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Identifying the Determinants of Commuting Travel Mode Choice from Daily Commutation Behavior

by

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Abstract

Understanding of commuting travel mode choice behavior is crucial for enhancing the effects of transportation demand management (TDM) policies and improving the utilization of mass transits. For the purpose, this paper focused on analyzing the influences of commutation activity on commuting travel mode choice from a viewpoint that commutation activity comprises a series of activities undertaken in the period that starts on departure time from home in the morning and ends at home-returning time in the evening. Several indicators were firstly addressed to represent commutation activity, then by using Person Trip (PT) data of the workers toward CBD in Fukuoka City, the characteristics of commutation activity of the workers using different travel modes were statistically analyzed to identify the determinants influencing workers' travel mode choices. Furthermore, disaggregate logit model was adopted to quantify contributions of the presented indicators to commuting travel mode choice. The results showed that the model of the workers with 2 trips has good fitness whereas the model of the workers with multi-trips should be modified in further study.

Keywords: Determinants, Travel mode choice, Commutation activity, Disaggregate logit model

1. Introduction

In recent years, the policies of transportation demand management (TDM) have been recognized as the important issues to alleviate urban traffic congestion[1]. A lot of TDM polices have been proposed and assessed in different cities. For examples, flexible or staggered work time system was initiated to temporally disperse the concentrated traffics in

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peak hours; park and ride mode, which aims to lead the car-based workers to use mass transits, was adopted for the purpose of decreasing the traffics toward central business district (CBD). However, it should be noticed that these policies impossibly bring their functions into full play, if the diversity of individual travel behavior is not well understood. To enhance the effects of TDM policies and improve the utilization of mass transits, it is necessary to grasp the determinants concerning with commuting travel mode choice.

As indicated in previous studies, there were numerous factors affecting workers on choosing their travel modes. Besides travel time and fare cost, which were generally thought of the fundamental factors, services of transit systems, social and economic characteristics of individual worker, residential location, household structure were often taken into account[2–5]. Some studies even remarked the influences of worker preference, perception and attitude to transit systems[6–8]. However, these factors are exogenously related to transit systems or travel subjects who undertake travel behaviors. The most studies ignored the influences of commutation activity itself on travel mode choice. As we know, the start time and end time of work are appointed and a penalty accompanies with late arrival or early leave. Additionally, despite commutation is a main activity, it is not independent of other activities and travels for business or private purposes that are also contained in worker daily life cycle. Therefore, conditional on temporal constraints and daily schedule, a worker would choose the most advantageous one among all available commuting travel modes regarding the abovementioned exogenous factors. From this viewpoint, it can be thought that the factors, involved not only in going to work process but also in home-returning process, actually play important roles in commuting mode choice. For examples, in the case that work is over late, less running frequency of mass transit systems or safety condition in routes of access and egress would make a worker to choose car mode. On the contrary, another worker would like to choose mass transits to avoid driving strain and risk or encountering road congestion twice in a day that will enforce his work stress, even if a car can provide him greater flexibility. However, the existing studies mostly focused on the process for work, whereas did not pay enough attention on home-returning process. Although a few studies recently began to discuss the relationships of home-returning behavior with other activities undertaken by a worker in a day cycle based on trip chain analysis and activity-based approach[9–12], the studies on influences of the factors relevant to home-returning process on commuting travel mode choice were still insufficient and not intensive.

Form the abovementioned viewpoint that a worker would incorporate various factors when he determines commuting travel mode, we can consider that the determinants of commuting travel mode choice are reflected in commutation activity of the workers using different travel modes. Therefore, this paper attempts to identify the determinants of commuting travel mode choice by analyzing the characteristics of commutation activity of the workers using different travel modes. Then, disaggregate logit model is adopted to quantify the factor contributions to commuting travel mode choice. Here, Person Trip (PT) survey data of the workers toward CBD in Fukuoka City were selected for analysis and model development, in which information about the activities undertaken in a day cycle is detailed recorded.

2. Analyzing the influences of commutation activity on travel mode choice

C.R. Bhat et al identified four patterns in a worker's daily activity-travel according to the following time periods: 1) before morning commuting, 2) commuting in the morning and home-returning in the evening, 3) midday and 4) post home-arrival[12]. Considering the activities undertaken before morning commuting or post home-arrival may become a circuit that begins at home and ends at home and have no direct relationships with commuting travel mode choice, this paper specifically expresses commutation activity to comprise a series of activities undertaken in the period that starts on departure time from home in the morning and ends at home-returning time in the evening, such as: commuting activity in the morning, home-returning activity in the evening and the stops on these ways. To indicate the influences of commutation activity on travel mode choice, trip numbers in a day, arrival time in workplace, leaving time from workplace, home-returning time, work hours and travel time are taken as indicators of commutation activity. In this section, the characteristics of commutation activity of the workers using different travel modes are analyzed.

2.1 Data and pre-processing

Besides individual attributes of the travelers, PT survey well documents the details about total trip numbers in a day cycle, start time and end time of each trip as well as trip purpose and travel mode. Thus, PT data of Fukuoka Urban Area that were surveyed in 1993 were selected as data source of this paper.

There are 111 c-zones in 7 administrative wards of Fukuoka City. No matter where the origins are, the trips arriving in every c-zone of Fukuoka City for work were counted according to travel destinations and purposes. Because the top 15 c-zones being located in Central Ward and Hakata Ward concentrated about 65% of all workers coming from Fukuoka Urban Area[13], these c-zones were appointed as CBD of Fukuoka City (**Fig. 1**). In addition, since the share of the trips for work among all trips arriving in CBD during the period of 7:00–10:00 were 80.3%, whereas the share of the trips for home among all trips

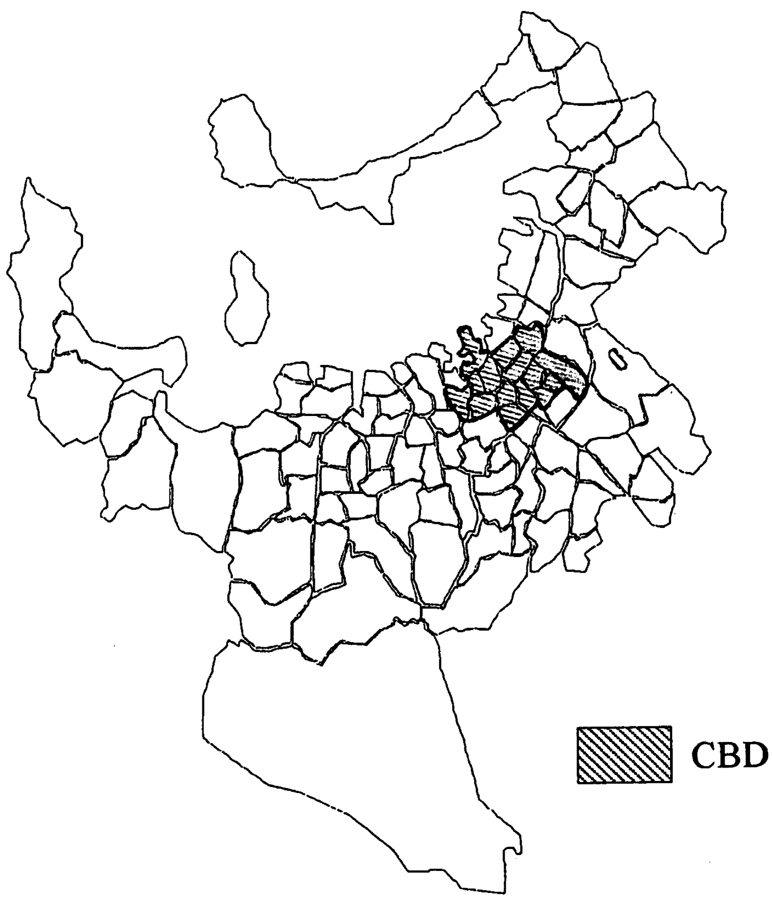


Fig. 1 c-zones and the location of CBD in Fukuoka City

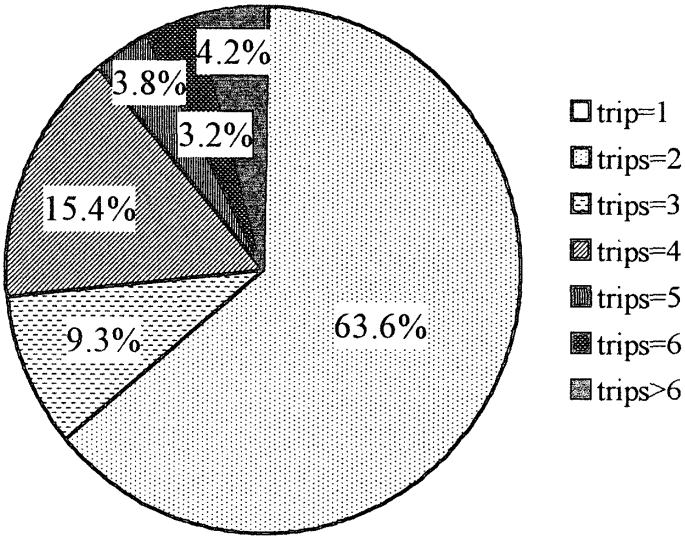


Fig. 2 Percentages of the workers having different trips

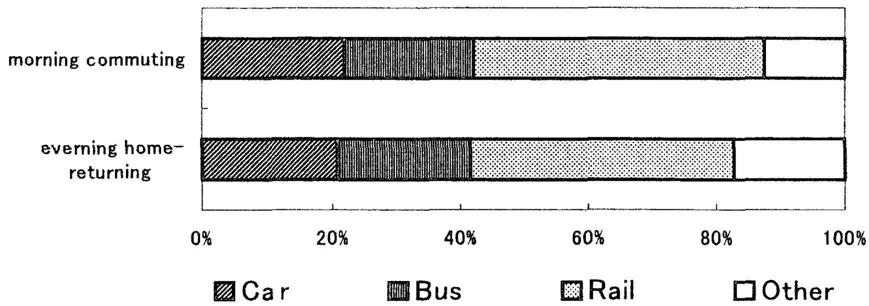


Fig. 3 Commuting travel mode splits of the workers toward CBD

leaving from CBD in the period of 17:00–19:00 were 78.3%, both periods were thereby defined as commuting peak hours in this paper. Then the workers who arrive in CBD in the period of 7:00–10:00 and leave from CBD after 17:00 were extracted as analyzing samples. By calculating the percentages of the workers having different trips (**Fig. 2**), it was found further that the most commuters have 2–6 trips so that those who have trips more than 6 were excluded from samples.

From PT survey data, trips undertaken in a day cycle and arrival time in workplace were obtained directly. Travel time was calculated as the difference between arrival time in workplace and home-departure time. Start time and end time of the trip for home were respectively appointed as leaving time from workplace and home-returning time. For the workers with only two trips for work and home, their work hours were calculated as the time duration between arrival time in workplace and time leaving from workplace. On the other hand, for the workers with more than 2 trips, their work hours were calculated by excluding the time for other non-work activities, the time spent on travel for these activities and the time for going to other workplaces.

Commuting travel modes recorded in PT survey can be mainly categorized into 4 types: by car, bus, rail and other modes (including taxi, motorcycle, bicycle, walk and so on). **Figure 3** shows the actual status of travel modes used by workers for morning commuting and evening home-returning. It was found that about 20% of all workers select cars as commuting travel modes, and 45% of all workers select rail systems, while about 20% and 15% of all workers use bus and other modes respectively. Additionally, distinguishing from other activities, commutation is a repeated activity in daily cycle so that the commuters are

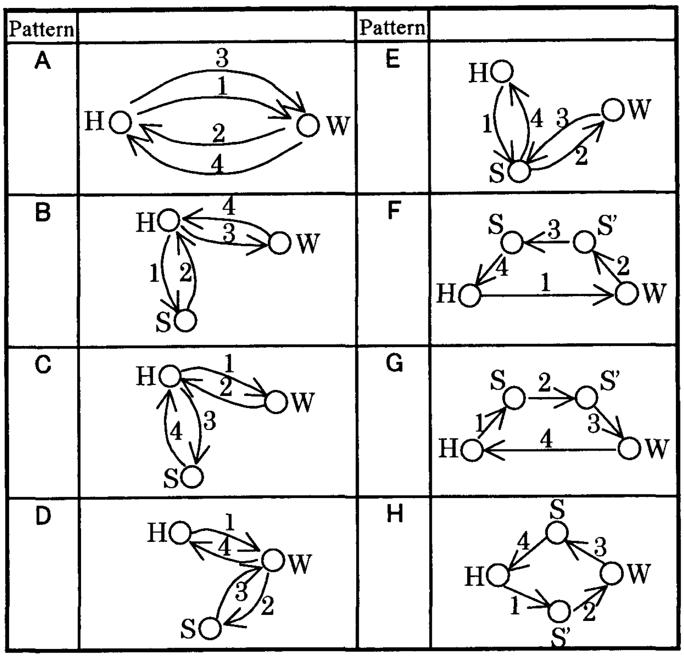


Fig. 4 Activity patterns of the workers with multi-trips
*H: Home, W: Workplace, S: One stop, S': Another stop

accustomed to use same transit for work and home, and using the same travel mode can save extra cost caused by different modes with disagreeable fare systems. Therefore, neither those who commutes by other modes of taxi, motorcycle, bicycle and walk, nor those who uses different travel modes for work and home were included, 2519 workers who commute by cars or mass transits were selected to reveal the influences of commutation activity in following sections.

Among all selected samples, the workers having 2 trips and multi-trips are 1715 and 804 respectively. Taking the workers having 4 trips as an example, it was known in **Fig. 4** that the activity patterns of the workers with multi-trips are diversified[14]. Regarding commutation activity as one cycle of home-workplace-home, the workers who have *A* activity pattern were excluded because they undertook repeated trips between home and workplace. The workers who have activity pattern *B* or *C* were not taken into account yet because they had trips undertaken before morning commuting or post home arrival that may be not related to commuting travel mode choice. Meanwhile, the workers who had trips in midday just for lunch break (partly included in activity pattern *D*) were also left out of consideration. As the result, 247 workers who had actual stops on the way to work or to home were extracted from all the commuters with multi-trips as samples.

2.2 Characteristics of commutation activity of the workers using different travel modes

Based on above data, we analyzed the characteristics of commutation activity of the workers using different travel modes in the following steps: (1) As shown in **Table 1**, the means and the standard deviations of abovementioned indicators representing commutation activity of the workers using different travel modes were calculated no matter whether they have 2 trips or multi-trips. (2) Considering that the other activities may influence commuting travel mode choice, the differences of commutation activity between the workers with 2 trips and the ones with multi-trips were identified by comparing distributions and related statistical values of the indicators (**Fig. 5** and **Table 2**). Despite travel time and arrival time in workplace seemed to be independent with trip numbers, the fact was consequently known

Table 1 Statistical characteristics of the indicators of the workers using different travel modes

Items		Car	Mass transits
workers		247	1715
Trip numbers in a day	Mean	3.15	2.79
(trips)	SD	3.22	1.94
Travel time	Mean	30.74	39.90
(min)	SD	12.21	13.30
Arrival time in workplace	Mean	8.50	8.68
(o'clock)	SD	0.66	0.53
Work hours	Mean	10.14	9.67
(h)	SD	1.71	1.43
Leaving time from workplace	Mean	18.96	18.84
(o'clock)	SD	1.38	1.26
Home-returning time	Mean	19.60	19.73
(o'clock)	SD	1.43	1.38

that the commutation activity of the workers with multi-trips indeed differs from that of the workers with 2 trips. Comparing with the workers with 2 trips, the workers with multi-trips have shorter work hours and trend to leave workplaces earlier but to return home later. (3) The workers with 2 trips and the ones with multi-trips were extracted into two groups, and the characteristics of the workers using different travel modes were further analyzed in the two groups respectively so as to identify the specific determinants of travel mode choice.

Incorporating the results shown in **Table 1**, **Fig. 5** and **Table 2**, the overall characteristics of every indicator were addressed as follows:

(1) trip numbers in a day

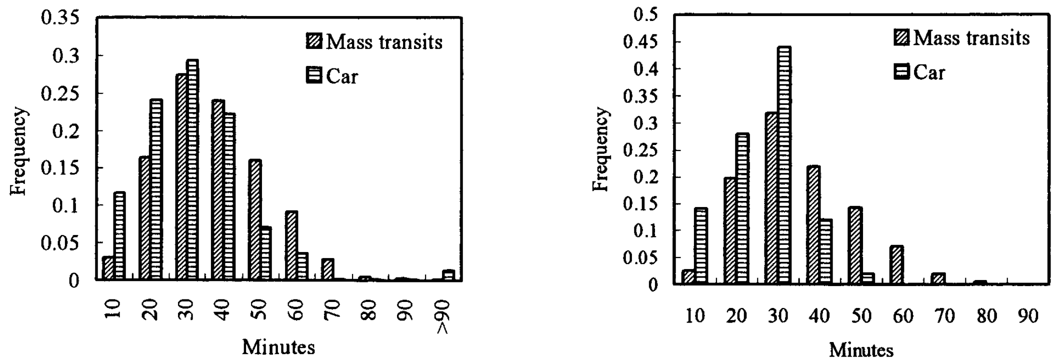
Table 1 shows that the average trip numbers in a day of the car-based workers and the workers using mass transits are 3.15 and 2.79 respectively. Analyzing the share of the car-based workers, it is found that 29.9% of the workers with multi-trips use cars as commuting travel modes, which is greater than 25.4% of the workers with 2 trips. A positive correlation between trip numbers and probability of choosing car mode can be contributed to the great flexibility and convenience of car mode for undertaking other business or private activities out of the workplace.

(2) travel time

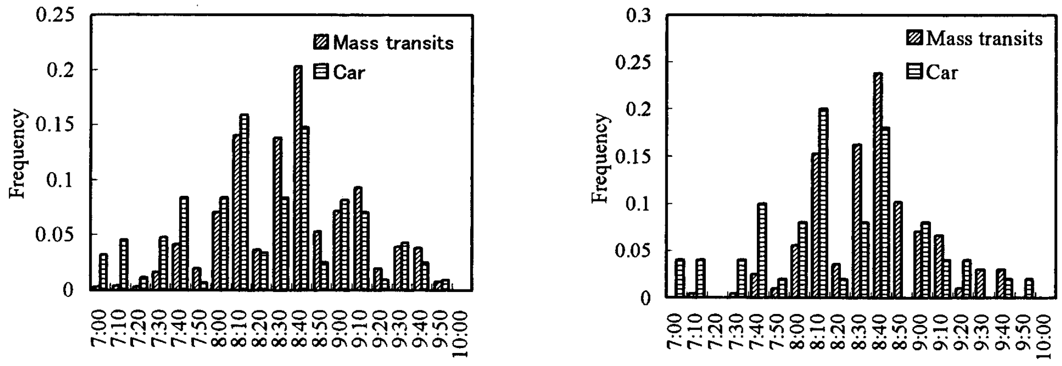
From **Table 1**, it is known that the average of travel time of the workers using mass transits is about 10 minutes longer than that of the car-based workers. Since travel time is related to commuting distance, the averages of travel time of the workers with same commuting distance are further calculated as shown in **Fig. 6**. It is obvious that the workers would take less travel time if they use cars rather than mass transits for work no matter how long their commuting distances are, especially within commuting distances of 3-7 *Km*. Similarly, for the workers with either 2 trips or multi-trips, it is indicated in **Fig. 5** and **Table 2** that average travel time of the car-based workers is less than that of the workers using mass transits. Therefore, travel time can be thought of an important influencing factor in commuting travel mode choice.

(3) arrival time in workplace and leaving time from workplace

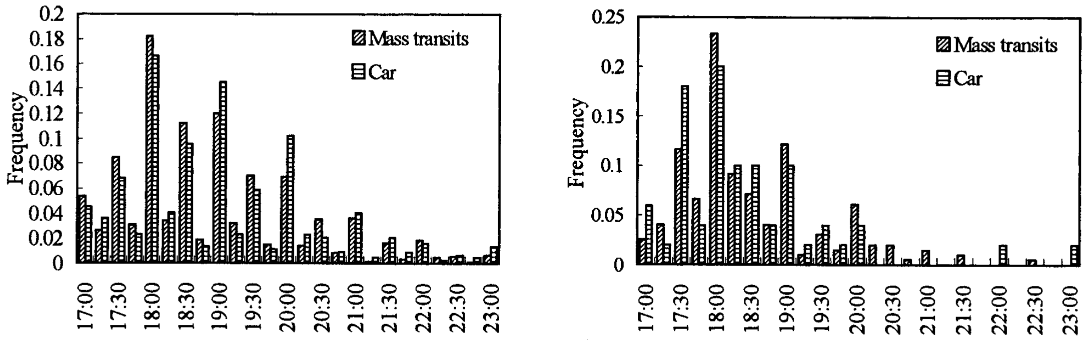
It is also known from **Table 1** that the workers on an average arrive in workplaces at 8:30-8:40, and leave from workplaces near 19:00. Analyzing the average arrival time, the car-based workers are found to arrive in workplaces earlier than the workers using mass transits. Furthermore, as shown in **Fig. 5** and **Table 2**, the similar results that the car-based



(a) travel time



(b) arrival time in workplace

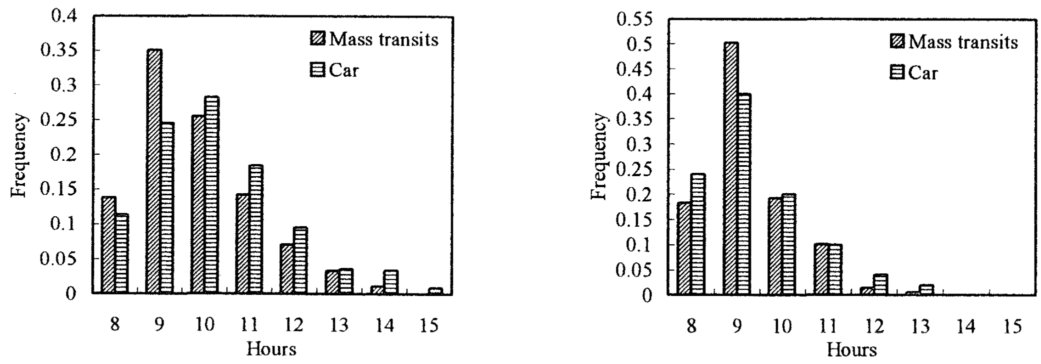


(c) leaving time from workplace

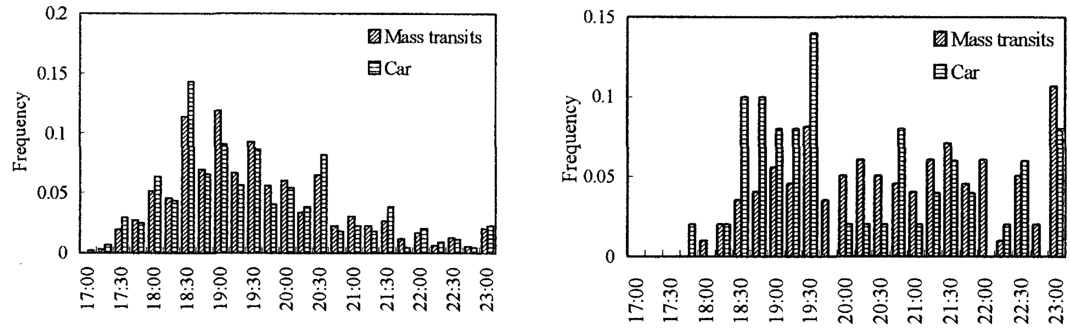
Fig. 5-1 Distributions of the indicators representing commutation activity
*Left side: For the workers with 2 trips
*Right side: For the workers with multi-trips

workers have earlier arrival time than the workers using mass transits are also found among the workers with either 2 trips or multi-trips. Arrival time in workplace is thus thought of another important influencing factor in commuting travel mode choice.

Although average leaving time of the car-based workers is shown to be later than that of the workers using mass transits in **Table 1**, as shown in **Table 2**, for not only the workers with 2 trips but also the workers with multi-trips, the significant differences of leaving time from workplace are not found between the car-based ones and the ones using mass transits.



(d) work hours



(e) home-returning time

Fig. 5-2 Distributions of the indicators representing commutation activity
*Left side: For the workers with 2 trips
*Right side: For the workers with multi-trips

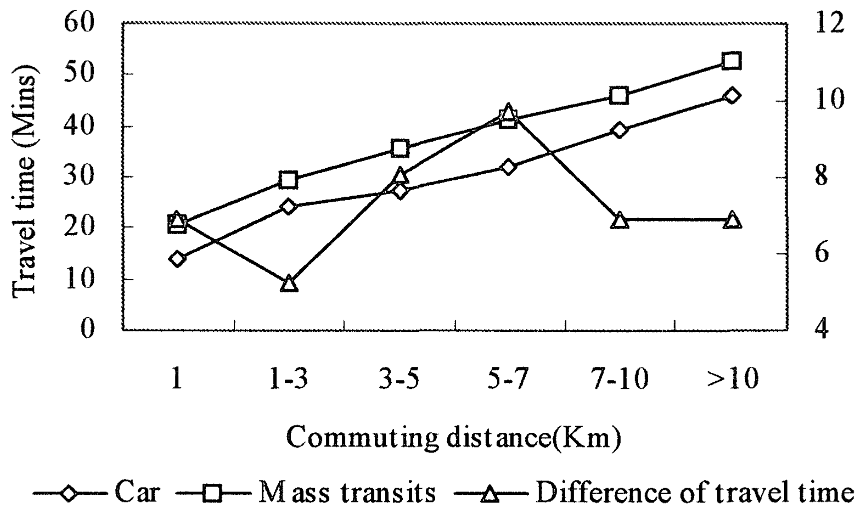


Fig. 6 Travel time by car mode or mass transits at different commuting distances

Considering the abovementioned fact that the workers with multi-trips trend to leave from workplaces earlier than the workers with 2 trips, leaving time from workplace would be a factor more related to trip numbers rather than travel modes.

(4) work hours and home-returning time

As shown in **Table 1**, the average work hours of the car-based workers are found to be longer than that of the workers using mass transits. Since there is no necessity to consider running schedule of mass transits, essential exchange and safety condition in routes of access

Table 2 Comparison of the indicators of the workers using different travel modes in two groups

(a) travel time

Types \ Modes	Car		Mass		Test result
	Mean	SD	Mean	SD	
2-trips	31.52	12.88	39.96	14.24	y
Multi-trips	27.70	8.90	38.02	13.39	y
Test result	y		n		

(b) arrival time in workplace

Types \ Modes	Car		Mass		Test result
	Mean	SD	Mean	SD	
2-trips	8.43	0.67	8.66	0.54	y
Multi-trips	8.40	0.65	8.68	0.45	y
Test result	n		n		

(c) work hours

Types \ Modes	Car		Mass		Test result
	Mean	SD	Mean	SD	
2-trips	10.62	1.57	10.26	1.32	y
Multi-trips	9.80	1.16	9.73	0.98	n
Test result	y		y		

(d) leaving time from workplace

Types \ Modes	Car		Mass		Test result
	Mean	SD	Mean	SD	
2-trips	19.06	1.40	18.92	1.29	n
Multi-trips	18.48	1.18	18.55	1.00	n
Test result	y		y		

(e) home-returning time

Types \ Modes	Car		Mass		Test result
	Mean	SD	Mean	SD	
2-trips	19.58	1.37	19.62	1.27	n
Multi-trips	20.31	1.60	20.85	1.51	y
Test result	y		y		

* y: difference at 5% level is significant.
n: difference at 5% level is not significant.

and egress, the car-based workers thus have high possibilities to work for a long time. Meanwhile, the average home-returning time of the car-based workers is earlier than that of the workers using mass transits. However, as indicated in **Fig. 5** and **Table 2**, for the workers with 2 trips, the average of work hours of the car-based workers is longer than that of the workers using mass transits, but a significant difference of average home-returning time is not found between the ones using different commuting travel modes. Contrarily, for the workers with multi-trips, a significant difference between the ones using different commuting travel modes is found in the average of home-returning time but is not found in the average of work hours. That is to say, work hours specifically influence commuting travel mode choice of the workers with 2 trips, and home-returning time has important influence on commuting travel mode choice of the workers with multi-trips.

Based on above analysis, we can summarize the principal points as follows: 1) Besides travel time and arrival time in workplace, some other factors related to midday activities and home-returning activity, such as: trip numbers in a day, work hours and home-returning time, also play important roles in commuting travel mode choice. When modeling commuting travel mode choice behavior, all abovementioned indicators should be taken into account. 2) The commutation activity of the workers with multi-trips obviously differs from that of the workers with 2 trips, so their influences on commuting travel mode choice should be analyzed and modeled separately. As indicated, work hours and home-returning time are specific factors respectively influencing commuting travel mode choice of the workers with 2 trips and the workers with multi-trips.

3. Mode choice model for commuting travel

Since 1970s, disaggregate model that can be developed based on disaggregated data, has been widely applied in transport planning field thanks to its advantage of applying random utility theory to represent individual behavior, and its capability of including some exogenous variables relevant to various policies. This paper applied disaggregate logit model to quantify the contributions of the previously presented indicators of commutation activity to commuting travel mode choice.

3.1 Disaggregate logit model

Disaggregate logit model is based on an assumption that an individual will choose the one with maximum utility among all available alternatives. The attributes of all alternatives as well as social and economic attributes of a choice-maker can be represented by utility function. Supposing there are n kinds of travel modes, utility derived from each mode is denoted as U_1, U_2 and U_n respectively and is described as follows:

$$U_j = V_j + \varepsilon_j \tag{1}$$

Where V_j is the deterministic portion and ε_j is the stochastic portion of the utility. Assume the stochastic portion is independent and identically distributed across alternatives with the Gumbel distribution, the probability of choosing travel mode j is obtained as follows:

$$P_j = \frac{\exp(V_j)}{\exp(V_1) + \exp(V_2) + \cdots + \exp(V_n)} \tag{2}$$

V_j is generally assumed as a linear function of all variables representing the attributes of the jth travel mode and the social and economic attributes of the choice-maker.

$$V_j = a_0 + \sum_i a_i X_{ij} \tag{3}$$

Where: X_{ij} is a variable representing the attribute relevant to the jth travel mode or the social and economic attributes of the choice-maker. a_i is a parameter of X_{ij} that should be estimated, a_0 is an alternative specific constant for mode j.

Since both travel modes of car and mass transits are taken into account in this paper, binomial logit model (BNL) was applied. According to formula (2), the probability that a worker chooses car mode for commuting can be determined as follows:

$$P_{car}=\frac{\exp(V_{car})}{\exp(V_{car})+\exp(V_{mass})} \tag{4}$$

3.2 Variables specification

The indicators presented in above section, trip numbers in a day, travel time, arrival time in workplace, work hours, leaving time from workplace and home-returning time, were introduced in the model. As mentioned above, fare cost, as well as travel time, is generally thought to be a fundamental determinant in travel mode choice. However, considering most enterprises usually pay travel fees to their employers, fare cost was not included in the model. Besides that, gender, age and occupation status that represent the individual attributes of a worker were also selected as independent variables in the model. The categories of the individual variables and the ratios of the car-based workers in every category were shown in **Table 3** and **Table 4** respectively.

Constrained by insufficient parking space, some enterprises located in CBD prohibit car-based commutation. Under the circumstance, the car-based workers have to pay extra costs for parking in CBD except those who can use workplace's park freely. Considering parking cost is also an important factor in determining whether or not use car mode for work, parking status was selected as a dummy variable of the car-based workers. The parking status of the car-based workers recorded in PT survey data was mainly categorized into 3 types as: no parking, freely parking in workplace, parking with payment. The percentages of different parking types were also shown in **Table 4**. Combining no parking type with type of freely park in workplace, parking status was defined as a binary variable with pay (0) and no pay (1).

3.3 Results analysis

Assuming choice result of the car-based workers as 1, and that of the workers using mass transits as 0 respectively, travel mode choice model of all workers were firstly calibrated based on formula (4). The estimated parameters of the variables were shown in **Table 5**. It is found that the variables such as: trip numbers in a day, age of a worker and parking status have positive relationships with car choice. That is to say, the workers with multi-trips and the workers aged more than 40 years old have high possibility to choose cars as their commuting travel modes. On the other hand, the variables of travel time, arrival time in

Table 3 Categories of individual attributes and parking conditions

Explanatory variables	Description
Age	0: <40, 1: ≥40
Gender	0: man, 1: woman
Occupation	0: sale, service
	1: business, management
	2: transport, production
Parking condition	0: pay, 1: no pay

Table 4 Percentages of the car-based workers in every category

Activity pattern	Gender		Age		Occupation			Parking		
	Male	Female	<40	>=40	0	1	2	0	1	2
2 trips	0.35	0.12	0.25	0.29	0.52	0.27	0.24	0.12	0.64	0.24
multi-trips	0.37	0.17	0.27	0.42	0.52	0.35	0.26	0.11	0.67	0.22

Table 5 Estimated parameters in the model of all workers

Variables	Parameters	*t*-stat.
Constant		
Car	8.433	6.042
Commute-related characteristics		
Trip numbers	0.037	0.364
Workplace-arrival time	-0.711	-5.358
Home-returning time	-0.084	-1.127
Leaving time from workplace	-0.184	-1.098
Travel time	-0.057	-10.165
Individual attributes		
Age	0.162	0.990
Gender	-1.211	-8.176
Occupation	-0.368	-3.392
Dummy variable		
Parking condition	18.102	0.105
Samples	1962	
ρ^2	0.297	
Hit ratio(%)	0.748	

Table 6 Estimated parameters in the model of the workers with 2 trips

Variables	Parameters	*t*-stat.
Constant		
Car	32.291	7.209
Commute-related characteristics		
Trip numbers	---	---
Workplace-arrival time	-2.290	-4.603
Home-returning time	-3.072	-6.129
Leaving time from workplace	2.941	5.951
Travel time	-0.014	-1.629
Individual attributes		
Age	0.151	1.474
Gender	-1.138	-6.756
Occupation	-0.368	-3.169
Dummy variable		
Parking condition	17.918	0.098
Samples	1715	
ρ^2	0.315	
Hit ratio(%)	0.751	

workplace, home-returning time and individual attributes of gender and occupation are negatively correlated with car choice. The results are almost identical with the analysis in section 2. The hit ratio and ρ^2 also suggest that the model in overall represents commuting travel mode choice well. However, from t-statistic test of every variable, it is known that some factors such as: trip numbers in a day, leaving time from workplace and home-returning time do not display significant contributions to the model, although the variables of travel time, arrival time in workplace, worker's gender and occupation show significant contributions. Meanwhile, leaving time from workplace shows a negative rather than an expected

Table 7 Estimated parameters in the model of the workers with multi-trips

Variables	Parameters	*t*-stat.
Constant		
Car	16.345	2.892
Commute-related characteristics		
Trip numbers	-0.016	-0.082
Workplace-arrival time	-1.375	-2.722
Home-returning time	-0.205	-1.187
Leaving time from workplace	-0.233	-0.853
Travel time	-0.097	-4.290
Individual attributes		
Age	0.897	2.903
Gender	-0.860	-1.826
Occupation	-0.486	-1.199
Dummy variable		
Parking condition	17.252	0.027
Samples	247	
ρ^2	0.376	
Hit ratio(%)	0.804	

positive relationship with car choice. From these results, it can be thought that the model of all workers should be modified.

Considering the differences of commutation activities between the workers with 2 trips and the workers with multi-trips, disaggregate logit model was further applied to the workers with different trips respectively, and the estimated results were shown in **Table 6** and **Table 7**. Comparing hit ratio and ρ^2 with that of the model of all workers, the model of the workers with 2 trips appears a better precision. Moreover, it should be addressed particularly that the contributions of leaving time form workplace and home-returning time are well reflected in this model because the variables have larger *t*-statistic values than before. The result indicates that the factors related to home-returning process actually influence the commuting travel mode choice of the workers with 2 trips. Similarly, the model of the workers with multi-trips also has better hit ratio and ρ^2 than the model of all workers. However, differing from the model of the workers with 2 trips, the effects of trip numbers in a day, leaving time from workplace and home-returning time are not well reflected in the model, and the significances of individual attributes also decreased. As the same as what are indicated in the model of all workers, leaving time from workplace appears a negative correlation with car choice. It can be explained that the workers who leave workplace earlier are possible to choose cars as their commuting travel mode for the purpose of other activities. In term that the model cannot reflect the influences of commutation activity on commuting travel mode choice, we think that our modeling method possibly are not suitable for grasping the complexity and diversity of commutation activity of the workers with multi-trips. So, it should be considered to incorporate other methods such as: trip-chain analysis and activity-based analysis, to develop a better commuting travel mode choice model for the workers with multi-trips.

Actually, as shown in **Table 4**, about 2/3 of the car-based workers can freely use parks of their workplaces. The influence of parking status was not reflected in all above models, although we thought it as one of the determinants of commuting travel mode choice. However, from its positive relationship with car choice that means a worker will not use car mode if he must pay for parking, we can believe that reducing car-based commutation toward CBD is possible to achieve if effective parking measures were adopted.

4. Conclusions and discussions

In order to make good effects of TDM policies, it is necessary to grasp the determinants related to commuting travel mode choice. Based on a review of the existing studies on commuting travel, this paper emphasized the influences of commutation activity on commuting travel mode choice, especially some factors involved in midday and home-returning processes. The main contents of this paper can be summarized as follows:

(1) Commutation activity was specifically expressed to comprise a series of activities undertaken in the period that starts on departure time from home in the morning and ends at home-returning time in the evening. From this viewpoint, several indicators, included in processes of morning commuting, midday and evening home-returning, were selected to represent commutation activity, such as: trip numbers in a day, travel time, arrival time in workplace, work hours, leaving time from workplace and home-returning time.

(2) Based on PT survey data in Fukuoka City, commutation activity of the workers who use different travel modes toward CBD were analyzed. It was indicated that the workers using different travel modes actually have different characteristics in commutation activity. Since the commutation activity of the workers with multi-trips obviously differs from that of the workers with 2 trips, the indicators representing commutation activity of the workers using different travel modes were further compared in two groups respectively. As indicated, not only travel time and arrival time in workplace are determinants, but also some other factors related to midday activities and home-returning activity play important roles in commuting travel mode choice. Especially, work hours and home-returning time were presented to be the specific factors respectively influencing commuting travel mode choice of the workers with 2 trips and the workers with multi-trips.

(3) Disaggregate logit model was adopted to quantify the contributions of the presented indicators to commuting travel mode choice. Although the model of all workers, no matter who have 2 trips or multi-trips, had good fitness, the indicators related to midday and home-returning processes were not represented as determinants in the model. Furthermore, commuting travel mode choice models of the workers with 2 trips and multi-trips were separately calibrated. Comparing with the model of all workers, the model of the workers with 2 trips appeared a better precision and it well reflected the contributions of the variables of leaving time form workplace and home-returning time. However, the model of the workers with multi-trips cannot reflect the influences of commutation activity on commuting travel mode choice, although the model also had better hit ratio and ρ^2 comparing with the model of all workers.

Through analyzing the commutation activity of the workers using different travel modes qualitatively and quantitatively, the influences on the commuting travel mode choice of the factors related to the processes of morning commuting, midday and home-returning in the evening were indicated. Although disaggregate logit model was applied to represent the commuting travel mode choice in this paper, there are a few problems in proposed models that should be dealt with in further study. For one case, to grasp the determinants in travel mode choice of the workers with multi-trips, other analyzing methods, such as: trip-chain analysis and activity-based analysis, should be incorporated to reveal the complexity and diversity of commutation activity. Moreover, since the start time and end time of work are appointed and a penalty accompanies with late arrival or earlier leave, the workers would determine their behaviors according to the time constraints, individual daily schedule and the operating status of transit systems. Strictly speaking, the staying time in workplace before or after work should be taken into account in the models because it brings about actual disutility to workers. However, the work start and end time are not recorded in PT survey data so that arrival time in workplace and leaving time from workplace were adopted in our models. To well represent commuting travel mode choice by incorporating individual difference that results in dispersion in commutation activity, a disutility model in time domain would be considered to develop in further study.

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