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TRAVEL MODE CHOICE OF URBAN COMMUTERS CONSIDERING THEIR HOME-RETURNING BEHAVIOR*

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1. Introduction

As a main activity in commuters' daily life cycles, commuting travel mode choices are affected by numerous factors except to operational features of transits. For instance, in the case when work is over late, less running frequency of mass transits or safety situation in access and excess makes a commuter choose automobile. Whereas, although automobile has greater flexibility without essential access and excess, a commuter would like to choose mass transits rather than encounter road congestion twice in a day that will enforce his working stress. Several previous studies have proposed models to deal with travel mode choice considering some operating features of transit systems, road situations and external individual attributes[1)~4)], but the most focused on going to work process.

Based on above reasons, although a series of measures and social experiments related to transport demand management (TDM) are adopted and performed in recent years for the purpose of improving automobile commuters to use mass transit systems, the urban traffic congestion, especially in peak hour, is still severe. Even there is a growing recognition to take into account of commuters' home-returning behaviors in commutation travel study, only a few studies began to discuss the related problems [5), 6)]. This paper attempts to propose a travel mode choice model for urban commuters in a more limited scope, with consideration of their going to work and home-returning behaviors. The model is expected to evaluate the effects of TDM.

2. Formulation of Commutation Behavior

This paper expresses commutation activity as a complete process that starts on departure time from home and ends in home-returning time. Travel time and fee, fatigue and stress spent in this process are called as disutility of commutation behavior. Because companies usually pay travel fees to commuters, this paper puts an emphasis on disutility related to time out of the regulated work period.

(1) Disutility Function for Going to Work Process

Suppose t_d, t_a and t_s are departure time from home, arrive time in company and appointed work start time respectively. When spent travel time, T_n, is given and a commuter departs at the time t_d, his arrive time, t_a, is obtained by:

$$t_a = t_d + T_n \tag{1}$$

In general, travel time by any kind of mode is thought to be varied with a certain probability distribution due to operating features of transits, therefore, given a departure time t_d, the probability density functions (hereafter express as PDF) of t_a is:

$$\phi_{t_a}(t \mid t_d) = \phi_{T_n}(t - t_d \mid t_d) \tag{2}$$

In such condition, the probability of being late than the appointed work time, λ, is calculated by:

$$\lambda = \int_s^\infty \phi_{t_a}(t \mid t_d)dt = \int_s^\infty \phi_{T_n}(t - t_d \mid t_d)dt \tag{3}$$

For not being late, a commuter must decide his departure time so as to minimize the probability of being late. The PDF of λ is proved to be well approximated by the following function:[2)]

$$f_\lambda(\lambda) = Af_1(\lambda) + Bf_2(\lambda) \tag{4}$$

$$f_i(\lambda) = \frac{1}{\sqrt{2\pi\sigma_i\lambda}} e^{-(\ln\lambda - \mu_i)^2/2\sigma_i^2} \quad i=1,2 \tag{5}$$

Where: $A=B=0.5$, $\mu_1=-4.0174$, $\sigma_1=1.0108$, $\mu_2=-8.0652$, $\sigma_2=1.9680$.

Taking probability of being late into account, a commuter's disutility for work is defined as the time interval from his departure time, t_d, to the appointed working time t_s. As the earlier the commuter departures from his home, the larger his disutility for work is, the disutility for work, D_W, is assumed to be a linear decreasing function as follows:

$$D_W(t_d) = \alpha_1(t_s - t_d) \tag{6}$$

Where: α_1 is a positive parameter.

(2) Disutility Function for Home-returning Process

Disutility for home-returning process consists of two parts: the one derives from overtime work and the other derives

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from travel for returning home. Suppose t_e, t_l and t_r are work end time, leave time from company and home-returning time respectively, the time interval from work end time, t_e, to home-returning time, t_r, can represent commuter's disutility in home-returning process. It is known that when work is over, the earlier the commuter leaves his company, the less his disutility of returning home is. Disutility for home-returning, D_R, is assumed as a linear increasing function with t_r :

$$D_R(t_r) = \alpha_2(t_r - t_e) \quad (7)$$

Where: α_2 is a positive parameter.

(3) Conceptual Model of Commutation Behavior

Based on above formulations, total disutility of commutation behavior, D_i, involving in both processes of going to work and home-returning, is defined as the sum of D_W and D_R :

$$D_i(t_d, t_r) = D_W(t_d) + D_R(t_r) = \alpha_1(t_s - t_d) + \alpha_2(t_r - t_e) + \beta_i \quad (8)$$

Where: β_i is a proper variable standing for some specific attributes of ith travel mode.
The conceptual model of commutation behavior is demonstrated in Figure 1.

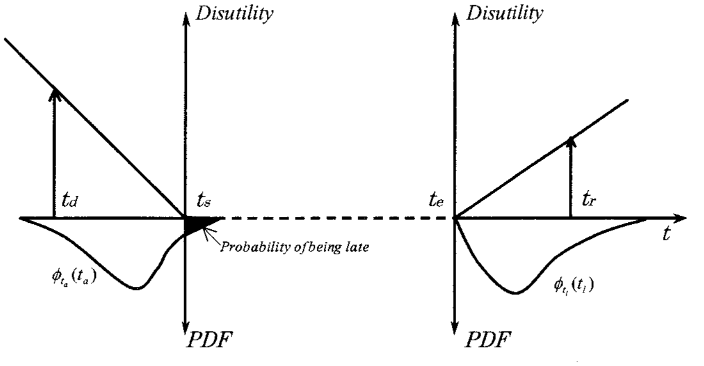

Figure 1. Conceptual Model of Commutation Behavior

3. Calibration of Travel Mode Choice Model

(1) Travel Mode Choice Model

This paper applies discrimination theory that is often used in psychology discipline to describe the individual choice behavior. If there are two kinds of travel modes, commuters are assumed to choose the one with minimum disutility. Disutility

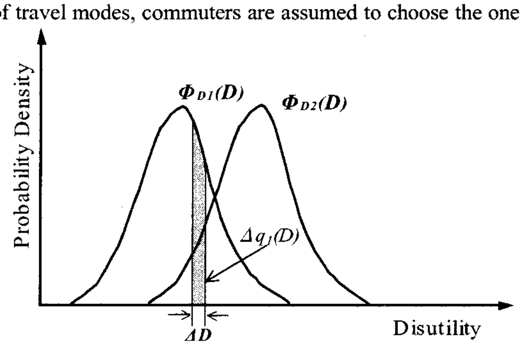

Figure 2. Travel Mode Choice Model

of mode *1* or mode *2*, denoted as *D1* or *D2*, is determined by its PDF, $\Phi_{D1}(D1)$ or $\Phi_{D2}(D2)$ respectively. As shown in Figure 2, in a little *D* section, probability that a person judges $D1 = D$, $\Delta q_1(D1)$, is calculated by:

$$\Delta q_1(D) = \Phi_{D1}(D)\Delta D \quad (9)$$

In the same condition, if the person judges $D2 > D$ and then decides to choose mode *1*, his choosing probability is:

$$\Delta P_1(D) = \Phi_{D1}(D)\Delta D \int_D^{\infty} \Phi_{D2}(s)ds \quad (10)$$

So, in whole scope of *D*, the person's choice probability of mode *1* is determined by:

$$P_1(D) = \int_0^{\infty} \Delta P_1(D)dD = \int_0^{\infty} \Phi_{D1}(D) \int_0^{\infty} \Phi_{D2}(s)dsdD \quad (11)$$

According to the definition of commutation disutility previously, if t_s-t_d, and, t_r-t_e, concerning with going to work and home-returning processes by different travel modes are known, probability distribution of disutility of each mode, $\Phi(D_i)$, can be obtained by giving arbitrary initial values to parameters of α_1, α_2 and β_1. Then, based on formula 11, the theoretical choice probability of each travel mode is determined. By adjusting the values of parameters and calculating the theoretical choice probabilities of all travel modes repeatedly, until the least square difference between these calculated values and the actual choice probabilities reached, the final optimum values of parameters are estimated.

(2) Data Selection and Processing

This paper selects the commutation trips toward CBD in Person Trips (PT) survey data of Fukuoka City in 1993 to calibrate commuter's travel mode choice model. Commuters' general travel modes are attributed into automobile, bus, rail and others such as bike or walking. Because some companies in CBD prohibit automobile commutation, nonetheless, congestion disutility must be considered in automobile commuters' behaviors[3)], this paper focuses on constructing a mode choice model for commuters using mass transit systems. Therefore, 8 zones with similar situations of mass transits are selected. The distributions of commuters' disutility that use bus and rail for commutation in these zones are used to calculate the theoretical choice probabilities, and the actual choice probabilities of bus and rail are used to compare with the theoretical choice probabilities.

Moreover, as commutation behavior is thought of a complete process from departure time to home-returning time, to delimitate influences of commuters' other activities during this process on travel mode choices, only home-work-home trip pattern is extracted.

PT data only reflect the actual results of travel mode choice, so it is difficult to distinguish the persons who have possibilities of commuting by automobile among all commuters using bus or rail. To eliminate the share of the ones with three alternatives, a telephone interview about the possibility of commuting by automobile is done, the result is referenced to rectify the actual choice probability of bus or rail in selected zones.

(3) Determining Work Start and End Time

For calculating disutility of going to work and returning home, it is necessary to know the work start and end time, but these data are not recorded in PT data. By analyzing the distributions of arrive time in company and leave time from company of commuters, it can be seen from Figure 3 that the most of commuters arrive in their companies in the period of 7:00-10:00 and begin to return home from 17:00. According to the more detailed distributions of arrive time and leave time in above

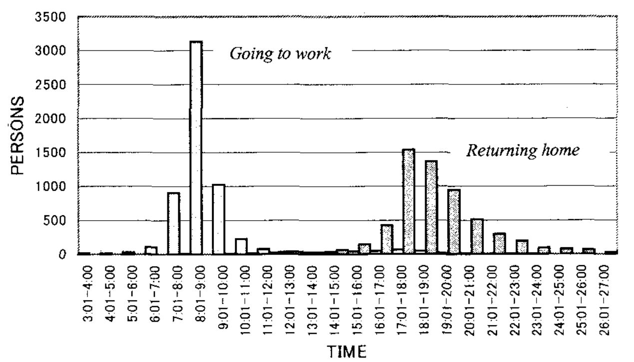

Figure 3. Distributions of Commuters' Arrive Time and Leave Time in a Daily Cycle

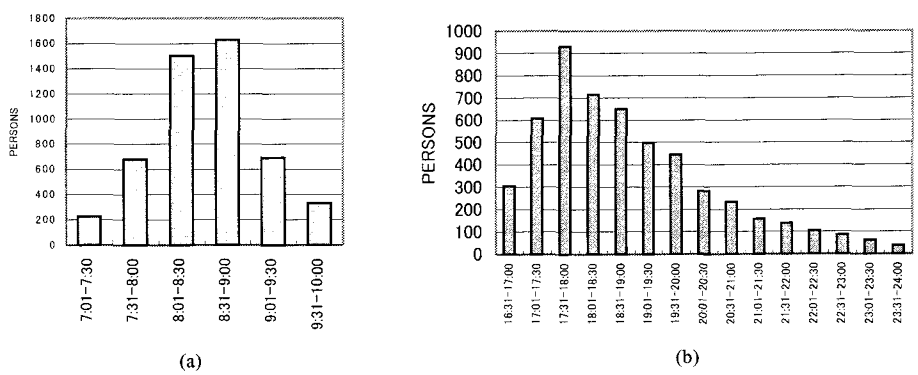

Figure 4. Arrive Time Distribution during 7:00-10:00 and Leave Time Distribution from 16:30

periods, as shown in Figure 4 (a) and (b), the most peak time 8:30 and 9:00 are assumed as work start time, meanwhile, 17:30 is assumed as the ending time of work.

(4) Calculation Result

Known work start and end time, t_s and t_e, the parameters included in commutation behavior model, α_1 , α_2 and β_i are estimated on the basis of the steps mentioned in 3(1). As commutation behavior model consists of going to work and home-returning processes, and there are only two kinds of travel modes discussed in this paper, to simplify calculation procedures and to reveal relative relationships between both processes and both travel modes, α_2 and β_{bus} are estimated in the assumptions of $\alpha_1=1$, and $\beta_{rail}=0$. As the result, $\alpha_2= 0.0674$ and $\beta_{bus}=0.1$are estimated. The comparison between the estimated value and the measured value of choice probability of rail in the selected zones is shown in Figure 5 with weighty correlation coefficient of 0.876. It is indicated that the model represents commuter's travel mode choice behavior within mass transits with good fitness.

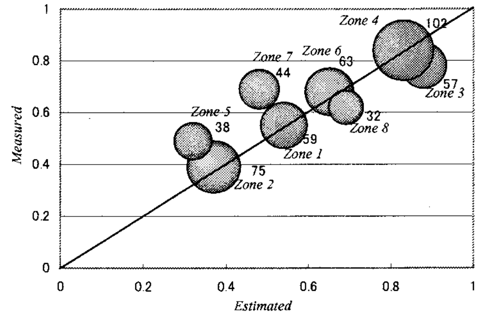

Figure 5 Comparison between the Estimated and the Actual Values of Choice Probability of Rail System

4 Conclusions and Discusses

In terms to definition of commutation process in this paper, disutility with respect to time out of the regulated work period is formulated. It is represented by commuters' virtual time consumptions in both processes of going to work and returning home.

A travel mode choice model for urban commuters is proposed based on the analysis of disutility involved in complete commutation process mentioned above. Applying person trips data of Fukuoka City, the model is calibrated and tested by comparing the theoretical and the actual values of travel mode choice probabilities of commuters using mass transits. The estimated result indicates that the proposed model with consideration of commuters' home-returning behaviors has good fitness in representing commuters' travel mode choices within mass transit systems.

However, as the first step of the study on travel mode choice considering commuters' home-returning behaviors, there are several aspects not be dealt with yet. For instance, to enable the model have greater applicability, travel mode choice of automobile commuters should be discussed by introducing additional congestion disutility in the model. That is to say, it is necessary to calibrate the commuters' behaviors with three alternatives of automobile, bus and rail. Moreover, travel mode choice probabilities in only 8 zones are used in this paper to calibrate the model, the further study should take more sufficient zones as samples to improve precision of the model. Furthermore, limited by PT data, there are so many assumptions included in calibrating model. When an applicable and complete model is developed, it is expected to evaluate effects of the measures of TDM by predicting commuters' transferring possibilities among various travel modes.

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