ANALYSIS OF DEPARTURE TIME CHOICE OF MORNING COMMUTERS ON MEX UTILIZING ETC DATA*

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1. Background and Objective

Commuters are frequent road users and usually travel within peak time periods of the day. Thus, understanding the variation of commuters' departure time can offer good insights into the nature of traffic peak congestion, and into the effectiveness of various measures aiming at peak-spreading (Kitamura et al, 2005), such as road pricing and flexible working time. The knowledge on such variation is also of great importance for the discrete or stochastic modeling of departure time choice behavior (Kuwahara, 1998).

On the other hand, approximately 75% of the Tokyo Metropolitan Expressway (MEX) users have installed Electronic Toll Collection (ETC) system in their vehicles, and thus ETC-OD data can be considered to represent all the MEX users (Pelata et al, 2008). ETC system enables to identify commuters by continuously reading vehicle identification number (ID) and collect the information on their daily trips, e.g., origin and destination, departure time (i.e. on-rump time) and arrival time (i.e. off-rump time), and travel time.

Nevertheless, this study is intended to explore the variation properties of departure time of morning commuters on MEX utilizing ETC-OD data.

2. Literature Review and Organization of the Paper

A great deal of efforts has been put upon the research of departure time choice since decades ago. The theoretical basis of departure time choice modeling had been well built (Vickrey, 1969; Small 1982; Arnott et al, 1990). Some extensions from the deterministic approach to the stochastic approach as well as from the aggregate modeling to the discrete modeling have been done by Newell (1985) and Ben akiva et al (1984). Two comprehensive literature reviews of the previous works can be found in Kuwahara (1998) and Bates et al (2001). Meanwhile, empirical studies based on stated-preference (SP) survey data such as Ozbay and Yanmaz-Tuzel (2008) have showed that travel time, travel costs, marital status and family obligations, income, occupation and the flexibility of work schedules affect the choice of departure time.

However, the analysis of intrapersonal (i.e., different behavior of one person from day to day) and interpersonal (i.e., differences in the behavior of different persons) variability of departure time remains fairly insufficient, due to the difficulty of obtaining data about travel behavior from respondents over a long period. Such analysis is very essential because it can not only help to determine the subjects of different traffic demand management (TDM) policies seeking to alleviate traffic congestion during peak, but also provide clues to the stochastic and discrete modeling of departure time choice behavior as stated earlier.

Based on a six-week travel diary of the research project Mobi*drive* implemented in Germany in 1999, a few studies have contributed to that. For instance, Kitamura et al (2005) found that the vertices vary more symmetrically than do the departure times of the first trips in the prisms, supposed to be commute trips, and the departure time varies from worker to worker according to unobserved heterogeneity much more than does the prism vertex. Chikaraishi et al (2009) confirmed that different activities show quite different variations in departure time, and the intrapersonal variation accounts for the largest percentage of the total variation. Although, the analysis dependent upon the data set in Japan and looking into the variation of departure time of commuters in Japan still needs to be performed, which is the motivation of this study.

The remaining of the paper is organized as follows. Study route and period are introduced in Section 3, followed by the method of identifying morning commuters. Then, Section 5 presents the analysis results of the variation of departure time of morning commuters. Finally, this paper is closed with conclusions and implications in Section 6.

3. Study Route and Period

The selected study route connects Sangenjaya (on-rump) of Shibuya Route and Kasumigaseki (off-rump) of Central Circular Shinjuku Route, as shown in Figure 1. The total length of the route is 7.18 km.

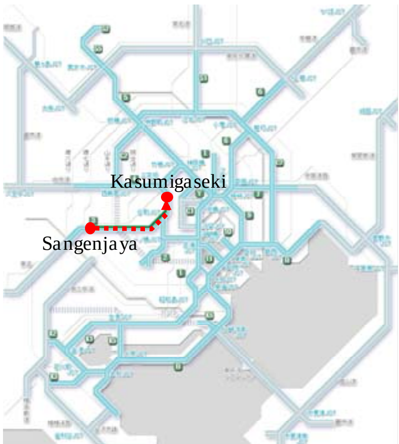

Figure 1 The location of study route

The study period is from July to September in 2006, a three-month data set. Historical data within the analysis

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period showed that travel times on the subject route during 06:00~10:00 am fluctuated drastically and largely fall between 8 and 16 minutes.

There are two reasons for choosing this route as the analysis subject. First, this route has large traffic volume during morning peak, which includes significant amount of commute traffic and can thus provide sufficient samples for the analysis. Second, this route has one recurrent bottleneck occurring during morning peak every weekday, which is located at the Shinjuku entrance to Central Circular Route. To avoid congestion at the bottleneck, commuters are supposed to alter their departure times more sensitively than other cases.

4. Identification of Morning Commuters

Based on the ETC-OD data of the aforementioned route and analysis period, two conditions were set to identify morning commuters: (1) enter the on-rump Sangenjaya between 06:00 and 10:00 am and arrive at the off-rump Kasumigaseki between 06:00 and 10:30 am on the same day; (2) travel frequency is greater than two days per week, excluding holidays and weekends.

Totally, 86 morning commuters were identified and are presented by travel frequency in **Figure 2**. Where, 25-30 days per three months represents the commuters who travel twice per week, and 45-50 days per three months is correspondent with those traveling not less than four weekdays every week.

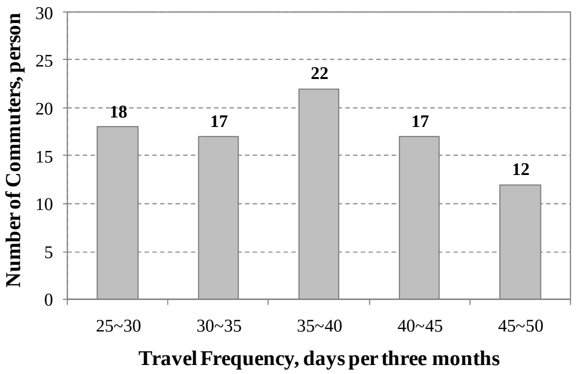

Figure 2 The identified number of morning commuters by travel frequency

5. Analysis of Departure Time Choice

This section presents the analysis results on intrapersonal and interpersonal variability of departure time of morning commuters. Note that the analysis of interpersonal variability was based on the aggregate data by person, while the analysis of intrapersonal variability was based on the disaggregate data by day. The analysis includes the variations of departure time by travel frequency, day of the week, and day and time of the day.

(1) Variation by Travel Frequency

It can be a consensus that the more frequently commuters travel, the more accurately they can predict travel times and more appropriately choose their departure times. The fact may lead to a variation of departure time of commuters by travel frequency.

Figure 3 shows the average departure times of morning commuters by travel frequency, i.e., interpersonal variation. A general trend can be found that departure time drops as travel frequency arises, i.e., the more frequently commuters travel, the earlier they intend to departure. The morning commuters traveling not less than four times per week departure almost 40 mins earlier than those traveling twice per week.

This result could be explained by two possible reasons. One is that the frequent commuters may have earlier time constraints, e.g., earlier working start time and higher late arrival cost. The other is that commuters perceive traffic congestion more sensitively or value travel time more highly as travel frequency increases, because the caused schedule disutility goes up with the increase of travel frequency. Therefore, they tend to budget much more time for the reliability of their trips.

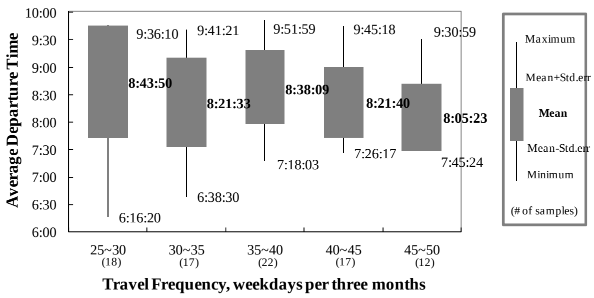

Figure 3 Average departure times by travel frequency

(2) Variation by Day of the Week

Commuters may have various activities and working schedules within a week, which might cause a variation of their departure times by day of the week.

Figure 4 presents the average departure times of morning commuters by day of the week, i.e., interpersonal variation. It was found that the average departure times range between 08:23 and 08:28 and are extremely close to each other.

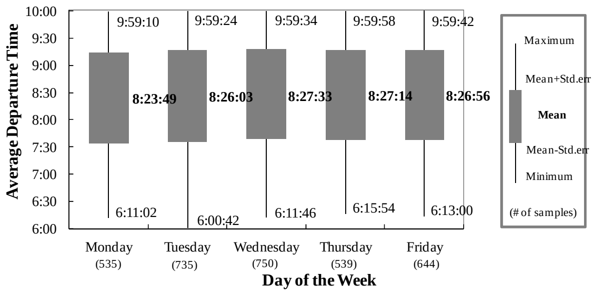

Figure 4 Average departure times by day of the week

It indicates that morning commuters on the subject route probably have almost identical activities and/or working schedules on different days of the week, and commute demand on the subject route holds a very small temporal fluctuation in terms of day the week.

Figure 5 further gives the observation frequencies and cumulative probabilities of departure time of

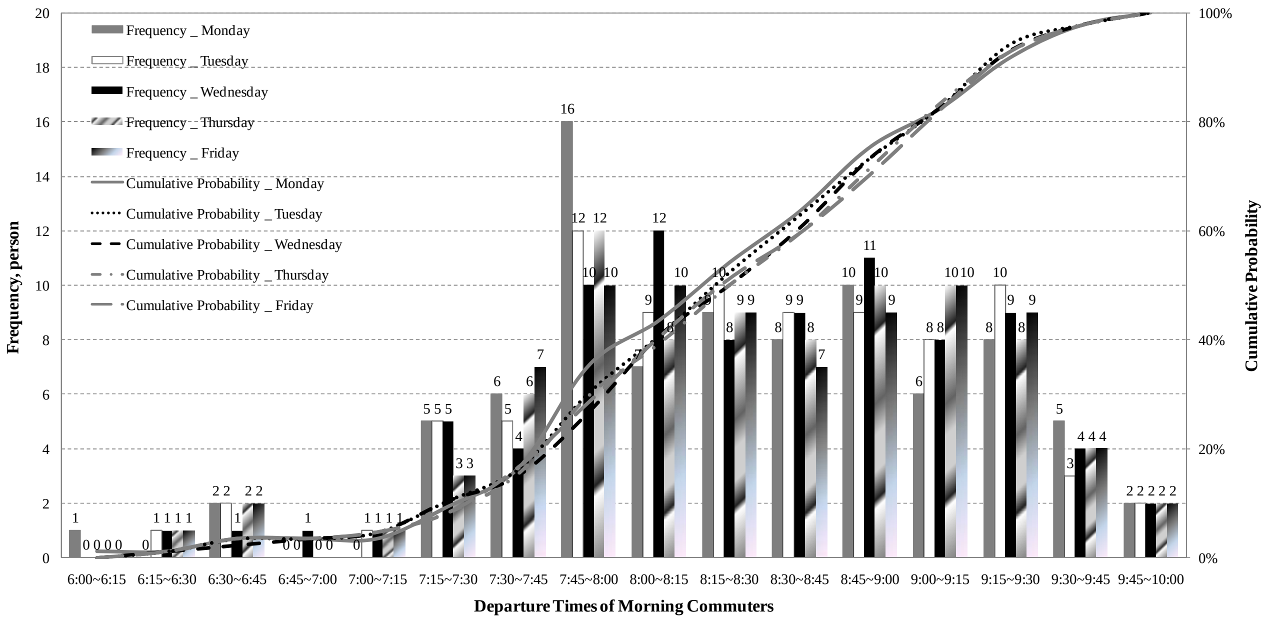

Figure 5 Distribution of departure time by Day of the Week

morning commuters by day of the week. It can be seen from the cumulative curves that departure times on different weekdays generally follow similar type of distribution, nearly Normal distribution. It supports the previous result presented in **Figure 4**.

Figure 6 exhibits the intrapersonal variation of departure time of morning commuters by day of the week, through showing the standard deviations of the average departure times. The standard deviation is used to measure how the average departure times on different days of the week vary from one another, which is computed by Equation (1).

$$\sigma_{DOW} = \sqrt{\frac{1}{5}\sum_{i=1}^{5}(\mathrm{DT_{Wi}} - \overline{\mathrm{DT_W}})^2} \qquad (1)$$

Where,

σ_{DOW}= standard deviation of the averaged departure times by day of the week, min;

DT_{Wi} = average departure time on weekday i, i=1(Monday), 2(Tuesday), 3(Wednesday), 4(Thursday), and 5 (Friday);

$\overline{\mathrm{DT_W}}$= total average departure time by weekday, $\overline{\mathrm{DT_W}} = \frac{1}{5}\sum_{i=1}^{5}\mathrm{DT_{Wi}}$;

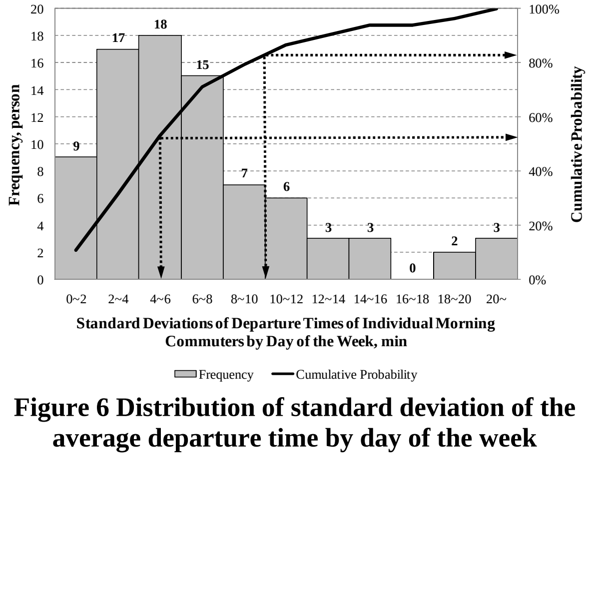

Figure 6 Distribution of standard deviation of the average departure time by day of the week

It was found that more than 80% of morning commuters have a standard deviation less than 10 minutes and over 50% of them less than 5 minutes, based on the averaged departure times for each day of the week. Researchers have postulated a "band of indifference" around the preferred arrival time, i.e., no schedule disutility is incurred provided the arrival is within certain duration of the preferred arrival time, e.g., 5 minutes (Mahmassani and Chang, 1986). If the same concept of "band of indifference" is applied to departure time, 80% of morning commuters can be considered to have the same departure time for a whole week in the case that 10 minutes is determined as the "band of indifference", and 50% of them in the case of 5 mins accordingly. It is also consistent with the earlier result that there is no significant difference in departure time of morning commuters in terms of day of the week.

(3) Variation by Day and Time of the Day

Differences in habitual travel behavior, official working start time, and the flexibility of working schedule among commuters are possible to result in a variation of departure time by day and time of the day.

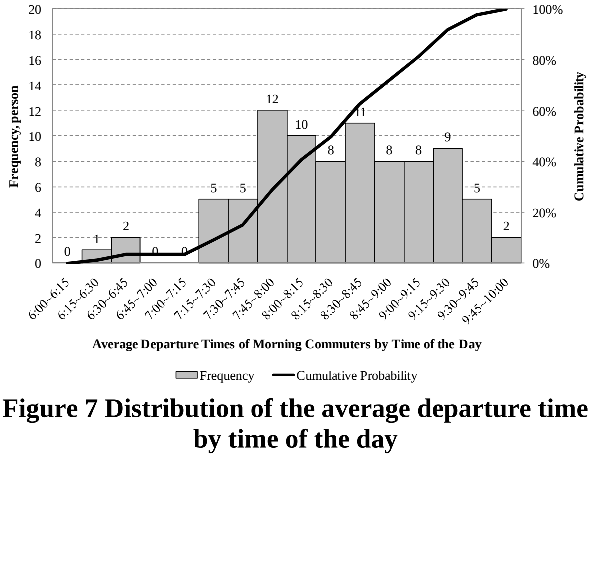

Figure 7 Distribution of the average departure time by time of the day

Figure 7 shows the observation frequencies and cumulative probability of the average departure times of morning commuters by time of the day, with a 15-min interval, i.e., interpersonal variation. It was found that departure times are fairly scattered, and almost 77% of them rang between 7:45 and 9:30 and distribute quite uniformly over the above time period.

It translates that morning commuters on the subject route likely have distinct travel habits and official working start times. Moreover, it seems that most of the commuters have adjusted departure times not to intensively concentrate on a single time period but uniformly scatter along the peak time period, i.e., commute demand distributes uniformly over the period.

To investigate the intrapersonal variation of departure time by time of the day, the standard deviation of day-to-day departure time of each morning commuter was calculated by Equation (2).

$$\sigma_{DTD} = \sqrt{\frac{1}{\mathrm{n}} \sum_{i=1}^{n} (\mathrm{DT_i} - \overline{\mathrm{DT}})^2} \qquad (2)$$

Where,

σ_{DTD} =standard deviation of day-to-day departure times, min;

$\mathrm{DT_i}$=departure time on day i;

$\overline{\mathrm{DT}}$=total average departure time, $\overline{\mathrm{DT}} = \frac{1}{n} \sum_{i=1}^{n} \mathrm{DT_i}$;

n=total number of travel days.

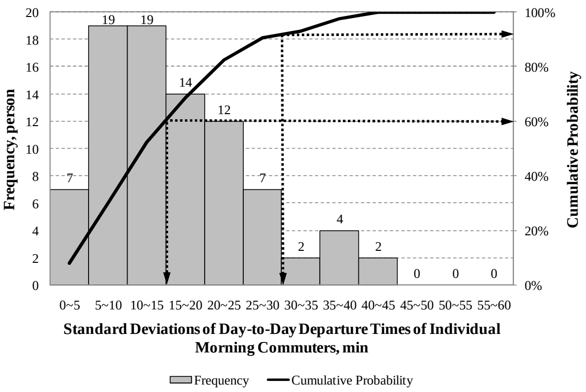

Figure 8 Distribution of standard deviation of day-to-day departure time

The results are presented in **Figure 8**. Standard deviations of greater than 90% of morning commuters were found to be less than 30 minutes, and almost 60% of them less than 15 minutes. The day-to-day variation is remarkable comparing with the variance based on the averaged values by day of the week, which is statistically natural. Furthermore, it also somehow supports the result found by Chikaraishi et al (2009).

The result reveals that most of the morning commuters on the subject route have quite flexible working schedule. It could be explained by that the commuters identified in this study are supposed to commute by car and have relatively high flexibility of work schedule, unlike the ordinary salary people who are comparably inflexible and thus often choose more reliable traffic mode for commute trips such as train.

6. Conclusions and Implications

Based on ETC-OD data, this study analyzed the interpersonal and intrapersonal variations of departure time of morning commuters on MEX by travel frequency, day of the week, day, and time of the day. The following conclusions are supported by the analysis.

- The more frequently morning commuters travel, the earlier they intend to departure.
- Based on the average values, no significant difference in departure time of morning commuters was found due to day of the week. Both its means and distributions for different days of the week are rather close.
- Departure time of morning commuters distributes pretty uniformly in terms of time of the day. In addition, its day-to-day variation was found to be remarkable.

The above conclusions suggest that TDM measures would be more effective for high travel frequency commuters as they may perceive congestion more sensitively. Commute demand on the subject route holds a very small temporal fluctuation in terms of day of the week based on the average values. However, it has an apparent fluctuation by day and time of the day as a result of various official working start time and high flexibility of work schedules, and is very likely uniformly distributed over the morning peak period.

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