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PERCEPTION OF THE TRAVEL TIME RELIABILITY OF THE URBAN RAILWAY SERVICE IN TOKYO

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Abstract

This paper analyzed departure time decision considering the travel time reliability of railway users in Tokyo Metropolitan Area. A questionnaire survey was conducted to obtain the data for the analysis. Hierarchical Bayesian method is applied to estimate the parameters by Markov Chain Monte Carlo (MCMC) simulation. From the results of the estimation, it became clear that some factors such as traveling distance and number of transits influences the departure time decision for the railway users in the Tokyo Metropolitan Area.

Keywords: travel time reliability, departure time decision model, MCMC

1 Introduction

There are many causes to delay the railway service schedule. To investigate the current condition of the delay in Tokyo Metropolitan Area (TMA), statistics by Ministry of Land, Infrastructure, Transport and Tourism (MLIT) can be utilized. This statistics compiles the notifications of every railway accidents, and troubles with more than 30 minutes delay. According to this statistics, we can know when the accident happened, what the cause was, how large the influence was, and etc...
Figure 1 shows the transition of the number of railway accidents. It had been decreasing until 2003. The reason is that MLIT devised measures to reduce the number of railway accidents. For example, MLIT indicated railway companies to install emergency stop buttons in platforms, fall detection mats into railroads, and evacuation spaces under platforms.
As shown above, many railway accidents occur in TMA, and chronically delayed by several accidents every day. Railway users receive disadvantages from them and this causes not only the actual time loss but also the loss of the opportunity cost. As a result, this influences the railway passengers' behavior.
However, there is little information on departure time decision considering travel time reliability of railway users. Therefore, this study aims to construct departure time decide model considering distribution of delay probability. And we will clarify the covariates that affect the departure time choice.

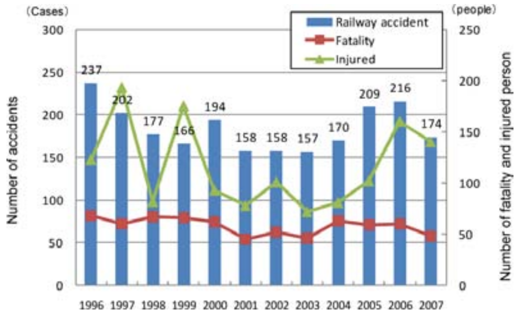


Figure 1 Transition of the number of railway accidents

2 Review of previous study

Over the past few decades, a considerable number of studies have been conducted concerning the departure time choice model which focused on road traffic. These researches are antecedents of travel time reliability.

Most popular researches for the departure time choice model are as follows. Small (1982) focused on the disutility of delay arrival. On the other hand, Gaver(1968) and Vickrey(1969) focused on the disutility of early arrival. Recently, topic of travel time reliability is actively researched.

Most popular researches for the travel time reliability concerning the road traffic are as follows. Eliasson(2004), Karlstrom(2009) and Fosgerau(2010) focused on the travel time of single link of road traffic. Fosgerau (2009), Fosgerau(2010) shows that travel time reliability has two approaches. First approach is mean-variance approach, the second approach is scheduling approach. In this research, the approach of the latter is adopted. Moreover, Bates (2001) arranged concept of travel time reliability.

However, there are few researches which examined the estimation of departure time choice model considering the travel time reliability. For example, Reitveld et al. (2001) defined that uncertainty of arrival time as the reliability. The probability distribution of arrival time and departure time were specified for each transport mode and also the policy option for the improvement of reliability was evaluated through the simulations. Takada et al. (2004) analyzed the railway accident using railway accident statistics issued by MLIT. The probability distribution of railway accident was specified. Moreover they built a simulation system, and estimated lost time caused by railway accidents. Moreover, Takada et al (2010) analyzed the willingness to pay (WTP) for reducing the lost time of railway users in Tokyo Metropolitan Area. Contingent valuation method (CVM) was applied to inquire their WTP in the survey. A statistical method for survival data analysis was applied to estimate the WTP function. As the results of the estimation, some significant factors which influence on the WTP were detected. Meanwhile, the expectation of the WTP was calculated using the estimated function.

The research of departure time choice and travel time reliability has been reviewed. However, there are no researches which examined the estimation of departure time choice model considering travel time reliability of each railway users under multiple OD link. Furthermore, factor of departure time choice considered travel time reliability is not still detected.

3 Data

In this study, a questionnaire survey was executed to collect the data of railway passengers' consciousness for improving the railway service. The survey was conducted in July11-12, 2009. The questionnaire survey was web based survey. We obtained a total of 1030 samples (515 samples a day). The valid response data used for the analysis were 863 samples.

Answerer attributes of this Web survey is as following 1 to 3. 1. Jobholder over 15-year-old (including part-time jobs). 2. Person who live in around Tokyo metropolitan area (Tokyo, Kanagawa, Chiba, and Saitama). 3. Person who uses train service daily.

Question contents of the questionnaire survey are as follows: personal attributes (sex age residential area, etc...), railway usage behaviors (times of use, perception travel time, delay times and lost times, etc...) and consumer satisfaction for railway service and WTP for reducing perception lost time.

In addition to the data collected from our survey, the travel time, number of transits and the distance of the OD pairs were collected from the timetable (published by JTB Co., Nov. 2009)

4 Analysis of Departure Time Decision

4.1 Methodology and Formulation

Before explaining the formulation proposed in this study, Fosgerau's approach which can integrate the mean-variance approach and the scheduling approach is described shortly. Fosgerau (2009) and Fosgerau (2010) assumed a cost function as written in equation (1).

$$U(D,T) = \alpha D + \omega T + \beta (T - D)^{+} \tag{1}$$

where $(T-D)^{+}$ is schedule delay late. The first term is the cost of starting early which is opportunity cost of interrupting a prior activity. The second term is the cost of travel time T. And, the third term is the cost of being late.

Meanwhile, travel time T is composed by two terms as seen in equation (2).

$$T = \mu + \sigma X, \quad X \sim \phi(0,1) \tag{2}$$

where μ is travel time under free flow condition, σ is a fluctuation of travel time, and X is a standardized random variable. He assumed that traveler chooses his/her departure time so as to minimize an expected cost under uncertainty of travel time. A formulation of this mathematical problem is formulated as written in equation (3).

$$E\big(U(D)\big) = \min\left[\alpha D + \omega\mu + \beta \int_{\frac{D-\mu}{\sigma}}^{\infty} (\mu - \sigma x - D)\phi(x)dx\right] \tag{3}$$

The solution of this problem is written in equation (4)

$$D^{*} = \mu + \sigma\phi^{-1}\left(1 - \frac{\alpha}{\beta}\right) \tag{4}$$

where $\frac{\alpha}{\beta}$ is defined optimal probability of being late by Bates(2001). By inserting the optimal head start D* into the cost function, optimal minimum expected cost is derived as seen in (5).

$$E\left(U(D^*)\right)=(\alpha+\omega)\mu+\beta\sigma\int_{1-\frac{\alpha}{\beta}}^{1}\Phi^{-1}(x)dx=(\alpha+\omega)\mu+\beta H\left(\frac{\alpha}{\beta},\Phi\right)\sigma \tag{5}$$

$(\alpha+\omega)$, the coefficient of μ, is the marginal cost of travel time, i.e. the value of time.
Meanwhile, $\beta H\left(\frac{\alpha}{\beta},\Phi\right)$, the coefficient of σ, is the marginal cost of fluctuation of travel time, i.e. the value of travel time reliability.

We applied the Fosgerau's approach to examine departure time decision of railway users who travel different Origin-Destination pairs.

Disutility is defined as following equation in this study.

In this study, travel time T is assumed to be composed by two terms as seen in equation (6).

$$T=\mu+T_s \tag{6}$$

First term, μ, is a minimum travel time based on timetable and second term, T_s, is spare time for not being late. The spare time is set by each traveler considering the occurrence probability of the delay of railway operation.

Meanwhile, T_s is a random variable whose probability density function is $f(T_s)$ and distribution function $F(T_s)$. In this study, the distribution of the spare time is assumed to be exponential distribution because it is reasonable that the distribution of delay is also exponential distribution.

Moreover, it is thought that each traveler has different distribution. Therefore, exponential distribution with covariates is applied and survival analysis is executed.

The proportional hazard function is applied to the function of the distribution. The hazard function $h(t|x_i)$ is written in the following equation (7).

$$h(t|x_i)=\lambda\exp\left(\sum_{i=1}^{n}\theta_i x_i\right) \tag{7}$$

where, x_i is covariates, θ_i is parameter, and λ is scale parameter.

Relationship between hazard function, $h(t|x_i)$, and survival function, S(t), is shown in equation (8).

$$S(t)=\exp\left(-\int_0^{T_s}h(u)du\right) \tag{8}$$

Hazard function is generally written in equation (9)

$$h(t|x_i)=\frac{f(t)}{S(t)} \tag{9}$$

Then, probability density function with covariates derived as written in (10).

$$f(T_s)=\lambda\exp\left(\sum_{i=1}^{n}\theta_i x_i\right)\cdot\exp\left\{(-\lambda T_s)\exp\left(\sum_{i=1}^{n}\theta_i x_i\right)\right\} \tag{10}$$

Thus, expected disutility, E[U(D)], is derived and the mathematical problem of minimizing the expected disutility is shown in the following equation (11).

$$E\left[U(D)\right]=\min\left[\alpha D+\omega\mu+\beta\int_{D-\mu}^{\infty}(\mu-T_s-D)f(T_s)dT_s\right] \tag{11}$$

Solution of this problem is the optimal departure time, D*, is derived as follows.

$$D^* = \mu + F^{-1}\left(1 - \frac{\alpha}{\beta}\right) \quad (12)$$

Then, equation (12) can be rewritten in equation (13).

$$D^* = \mu - \left(\frac{\ln\left(-\left(1 - \frac{\alpha}{\beta}\right) + 1 \right)}{\lambda \cdot \exp\left(\sum_{i=1}^{n} \theta_i x_i \right)} \right) \quad (13)$$

It is assumed that $\frac{\alpha}{\beta}$ is recognized optimum probability of being late.

4.2 Estimation

In this study, hierarchical Bayesian method is applied to estimate the parameters in equation (13) and the parameters were estimated by Markov Chain Monte Carlo simulation.

There are two parameters in the expression, $\frac{\alpha}{\beta}$, however these are unified to one parameter for the estimation.
Respondents' answer to the question about the expected travel time was considered as optimal departure time, D*.
The result of parameter estimation is shown in Table 1.

What the parameter, $\frac{\alpha}{\beta}$, is 0.045 indicates that the occurrence probability of operation

delay expected by travelers is 4.5 percent.
The plus sign of the parameter indicates that the spare time increases in accordance with the increase of the value of the concerned variable and the minus sign vice versa. For example, when traveling distance become longer, the spare time becomes long. Sign's condition of all variables is reasonable.
The scale parameter of the exponential distribution, λ, was estimated by each traveller to consider the heterogeneity of the characteristics of travellers and their trips. Figure 2 shows frequency distribution of λ and it also shows that the λ is widely distributed. This indicates the appropriateness of considering the heterogeneity.

Table 1 Estimation result

		parameter	t-statistics	Prior distribution
$\frac{\alpha}{\beta}$	Optimum probability of being late	0.045	2.618	Uniform
θ_1	Logarithm of traveling distance (km)	-0.120	-3.300	Normal
θ_2	Number of transits (times/trip)	-0.217	-6.061	Normal
θ_3	Freq. of taking on trains (times/week)	-0.019	-1.170	Normal

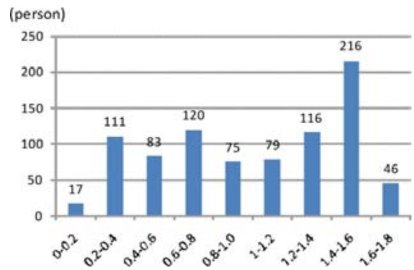
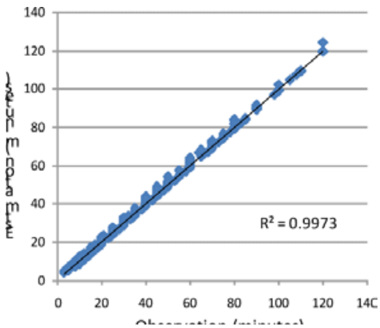


Figure 2 Frequency Distribution of λ



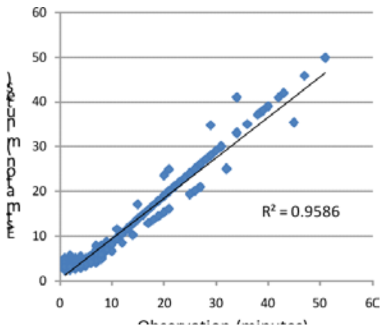


Figure 3 Reproducibility of departure time

Figure 4 Reproducibility of spare time

Finally, reproducibility of the estimated function is verified in terms of departure time and spare time. Figure 3 and 4 are results of verification respectively. The coefficient R^2 is more than 0.95 in both cases so that it can be concluded that explanatory power of the function is high.

5 Conclusion

In this study, a questionnaire survey was conducted to collect the person trip data of railway users. Then, departure time decision model was estimated considering the distribution of the spare time.
From the results of the estimation, it became clear that some factors such as traveling distance and number of transits influence the departure time decision.
Therefore, this study proposed estimation method of travel time reliability which can consider multiple OD link.
However, the value of reliability is not estimated directly in this study.

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