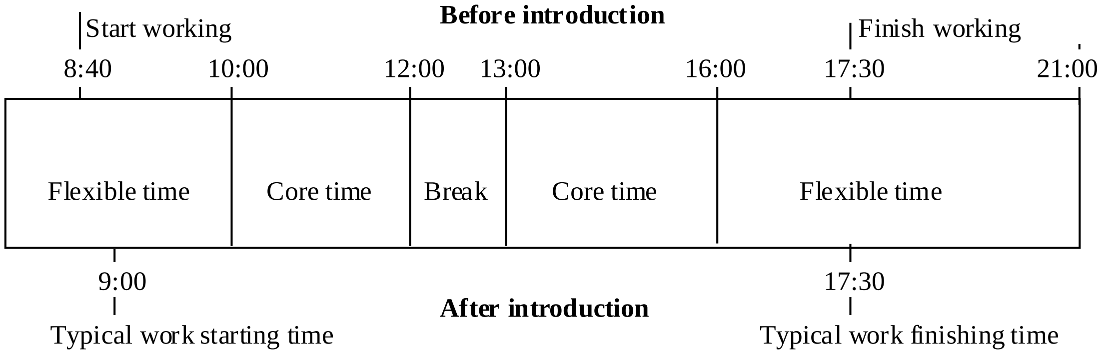

Figure 1. Changes in the Working System Before and After Introducing Flextime

3. CHANGES IN PANEL DATA WITH RESPECT TO TRAVEL BEHAVIOR

Average (variance) of times to and from work are tabulated over the four time points in Table 1. All averages, from "departure time from home" to "departure time from work", become gradually later during three years after introduction of the flextime system, and variance of these times becomes also gradually larger over time. These findings indicate that commuting time behavior varies at least for a few years after the introduction.

Table 1. Change in Average Times to and from Work

Times to and from work	Before introduction	After introduction (1 month)	After introduction (1 year)	After introduction (3 years)
Departure time from home	7:43 (926)	8:11 (1262)	8:19 (1450)	8:29 (1590)
Arrival time at the office	8:27 (171)	8:51 (677)	8:59 (783)	9:06 (877)
Time to start working	8:40 (42)	9:01 (496)	N.D.	9:17 (732)
Departure time from work	19:04 (4285)	19:01 (4735)	19:04 (5841)	19:43 (6250)
Sample size	167			

( ): Variance (min)

Changes in hourly distribution of arrival and departure times to and from work are illustrated in Figures 2 and 3 based on four sets of time-point panel data over the three years. Figure 2 indicates that arrival time to work becomes later over time; it greatly changes from one month to one year, but not greatly from one year to three years after introduction of the system. On the other hand, we can see from Figure 3 that departure time from work does not change greatly for the first three time points, but does vary greatly after three years. However, it is not clear whether or not it becomes stable three years later.

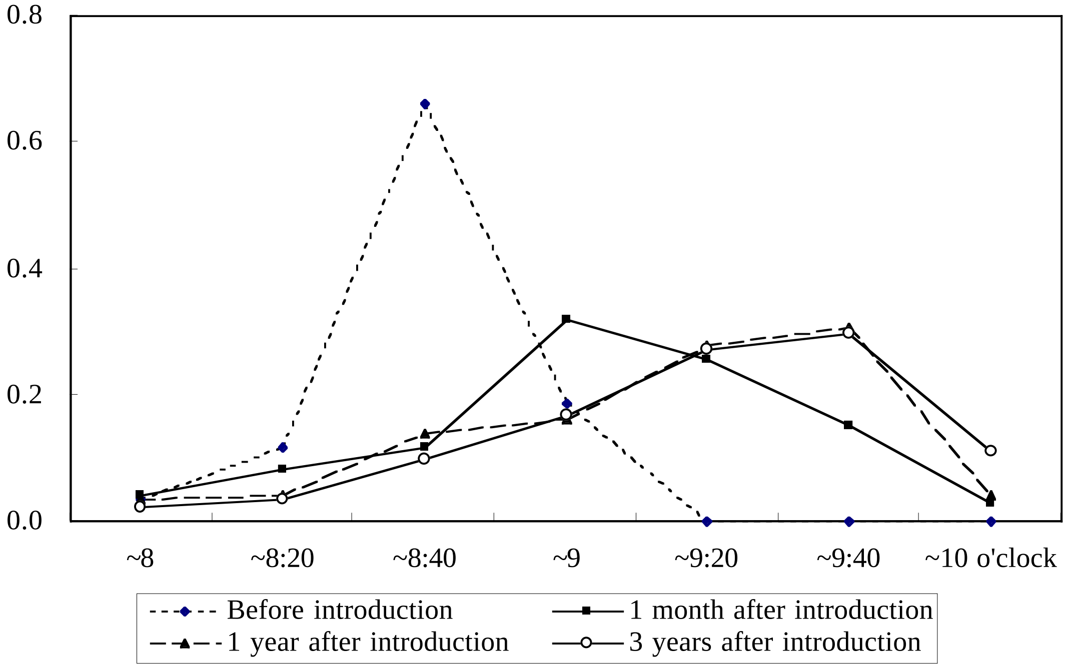

Figure 2. Changes in Distribution of Arrival Time to Work

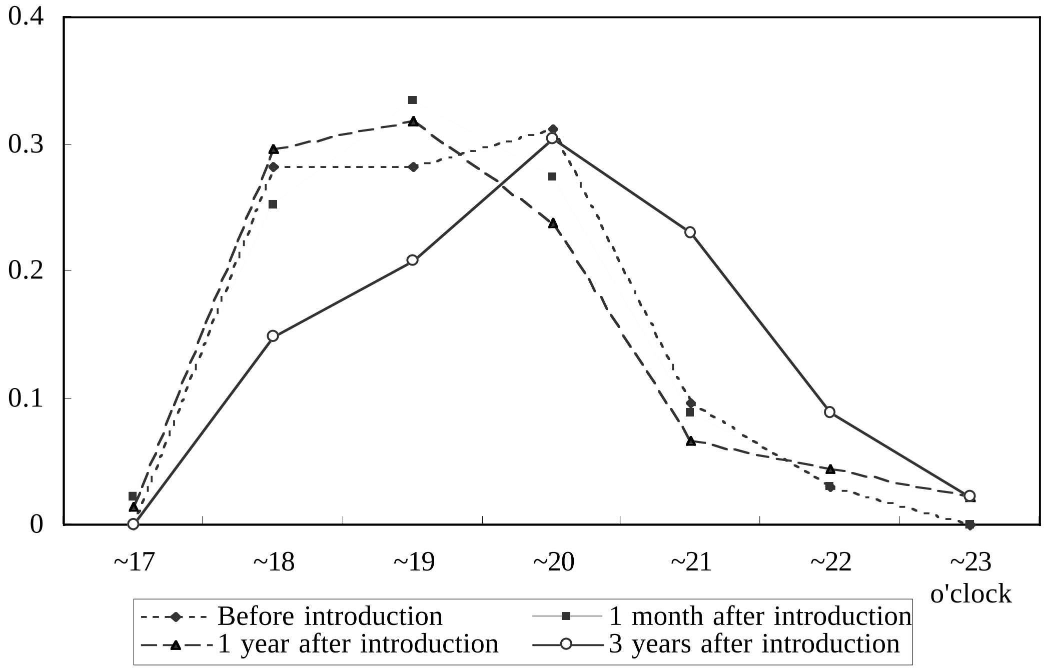

Figure 3. Changes in Distribution of Departure Time from Work

Changes in modal shares during the four time points are set out in Figure 4. Interestingly, the number of public transport users decreased by 9%, while car users increased by 7% during the three years. This implies that modal shares are greatly affected by the flextime system. It is assumed that public transport users changed their modes to work by making use of the system which can allows them to avoid the peak hour congestion for car commuting. Other travel modes have also changed. The number of bicycle users has gradually increased, while the number of walkers has gradually decreased during the three years. This may not be caused by introducing the system, but the reason cannot be explained clearly.

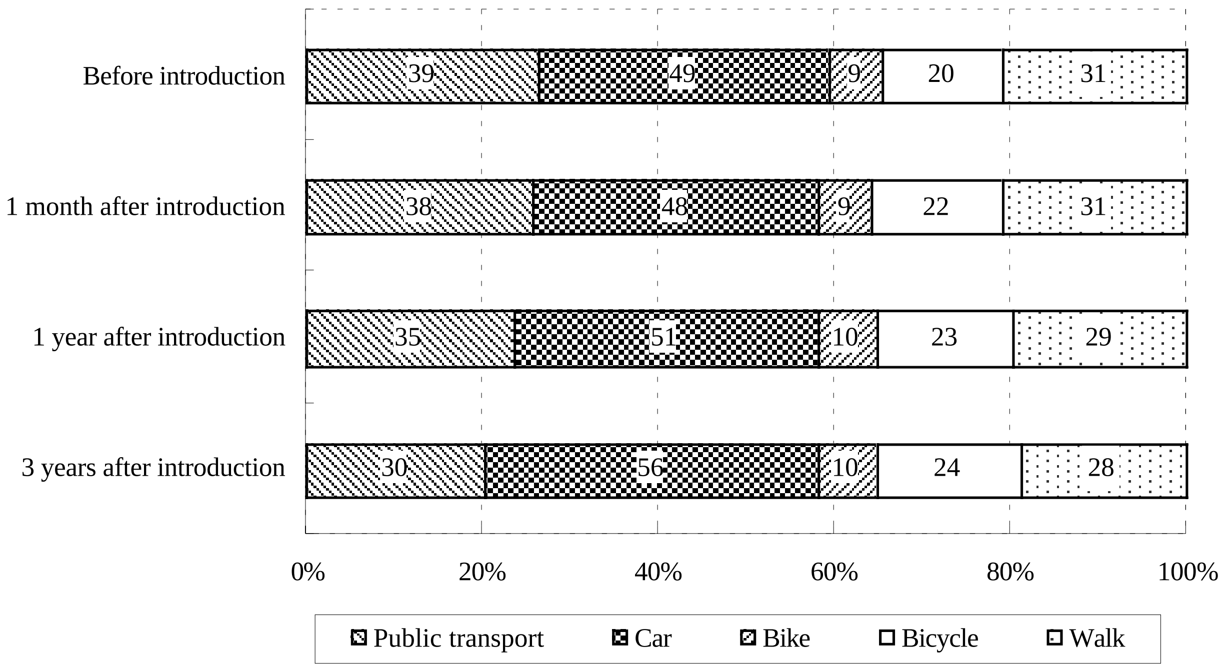

Figure 4. Changes in Modal Shares by the Flextime System

4. ANALYSIS OF ARRIVAL TIME CHOICE BEHAVIOR TO WORK

4.1 Formulation of Arrival Time Choice Models

Arrival time choice models at each point in time will be developed using four sets of time-point panel data consisting of one before and three after introduction of the flextime system. An Ordered Probit Model is employed for that, which can flexibly express temporal variation of time choice behavior by making continuous time to and from work discrete, and can easily introduce these two interactive relations by means of proper statistical methods.

It is presumed for this formulation that arrival time to work under the flextime system is decided by attributes including mode choice, household structure, etc., departure time from work, and marginal time before starting work.

When classifying arrival time to work into some continuous time categories (i.e., time zones), probability to choose time category k can be expressed as follows:

$$P_k = \Phi(\delta_k - V) - \Phi(\delta_{k-1} - V) \quad (1)$$

$$V = \sum_p \beta_p X_p \quad (2)$$

where P_k: Probability to choose time category k, Φ: Accumulated density function of standard normal distribution, δ_k: Value of k'th threshold (i.e., δ_0 = $-\infty$, δ_1 = 0, … , δ_K = $+\infty$ in the case of K categories), *V*: Determinant of utility function, X_p: p'th variable, β_p: Parameter of X_p.

Four time categories are employed in this analysis; ~8:29, 8:30~8:59, 9:00~9:29, and 9:30~10:00 for after the flextime introduction, while ~8:29, 8:30~8:34, 8:35~8:39, and 8:40~ for before the introduction. Household structure, gender, and travel mode used as explanatory variables in the model are expressed by binary dummy variables (1 or 0). Marginal time is defined as the time from arrival time to the start of work before the flextime introduction (i.e., 8:40). On the other hand, departure time from work is also classified into four categories every 45 minutes, and they are represented as four continuous numbers: ~18:09=1, 18:10~18:54=2, 18:55~19:39=3, and 19:40~=4.

4.2 Estimated Results of Arrival Time Choice Models

Arrival time choice models are estimated over the four time points as shown in Table 2. The explanatory power of estimated parameters at each point in time and temporal variation of parameters and model structure are discussed. Table 2 indicates that the greater the product of estimated parameter and explanatory variable value, the later the arrival time to work. All three models after introduction of the system represent a good degree of fit since adj. Rho-bars squared (i.e., Log likelihood ratio) are greater than 4.0 for the three models. All model parameters before the introduction are not statistically significant and adj. Rho-bar squared is comparatively small (i.e., 0.103), probably because the time zones to be chosen for arrival time are smaller than in the other three cases.

Table 2. Estimated Results of Arrival Time Choice Models to Work

Variable	Before introduction ('96)		One month after introduction ('96)		One year after introduction ('97)		Three years after introduction ('99)	
	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value
Travel time to work (min)	0.002	0.55	0.013	2.87**	0.011	2.79**	0.009	1.96*
Travel mode (car=1)	0.003	0.01	0.330	1.58	0.464	2.30*	0.221	1.12
Age (years)	-0.007	0.98	0.034	3.58**	0.012	1.48	0.011	1.25
Gender (m=1, f=0)	0.555	1.81	-0.870	2.64**	-0.079	0.28	-0.626	2.14*
Single (yes=1)	-0.012	0.05	1.313	4.36**	1.382	4.67**	0.858	2.58**
Preschool child (yes=1)	-0.115	0.49	0.090	0.37	-0.019	0.08	0.151	0.58
Senior citizen (yes=1)	-0.171	0.61	-0.168	0.57	-0.158	0.61	-0.305	-1.18
Spouse's work (yes=1)	-0.096	0.44	-0.100	0.45	-0.046	0.23	0.055	0.29
Marginal time (min)			-0.050	6.43**	-0.027	4.18**	-0.022	3.53**
Departure time from work	0.122	1.71	0.584	6.80**	0.364	4.93**	0.589	7.26**
Threshold parameter δ_2	0.917	8.66**	1.559	9.30**	0.985	7.89**	1.086	7.06**
δ_3	1.446	11.04**	3.293	13.41**	2.223	13.23**	2.176	12.05**
Initial likelihood	-241.90		-325.89		-333.38		-393.72	
Maximum likelihood	-216.92		-159.23		-198.03		-191.16	
Adj. rho-bar squared	0.103		0.511		0.406		0.514	
Sample size	167		167		167		167	

*: Significant at 5%, **: Significant at 1%

Table 2 also indicates that both commuters with longer travel time to work and car commuters tend to go to work later than others, because those parameter signs are plus. As departure time from work is highly significant, we can say that it is strongly related to the arrival time, e.g., those who go to work later will leave the office later, and vice versa. Marginal time has a minus sign for all three models after the introduction, which implies that those who used to go to work earlier before introduction of the system have an inclination to go to work earlier also under the flextime system. This is referred to as state dependence, which plays a very important role in developing dynamic models based on panel data (Kitamura, 2000; Sugie et al., 2003). Furthermore, the absolute value of the parameter becomes smaller over time with its t-value, so we can see that the effect of travel behavior to work before the system becomes smaller year after year.

Age and gender as personal attributes have effects on arrival time to work, while household structure has small effects on it, except for single persons who go to work later than non-singles. This is an interesting result, because it is reported in Europe that a life cycle consisting of household structure has a close connection with travel behavior of household members (Jones at al., 1983).

5. ANALYSIS OF DEPARTURE TIME CHOICE BEHAVIOR FROM WORK

5.1 Formulation of Departure Time Choice Models

In the same way as in the last section, departure time choice models at each point in time will be developed using four sets of time-point panel data. Model formulation is made by using the same model structure as in the previous one, and it is also presumed that departure time choice depends on mode choice, personal and household attributes, and arrival time to work. Marginal time will be excluded from explanatory variables in this case.

Departure time choice categories employ the same ones used in formulating arrival time choice models in the previous section, and arrival time choice categories in explanatory variables are similarly replaced by four continuous numbers, from 1 to 4. Household structure, gender, and travel mode are also expressed by (1 or 0) dummy variables.

5.2 Estimated Results of Departure Time Choice Models

Departure time choice models are estimated at four time points as shown in Table 3. Travel time from work and travel mode in departure time choice models have smaller explanatory power than in arrival time choice models (cf. Table 2). As for personal attributes, age and gender have great effects on departure time choice as in arrival time choice to work. The preschool child dummy variables are significant in all three models under the flextime system, and their plus signs imply that those who have preschool children have a strong tendency to leave the office later. However, we cannot understand well why they go home later. One reason may be that they belong to the younger generation in the company and may be obliged to work longer than the elders even though they want to go home earlier. This will be discussed again in the next section.

The single dummy variables which are all significant in the arrival time choice models, have small explanatory power in the departure time choice models. However, we can confirm an interesting fact also in this analysis that departure time to work greatly depends on the arrival time; if they go to work later, they go home later, and vice versa.

Table 3. Estimated Results of Departure Time Choice Models from Work

Variable	Before introduction ('96)		One month after introduction ('96)		One year after introduction ('97)		Three years after introduction ('99)	
	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value
Travel time from work (min)	0.001	0.34	-0.004	0.77	-0.004	0.84	-0.003	0.71
Travel mode (car=1)	0.102	0.48	0.023	0.11	0.366	1.75	0.215	1.01
Age (years)	-0.045	5.28**	-0.061	6.35**	-0.037	4.45**	-0.040	4.60**
Gender (m =1, f=0)	1.757	5.53**	1.921	6.14**	1.231	4.36**	1.737	5.97**
Single (yes=1)	-0.336	1.17	-0.680	2.16*	-0.247	0.79	0.317	0.83
Preschool child (yes=1)	0.455	1.88	0.495	1.97*	0.725	2.93**	1.011	2.73**
Senior citizen (yes=1)	0.289	0.97	0.247	0.83	0.252	0.93	0.176	0.63
Spouse's work (yes=1)	0.318	1.43	0.276	1.22	0.016	0.08	0.038	0.18
Arrival time to work	0.248	3.05**	0.640	6.10**	0.292	3.62**	0.490	5.77**
Threshold parameter δ_2	0.249	3.62**	0.409	4.41**	0.409	4.92**	0.306	3.33**
δ_3	1.323	9.71**	1.562	9.93**	1.274	9.72**	1.307	8.48**
Initial likelihood	-240.89		-267.47		-244.72		-298.18	
Maximum likelihood	-180.53		-170.49		-193.61		-152.16	
Adj. rho-bar squared	0.251		0.363		0.209		0.490	
Sample size	167		167		167		167	

*: Significant at 5%, **: Significant at 1%

6. SIMULTANEOUS-EQUATIONS MODELS OF ARRIVAL AND DEPARTURE TIMES TO AND FROM WORK

6.1 Formulation of Simultaneous-equations Models

It was indicated by studies in sections 5 and 6 that choice of arrival and departure times is not decided independently, but rather simultaneously by affecting each other. Since interdependence of this sort seems to exist between observed factors (i.e., determinants of latent preference functions) and between unobserved factors (i.e., error components), we propose a model structure which can represent such an interdependent mechanism as shown in Figure 5. At the outset, choice models of arrival and departure times to and from work developed in the previous sections will be applied in this study.

Latent preference functions ξ_i^1 and ξ_i^2 of individual i to choose arrival and departure times to and from work can be expressed by following equations:

$$\xi_i^1 = V_i^1 + \varepsilon_i \tag{3}$$

$$\xi_i^2 = V_i^2 + \eta_i \tag{4}$$

where V_i^1, V_i^2: Determinants of latent functions ξ_i^1, ξ_i^2, ε_i, η_i: Error components.

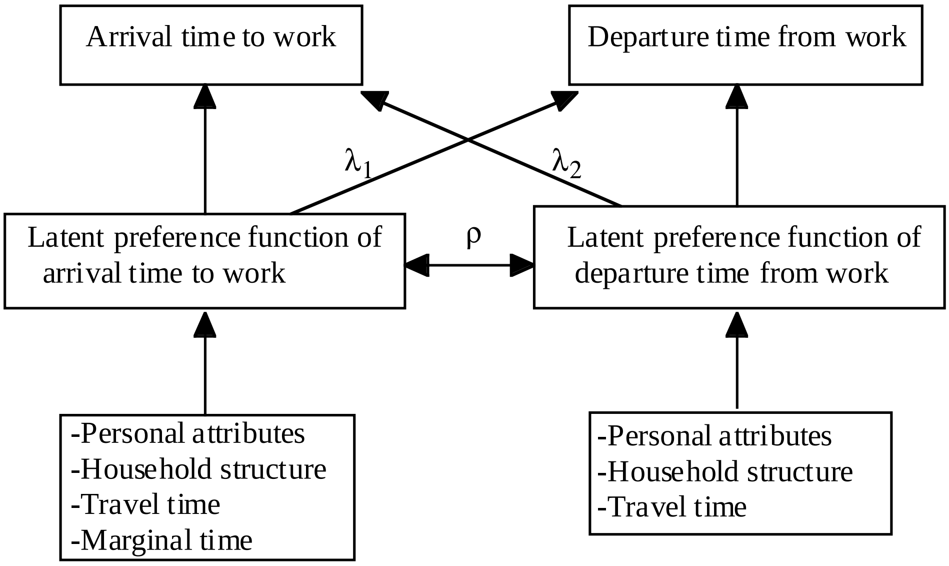

Figure 5. Concept of Simultaneous-equations Model

Probabilities of individual i to choose arrival time zone j (P_{ij}^1) and departure time zone k (P_{ik}^2) can be given as follows:

$$P_{ij}^1 = \int_{\delta_{j-1}^1 - V_i^1}^{\delta_j^1 - V_i^1} f(\varepsilon) d\varepsilon \tag{5}$$

$$P_{ik}^2 = \int_{\delta_{k-1}^2 - V_i^2}^{\delta_k^2 - V_i^2} f(\eta) d\eta \tag{6}$$

where $f(\varepsilon)$, $f(\eta)$: Probability density functions of error components ε_i and η_i, δ_j^1, δ_k^2: j'th and k'th thresholds for arrival and departure times.

A simultaneous-equations model taking into account the correlation of error components ε_i and η_i is formulated here. If we assume that they follow a bivariate normal distribution, their probability density function (η, ε) can be expressed as:

$$g(\varepsilon,\eta) = \frac{1}{2\pi\sigma_1\sigma_2\sqrt{1-\rho^2}} \exp\{-\frac{1}{2(1-\rho^2)}[(\frac{\varepsilon}{\sigma_1})^2 - 2\rho\frac{\varepsilon}{\sigma_1}\frac{\eta}{\sigma_2} + (\frac{\eta}{\sigma_2})^2]\} \tag{7}$$

where ρ : Covariance of ε_i and η_i .

Depending on the validity of the above assumption, the joint probability that individual i chooses arrival time zone j and departure time zone k is shown as Equation (8):

$$P_{ijk} = \int_{\delta_{j-1}^1 - V_i^1}^{\delta_j^1 - V_i^1} \int_{\delta_{k-1}^2 - V_i^2}^{\delta_k^2 - V_i^2} g(\varepsilon,\eta) d\varepsilon d\eta \tag{8}$$

In order to ease the calculation of the double integration in Equation (8), it can be transformed to the following simple function by coordinate rotation:

$$P_{ijk} = 2\pi\sqrt{1-\rho^2}\,(\Phi(\frac{(\delta_j^1 - V_i^1)/\sigma_1}{\sqrt{1-\rho^2}}) - \Phi(\frac{(\delta_{j-1}^1 - V_i^1)/\sigma_1}{\sqrt{1-\rho^2}}))\cdot(\Phi(\frac{(\delta_k^2 - V_i^2)/\sigma_2}{\sqrt{1-\rho^2}}) - \Phi(\frac{(\delta_{k-1}^2 - V_i^2)/\sigma_2}{\sqrt{1-\rho^2}})) \quad (9)$$

The maximum likelihood method is applied to estimate the parameters of Equation (9). To do this, as the total sum of all probabilities for P_{ijk} is $2\pi\sqrt{1-\rho^2}$, then the probability function in Equation (9) divided by $2\pi\sqrt{1-\rho^2}$ must be substituted in the log likelihood function in order to satisfy $\sum_j \sum_k P_{ijk} = 1$.

In order to explicitly represent the interdependence of arrival and departure time choices to and from work, utility functions V_i^{*1}, V_i^{*2} of arrival and departure times are redefined by employing effects parameters of these two functions:

$$V_i^{*1} = V_i^1 + \lambda^2 V_i^2 \quad (10)$$

$$V_i^{*2} = V_i^2 + \lambda^1 V_i^1 \quad (11)$$

where λ^1, λ^2: Effects parameters of determinants for arrival and departure times.

Thus, the effects of departure time on arrival time, and, conversely, arrival time on departure time can be expressed as determinants (V_i^2) and (V_i^1) of utility functions which represent departure and arrival time choices, respectively. It is not preferable to include both effects at the same time in the SE model from a point of correlation between the two determinants. Therefore, the following two cases will be examined concerning the interdependence of the above two time choices.

Case 1: Considers the effect of departure time, but not arrival time.

$$V_i^{*1} = V_i^1 + \lambda^2 V_i^2 \quad (9a)$$

$$V_i^{*2} = V_i^2 \quad (11)$$

Case 2: Considers the effect of arrival time, but not departure time.

$$V_i^{*1} = V_i^1 \quad (12)$$

$$V_i^{*2} = V_i^2 + \lambda^1 V_i^1 \quad (10a)$$

6.2 Estimated Results of Simultaneous-equations Models

The same explanatory variables as those used in the development of arrival and departure time choice models and new year dummy variables (1997 and 99) are employed in this study with pooled panel data over the three time points after introducing flextime. Estimated results of SE models are presented as Cases A-1 and A-2 in Table 4, which considers the effects of departure and arrival times, respectively. The table indicates that covariance parameters of error components (ρ) are statistically significant at the 1% level for both cases. This gives us a preferable result that supports the validity of SE models.

Table 4. Estimated Results of Simultaneous-equations Models for Arrival and Departure Times

Variable	Case A-1		Case A-2		Case B-1		Case B-2	
	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value
To work								
Travel time to work (min)	0.001	0.30	0.010	2.10*	0.009	4.01**	0.007	4.46**
Travel mode (car=1)	1.104	1.18	0.333	0.46	0.194	1.59	0.247	2.79**
Age (years)	-0.070	3.18**	0.002	0.17	0.022	3.25**	0.009	2.43*
Gender (m=1, f=0)	3.972	4.09**	0.277	0.42	-0.456	1.20	0.348	3.11**
Single (yes=1)	1.728	2.23*	1.107	1.51	1.080	7.09**	0.891	6.76**
Preschool child (yes=1)	2.158	2.34*	0.352	0.72				
Senior citizen (yes=1)	0.542	0.57	-0.098	0.11				
Spouse’s work (yes=1)	0.484	0.53	0.111	0.21				
Marginal time (min)	-0.019	6.51**	-0.019	2.97**	-0.014	4.84**	-0.012	4.76**
1997 dummy	1.047	1.28	0.637	1.28				
1999 dummy	3.346	3.76**	0.948	1.96*				
Effect of departure time (λ^2)	-2.720	5.65**			0.567	2.41*		
Threshold parameter δ_2	0.856	9.32**	0.854	5.63**	0.784	10.34**	0.694	10.21**
δ_3	1.854	12.76**	1.855	6.54**	1.706	12.55**	1.521	12.74**
From work								
Travel time from work (min)	-0.003	2.80**	-0.002	0.66	-0.001	0.54	-0.003	1.72
Travel mode (car=1)	0.260	0.88	0.205	0.28	0.204	2.04*	0.151	1.65
Age (years)	-0.026	3.97**	-0.027	1.69	-0.017	4.85**	-0.015	4.35**
Gender (m=1, f=0)	1.343	4.79**	1.295	1.72	1.276	8.26**	1.016	6.70**
Single (yes=1)	0.232	0.90	0.157	0.23				
Preschool child (yes=1)	0.664	2.07*	0.653	0.80	0.589	4.78**	0.551	4.68**
Senior citizen (yes=1)	0.224	0.69	0.197	0.21				
Spouse’s work (yes=1)	0.134	0.43	0.123	0.14				
1997 dummy	0.136	0.46	0.034	0.10				
1999 dummy	0.872	3.40**	0.766	2.20*				
Effect of arrival time (λ^1)			0.146	0.70			0.244	1.94
Threshold parameter δ_2	0.269	1.65	0.271	4.60**	0.245	6.61**	0.222	6.50**
δ_3	1.015	10.68**	1.027	5.68**	0.935	11.29**	0.847	11.23**
Covariance parameter (ρ)	0.557	9.06**	-0.537	3.03**	0.495	6.16**	0.624	13.50**
Initial likelihood	-1628.90		-1630.70		-1589.20		-1553.00	
Maximum likelihood	-1155.09		-1159.07		-1248.47		-1251.42	
Adjusted rho-bar squared	0.291		0.289		0.214		0.194	
Sample size	501		501		501		501	

*: Significant at 5%, **: Significant at 1%

The effect of departure time (λ^2) in Case A-1 is statistically significant, but has an unexpected minus sign, while the effect of arrival time (λ^1) in Case A-2 has an expected plus sign, but is not statistically significant. This is probably due to a correlation between explanatory variables, so another model estimation was made by excluding insignificant variables used in the estimation of independent models (see Tables 2 and 3). The estimated results are presented for Cases B-1 and B-2 in Table 4. Some considerations given by this analysis can be summarized as follows:

1) The effect of arrival time (λ^1) in Case B-1 is statistically significant and has the expected sign, which indicates logical interdependence between the observed factors. On the other hand, even though the departure time (λ^2) in Case B-2 has a t-value of 1.94, which is slightly less than that at the 5% significance level, the validity of the SE model proposed in this study is believed to be confirmed as a whole.

2) All the estimated covariance parameters (ρ) of the error components lie within [-1,1] and have statistically significant values, so it is confirmed that there exists a significant correlation between unobserved factors of arrival and departure time choices (i.e., an interdependence between unobserved factors).

3) The model including the effect of departure time (i.e., Case B-1) is slightly superior to that including the effect of arrival time (i.e., Case B-2) in terms of model accuracy which is expressed as Rho-bar squared. This means that the expected departure time from work has a greater effect than the expected arrival time on the decision of a full-day time schedule.

4) The travel mode which is expressed by “go to work by car or not” has significant effects on departure time choice for Case B-1 and on arrival time for Case B-2. Since they have plus signs for both cases, it can be concluded that car commuters tend to go to work later and to come home later than non-car commuters.

5) As for effects of travel time to and from work, only estimated parameters of travel time to work are significant and have plus signs for both models. This suggests that longer travel time to work tends to make commuters go to work later. They may want to get up later or to avoid traffic congestion early in the morning. On the other hand, the reason why travel time from work is not significant in the model may be that commuters are not sensitive to temporal variation of travel time, since time constraints are not severe after work.

6) The significance level of personal attributes including age, gender, and household attributes such as marital status and the existence of a preschool child was greatly improved by excluding insignificant other attributes.

6.3 The Evaluation of Interdependence between Arrival and Departure Times

The partial utility shares of each personal and household attribute (i.e., parameter value $\times$ the average of attributes) in the utility function (see Equations (10) and (11)) are presented for the two cases in Table 5. In this way it is possible to examine the effects of these attributes on arrival and departure times to and from work at the same level. The higher the share, the greater the effect of attributes. For example, the greatest effect on them is contributed by the gender variable from work (i.e., 23.3% for case B-1 and 24.7% for case B-2).

Accordingly, it can be seen that personal attributes consisting of age and gender as well as habitual dependence (i.e., marginal time) have greater effects on arrival and departure time choices than other attributes such as the utility functions of the two times in the model. This is partly because arrival and departure times cannot be included explicitly, but are included implicitly in the model as their utility functions which are explained by personal and household attributes. This may lead to the generation of a multi-collinearity problem between the utility functions of arrival and departure times and their attributes. The reason why gender presents the highest P.U. share for departure time from work is probably that many female employees in this company are part-timers and engage in less important tasks. Therefore, they can leave the office easily after 17:30.

Even though the effect of arrival time was not significant in statistical evaluation of estimated models (see Table 4), its contribution based on the average value of attributes (i.e., 5.4%) becomes closer to the effect of departure time (i.e., 6.4%). Conversely, though the preschool child attribute was highly significant in the previous analysis, its contribution to departure time choice becomes smaller in this analysis for both cases (i.e., 2.4% and 3.0%), probably because samples having preschool children account for only 18.2% of the whole.

Table 5. Partial Utility Shares of Personal and Household Attributes in the Total Utility

Attribute	Average	Case B-1			Case B-2		
		Parameter	Partial utility	P.U. share	Parameter	Partial utility	P.U. share
To work				(%)			(%)
Travel time to work (min)	39.24	0.009**	0.349	7.8	0.007**	0.288	8.5
Travel mode (car=1)	0.337	0.194	0.065	1.4	0.247**	0.083	2.5
Age (years)	39.18	0.022**	0.857	19.1	0.009**	0.358	10.6
Gender (m =1, f=0)	0.820	-0.456	-0.374	8.3	0.348**	0.285	8.4
Single (yes=1)	0.124	1.080**	0.134	3.0	0.891**	0.110	3.3
Marginal time (min)	33.32	-0.014**	-0.480	10.7	-0.012**	-0.382	11.3
Effect of departure time (λ^2)	0.508	0.567**	0.288	6.4			
From work							
Travel time to work (min)	39.24	-0.001	-0.035	0.8	-0.003	-0.116	3.4
Travel mode (car=1)	0.337	0.204*	0.069	1.5	0.151	0.051	1.5
Age (years)	39.18	-0.017**	-0.679	15.1	-0.015**	-0.590	17.4
Gender (m =1, f=0)	0.820	1.276**	1.047	23.3	1.016**	0.833	24.7
Preschool child (yes=1)	0.182	0.589**	0.107	2.4	0.551**	0.100	3.0
Effect of arrival time (λ^1)	0.744				0.244	0.182	5.4

P.U. stands for partial utility, *: Significant at 5%, **: Significant at 1%

7. CONCLUSIONS

This study first demonstrates four consecutive sets of time-point panel survey results, delineating commuting behavior over a three-year period after introduction of a flextime system in a specific company in Hiroshima. As a result of empirical studies, it was shown that arrival time to work in the morning does not greatly change one year after introduction of the system, while departure time from work in the evening does not change greatly for the first one year, but tends to become later in the day three years afterwards. It is also indicated that the flextime system has a great impact on mode choice to work, which is to increase the number of car users and to decrease the number of public transport users.

In the modeling analysis of arrival and departure time choice to and from work, some interesting facts were revealed, including that the habitual effect of arrival time to work (i.e., the effect of marginal time before starting working in the morning) continues after the new system is implemented, but decreases over time, and that household structure does not have a great effect on the arrival and departure times. In addition, it was indicated that those times have a great interdependence in making decisions involving time choice.

Thus, it is anticipated that the arrival and departure times to and from work are not decided independently, but simultaneously in a full-day time schedule, so a simultaneous-equations model was formulated by introducing utility functions of the two times in the model, and estimations were made using the same above panel data. Consequently, it was statistically confirmed that the expected departure time from work has a great effect on the decision of arrival time, and that the effect is greater than that of the expected arrival time to work on departure time from work.

In the comparison of partial utilities in the utility function of SE models, it was demonstrated that personal attributes consisting of age and gender as well as habitual dependence have greater effects on arrival and departure time choices than other attributes including utility functions of the two times in the model.

However, a number of explanatory variables could not be included in the SE models since there are numerous and complex correlations among the variables. Hereafter, it will become more necessary to examine suitable combinations of variables in model development and to work out a way to exclude the multi-collinearity. As the classification of arrival and departure times into several categories generates problems of similarity and non-identity among alternatives (i.e.. time zone) (Fujiwara et al., 2001), some solutions must be considered to improve the model specification.

Mode choice was given externally as a dummy variable in the model. But it is essential to make it endogenous to improve SE models further, because a flextime system seems to greatly affect mode choice. By this model refinement, interdependence among arrival and departure time choices to and from work, and mode choice, is expected to represent more clearly actual travel behavior, and the SE models will become a more effective tool to evaluate transportation policies.

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