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3rd International Conference on Road and Rail Infrastructure
28–30 April 2014, Split, Croatia

Road and Rail Infrastructure III

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TESTING A MIXTURE MODEL FOR THE DISTRIBUTION OF ARRIVAL TIME OF URBAN RAILWAY TRAVELLERS

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Abstract

Recently the evaluation of the travel time reliability has become great concern in transportation planning and many studies have investigated the travel time reliability. However most of them have focused on the reliability regarding road transports. Then the reliability of rail transport is focused on in this study. Authors have already investigated the departure time decision of railway users in Tokyo Metropolitan area (TMA) and developed a model describing a spare time for not being late behind the desired arrival time by considering the heterogeneity of the distribution of the late arrival. In order to estimate the coefficients of the model, we set a strong condition that the railway users in TMA recognized that the delay of arrival time obeyed exponential distribution. However the difference between the desired arrival time and the actual arrival time does not always obey exponential distribution. Then, we started the research to ease this strong condition by adopting the mixture distribution model. There are few studies investigating departure time decision dealing the mixture model. An internet survey was conducted to collect the data for the study. The question items are name of origin and destination stations, travel path, departure time, desired arrival time, required travel time, distribution of arrival time and socio-economic attributes.

Keywords: urban railway, reliability of travel time, mixture distribution model

1 Introduction

Reliability of travel time is one of the important factors affecting mode choice and route choice behaviour. Recently, many studies have investigated variability of travel time and engaged in developing methodology to evaluate economic value of the travel time reliability. Most of them have focused on the reliability of road traffic. Meanwhile, research on the travel time reliability of railroad and air transport which operates based on the planned timetable has not sufficiently advanced so far.

We have investigated the travel time reliability of the railroad from the point of departure time decision of railroad users [1-4]. As the results of our previous studies, it becomes clear that railroad user prepares buffer time to deal with the delay of railroad. Furthermore, it indicates that the buffer time is influenced by several factors such as travel distance, usages frequency of railroad, and number of times of transfer.

In order to analyze the departure time choice behavior, we set a strong condition that the railway users recognized that the delay of arrival time obeyed exponential distribution. However the difference between the desired arrival time and the actual arrival time does not always obey exponential distribution. Then, we got to work on research to ease this strong condition by adopting the mixture distribution model. There are few studies investigating departure time decision dealing the mixture model. The contents of this paper is as follows. In chapter 2, the data used for the analysis is descrived. In the chapter 3, the charactoristics of the difference between the desired and realized arrival times is examined. In chapter 4, Gaussian Mixture Model (GMM) is applied to estimate the probability density function of the difference between the desired and realized arrival times. In chapter 6, the results of this paper is summarized.

2 DATA

A web survey utilizing the internet was conducted in this study. The respondents were monitors of the Macromill, INC. summary of the survey was shown in table 1.

Table 1 Summary of web survey.

Conditions of the respondents	Resident area: Tokyo, Kanagawa, Saitama, and Chiba prefectures Age: over 15 years old Occupation: Yes Other condition: person who uses railway more than 5 days in a week
Date	2012.March,26-28
Number of respondents	1700
Valid respondents	1418

2.1 Measurement of accuracy of arrival time

Table 2 shows the question about desired arrival time and Table 3 shows the question about the arrival situation. Data of the frequency of difference from the desired arrival time was produced by these questions. Data format is shown as table 4.

Table 2 Inquiries about desired arrival time

Question 1.	What time is the most desired arrival time at the station of the destination?

Table 3 Inquiries about the arrival situation

Question 2-1.	How many times do you arrive at the station within two minutes difference from the desired arrival time?
	Answer: ( ) time(s) out of ten times
Question 2-2.	How many times do you arrive at the station more than 2 minutes before the desired arrival time?
	Answer: ( ) time(s) out of ten times
Question 2-3.	How many times do you arrive at the station more than 2 minutes after the desired arrival time?
	Answer: ( ) time(s) out of ten times
Question 3-1.	Your answer of the Question 2-2 is ( ) time(s). Well then how many times do you arrive at the station more than 5 minutes before the desired arrival time?
Question 3-2.	Your answer of the Question 2-2 is ( ) time(s). Well then how many times do you arrive at the station more than 10 minutes before the desired arrival time?
Question 4-1.	Your answer of the Question 2-3 is ( ) time(s). Well then how many times do you arrive at the station more than 5 minutes after the desired arrival time?
Question 4-2.	Your answer of the Question 2-3 is ( ) time(s). Well then how many times do you arrive at the station more than 10 minutes after the desired arrival time?

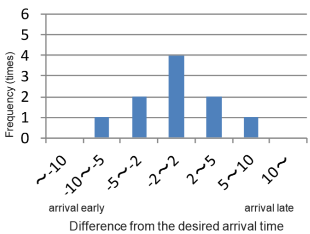
Table 4 Data format of arrival situation

ID	Early arrival				Late arrival		
	More than 10min.	5 min. to 10 min.	2 min. to 5 min.	Within 2 min.	2 min. to 5 min.	5 min. to 10 min.	More than 10min.
1	1	1	1	2	3	0	2
2	0	0	2	3	5	0	0
3	0	2	2	2	2	2	0
…	…	…	…	…	…	…	…
1313	0	0	1	8	1	0	0
1414	0	0	0	4	3	2	1

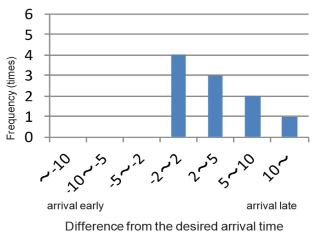
3 Characteristics of the difference between the desired and realized arrival times

3.1 Patterns of the difference between the desired and realized arrival time

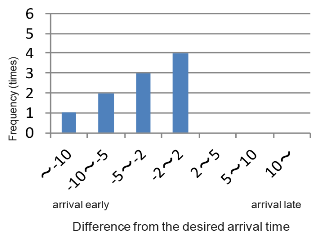
The difference between the desired and realized arrival time was analyzed. After examining the data regarding the difference, it became clear that there were six, from (a) to (g), patterns as shown in the Figure 1.



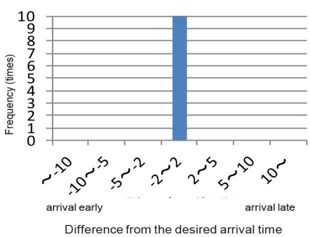
(a) symmetric pattern (449/1418 cases)



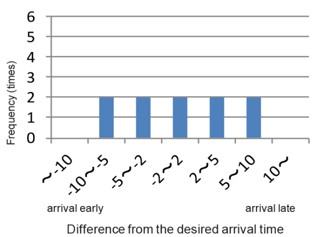
(b) late arrival pattern (434/1418 cases)



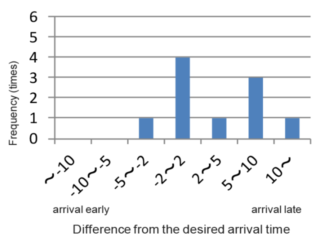
(c) early arrival pattern (41/1418 cases)



(d) on schedule pattern (333/1418 cases)



(f) Uniformly symmetric pattern (31/1418 cases)



(g) Nondesrict pattern (130/1418 cases)

Figure 1 Patters of the difference from the desired arraival time.

4 Methodology

4.1 Mixture distribution model

Mixture distribution is the distribution that mixed plural distribution. The probability density function of mixture distribution is written in (1).

$$p(x;\theta)=\sum_{m=1}^{M}\pi_m h(x;\omega_m). \tag{1}$$

where:

M number of mixture components;
$h\ (x;\omega_m)$ component distribution;
$\theta=\{(\pi_m,\omega_m),1\leq m\leq M\}$ parameter of distribution associated with component i, observation i;
π_m mixture weight and it satisfies $\sum_{m=1}^{M}\pi_m=1$.

In this study, Gaussian mixture distribution that is most general mixture distribution, is applied as the component distribution as shown in (2).

$$h(x;\theta)=\sum_{m=1}^{M}\pi_m\varphi(x;\mu_m,\Sigma_m). \tag{2}$$

where:

$\phi(x;\mu_m,\Sigma_m)$ Gaussian distribution;
μ_m mean of component distribution;
Σ_m variance of component distribution.

By estimating the maximum likelihood estimators of the all parameters, the shape of the mixture distribution is obtained. However the number of component distribution, M, is unknown so that the M is estimated by EM(Expectation-Maximization) algorithm.

4.2 Estimation results

The results of parameter estimation is described in this section. A table in the Figure 2 shows the estimated parameters such as weight, mean and variance. The number of components is four and each component is indicated by different colours. The graph shows the probability density function of each component. Furthermore, the probability density function of mixture distribution is shown by the black broken line.
Reproducibility of the estimated mixture distribution is confirmed. Figure 3 shows the result of comparison between the histogram of the observation and the estimated probability of mixture distribution. As seen in the figure, the reproducibility of the mixture model to the observation is high.

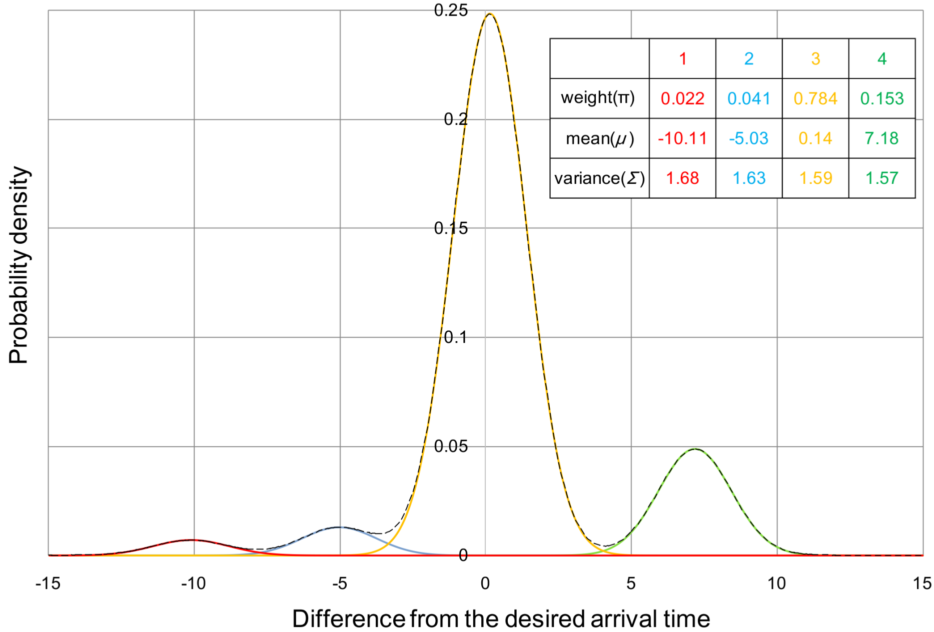


Figure 2 Density functions of component distributions and mixture distribution

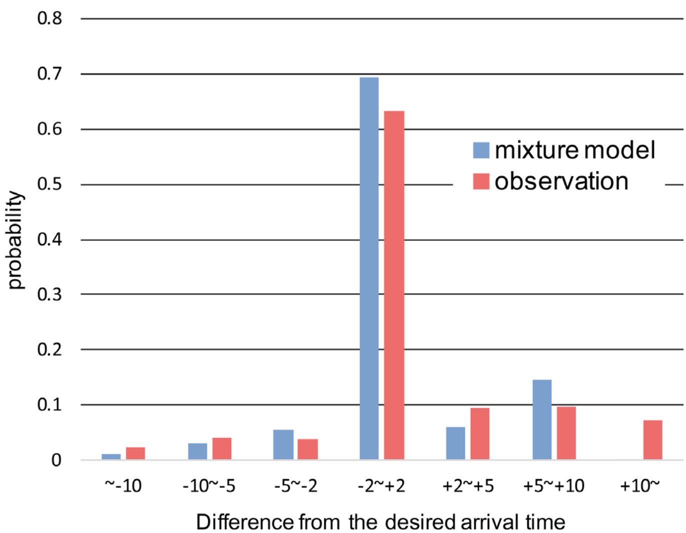


Figure 3 Reproducibility of the estimated mixture distribution

5 Conclusion

Our previous studies regarding departure time decision of railway users, there was a strong condition that the railway user recognized that the delay of arrival time obeyed exponential distribution. However the difference between the desired arrival time and the actual arrival time does not always obey exponential distribution. Then, we commenced the research for easing this strong condition by appling the mixture distribution model.
In this study, we confirmed the availability of the mixture model which can consider the arrival situation such as arrival on time, arrival early and arrival late. The estimated mixture distribution can explain the characteristics of the arrival situation.
In this study, Gaussian distribution was applied to all component distribution. However, as shown in the Figure 1, there are several patterns in arrival situation. To consider this diversity of the arrival situation, we study the availability of mixture model that applied different distribution to component distributions.

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