THE UNIVERSITY OF TOKYO

Departure-Time Choices of Urban Rail Passengers Facing Unreliable Service: Evidence from Tokyo

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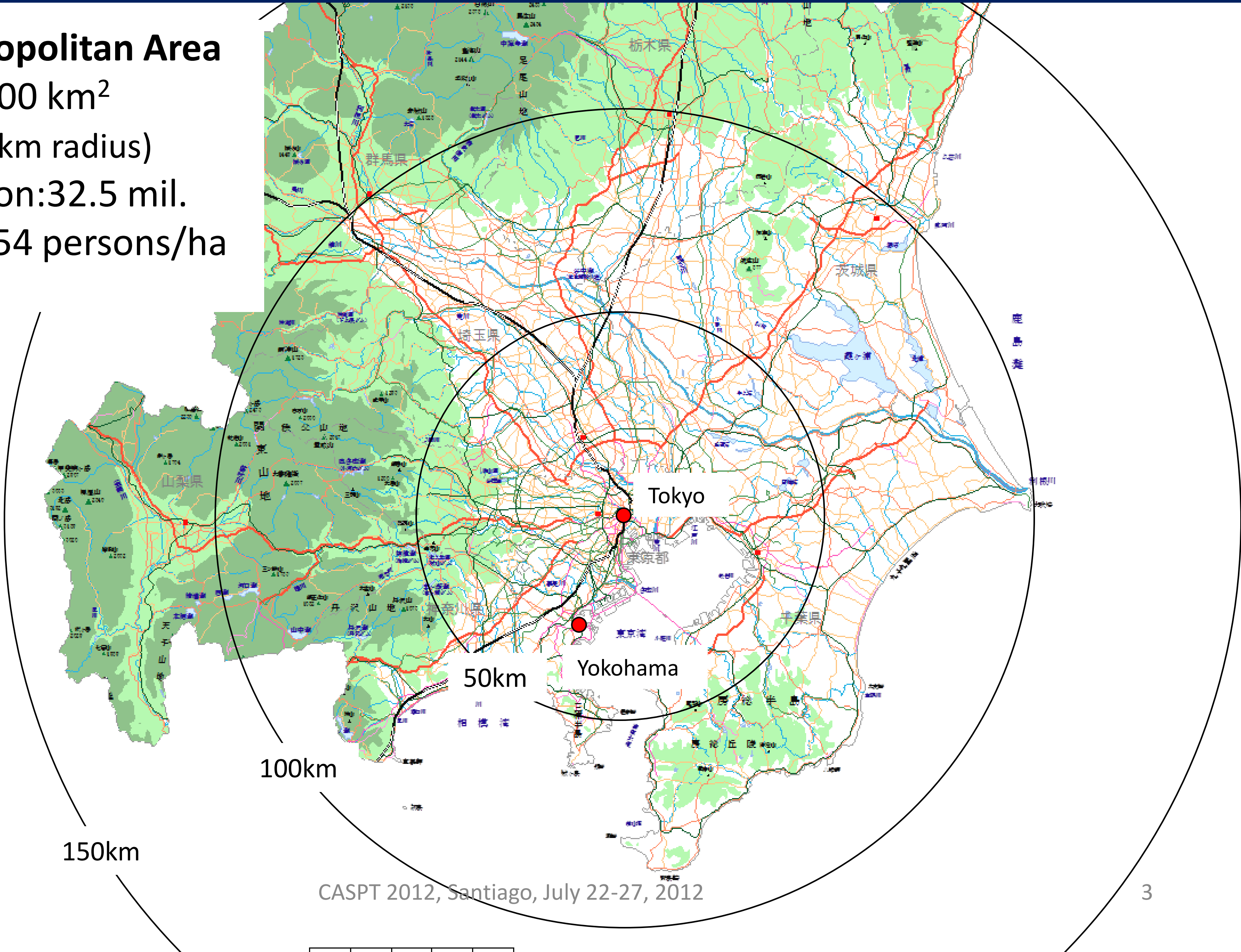
Outline of Presentation

- Introduction
- Survey of Rail-use at Urban Rail Line in Tokyo
- Analysis of Delays for Official-Work Start Times
- Departure Time Choice Modeling
- Concluding Remarks

Tokyo Metropolitan Area

Tokyo Metropolitan Area

- Area:6,000 km^2
  (about 45 km radius)
- Population:32.5 mil.
- Density:54 persons/ha



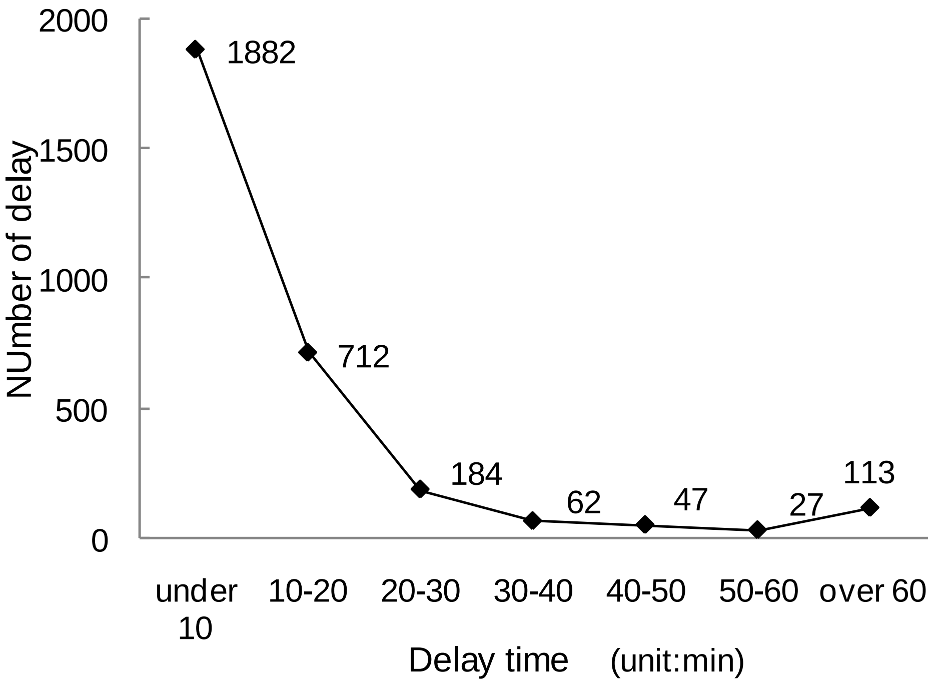
Introduction

- It has been widely reported that the rail service in Japan is punctual.
- However, the urban rail service in the Tokyo metropolitan area has recently been suffering from frequent service delays particularly during morning peak hours.

Recent Study (MLIT, 2009)

- The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) collected data on the service delays in the urban rail network of the Tokyo, Osaka, and Nagoya metropolitan areas in 2007.
- The results showed that there were 3,027 delays in 2007.

Distribution of delay time in urban rail service in metropolitan areas in Japan

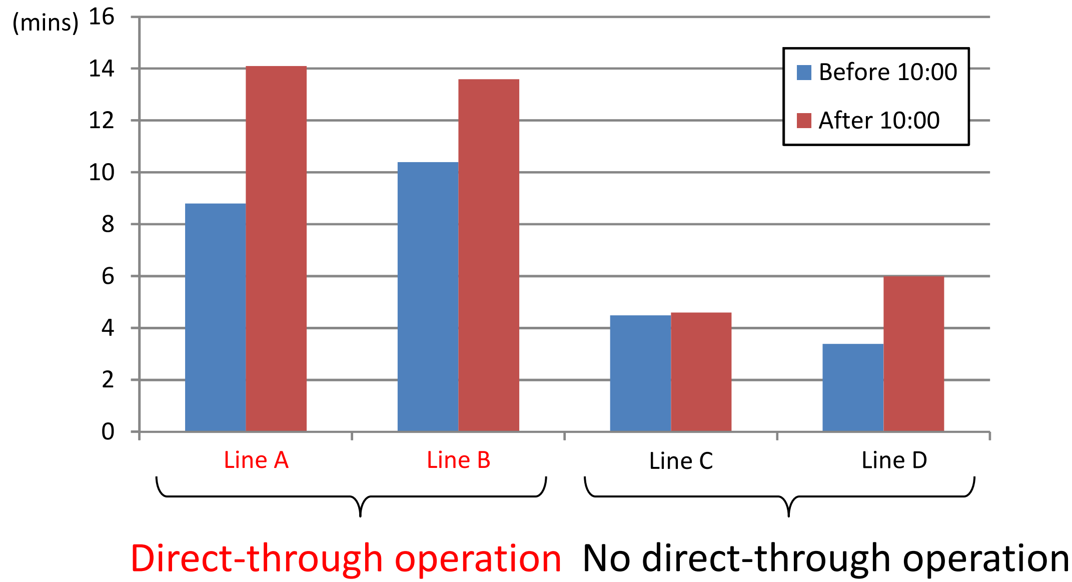


Source: MLIT, Japan (2009)

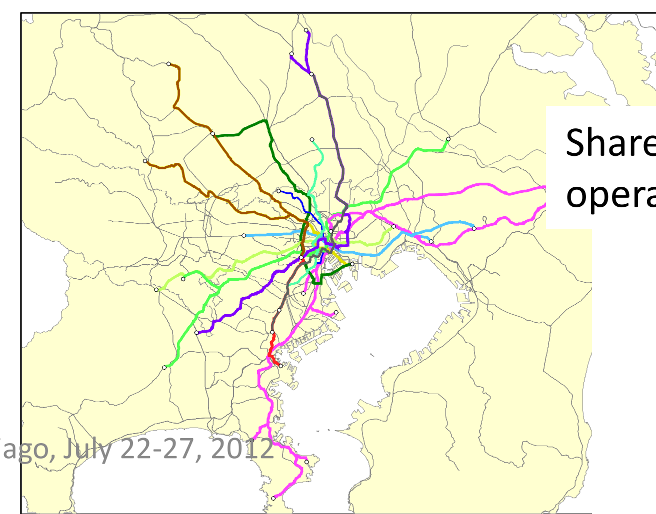
Rail Service Delay in Tokyo

- Since many suburban rail services are connected directly to the urban rail service in Tokyo, even one service delay at a rail section impacts the services at other rail sections located far from the original section.
- In this manner, service delays at one section influences a number of passengers over wide areas.

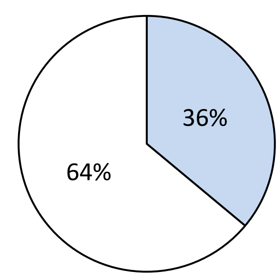
Average service delay on observed days in 2010



Direct-through rail operation in Tokyo, 2010



Share of direct-through operated lines in length



Motivation

- Such frequent delays in rail services influence passengers’ perceptions of service reliability.
- In addition, the delays may also affect their behaviors including their choice of departure time.
- However, no study has reported the expected impacts of chronic delays in rail services on passenger behaviors and perceptions in Japan.

Goals of This Study

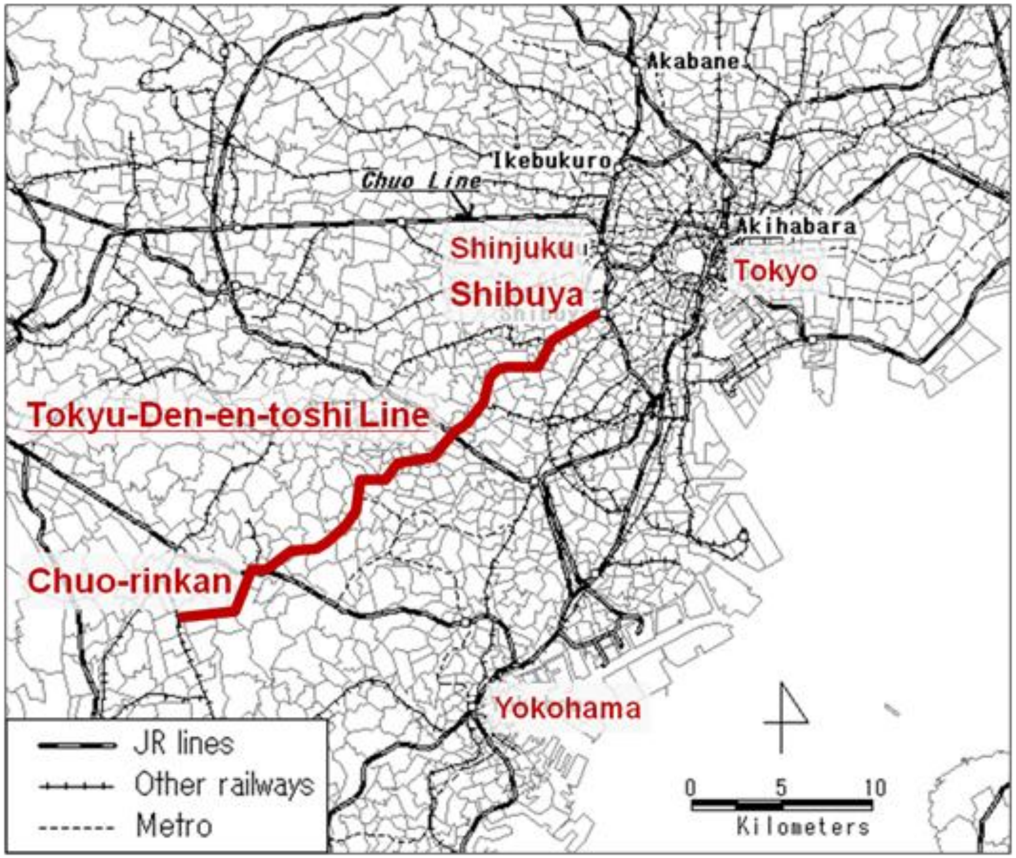
- This study report the results of the survey on the behaviors and perceptions of suburban rail users pertaining to the issue of rail service delays in Tokyo.
- It formulates the departure-time choices of urban rail passengers who face unreliable service and analyzes them by using the empirical data.

Survey Design

- A paper-based questionnaire survey for rail-use commuters at four rail stations on the Tokyu Den-en-toshi Line.
- The survey was conducted in November 2009 with the cooperation of the rail operator.
- The respondents were requested to provide:
  - their daily commuting travel schedules including origin, destination, route, departure time, arrival time, and rail-use travel time;
  - their previous experiences with service delays when using the railways;
  - their opinions about service delays in rail services and preferred arrival times; and
  - their socio-demographic information including their age, gender, and occupation.

Tokyu Denentoshi Line (TD Line)

Map of TD Line

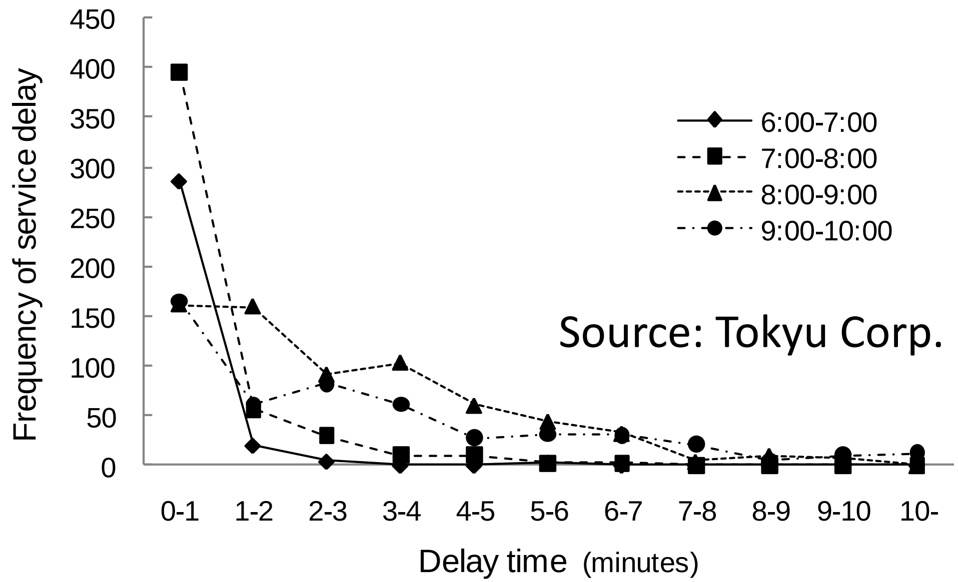


- One of the major suburban rail lines in the western part of the Tokyo.
- 31.5 km long and it connects the terminal station in Tokyo with the suburban stations.
- It is directly connected with subway line.
- The average rail demand is 1.1 million passengers/day (2011).
- Service headway is approximately 2 minutes during a morning peak hour.

Major Problems in TD Line

- Most of the trips made by passengers are for commuting to their workplace or study.
- It has been reported that in-vehicle congestion is very serious in this line particularly during morning peak hours.
- The serious in-vehicle congestion also causes service delays during the morning peak hours.

Observed service delay by arrival time at the Shibuya terminal station (Sep. 19–Oct. 31, 2008)



Source: Tokyu Corp.

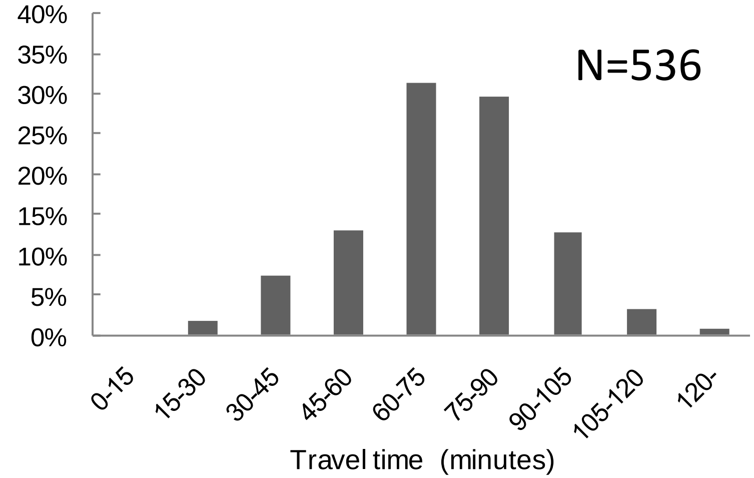
Mizonoguchi Station in the morning

Source: Tokyu Corp.

Dataset Used in the Analysis

- In total, 1,920 survey sheets were distributed and 721 responses were collected through postal mail.
- Finally, the dataset collected from 536 respondents is used for our analysis.

Distribution of Travel Time



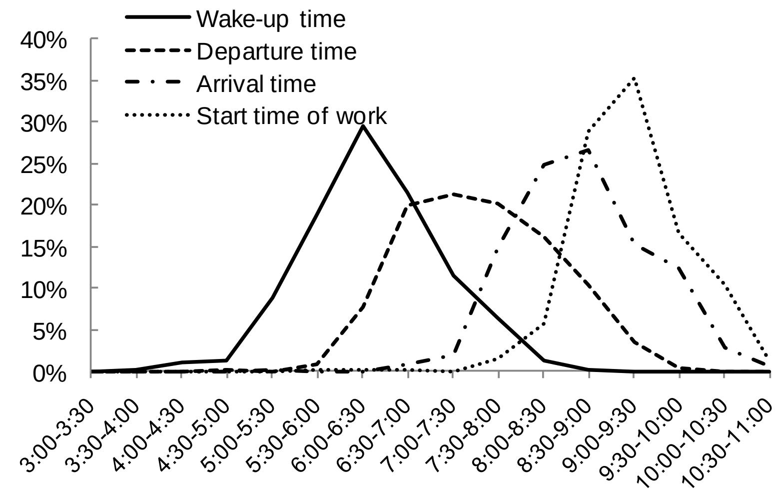
Descriptive Statistics of Respondents

Gender	Male	Female					
	358 (66.8%)	178 (33.2%)					
Age	<20	20–29	30–39	40–49	50–59	60–69	>70
	6 (1.1%)	25 (4.7%)	104 (19.4%)	204 (38. 1%)	129 (24.1%)	62 (11.6%)	6 (1.1%)
Occup.	Employee	Manager/ employer	Public servant	Self-employed	Student	Others	
	408 (76.1%)	30 (5.6%)	30 (5.6%)	4 (0.7%)	12 (2.2%)	52 (9.5%)	
Work system	Fixed work-time	Flexible work-time					
	480 (89.6%)	56 (10.4%)					

Distributions of Arrival Time

- Individuals arrive at their offices earlier than official-work start times by 0-30 minutes.
- However, approximately 30% of them cannot arrive before the preferred arrival times.

N=536

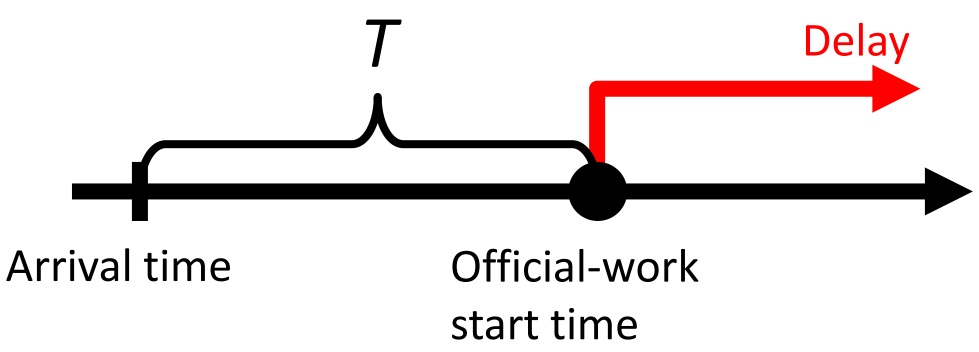


Delays pertaining to official-work start times and desired arrival times

	For official-work start times		For preferred arrival times	
30 to 45 min	0	0.0%	7	1.3%
15 to 30 min	0	0.0%	47	8.8%
0 to 15 min	0	0.0%	108	20.1%
0 min	41	8.0%	242	45.1%
–15 to 0 min	147	28.5%	79	14.7%
–30 to –15 min	158	30.7%	29	5.4%
–45 to –30 min	72	14.0%	14	2.6%
–60 to –45 min	38	7.4%	7	1.3%
–75 to –60 min	33	6.4%	2	0.4%
–90 to –75 min	12	2.3%	0	0.0%
–105 to –90 min	13	2.5%	0	0.0%
–120 to –105 min	1	0.2%	0	0.0%

Analysis of Early Arrival for Official-Work Start Times

- The early arrivals for the official-work start time are analyzed using a linear Tobit model.
- The dependent variable (T)
  - –(the delay for the official-work start time) in minutes



- The independent variables ($\boldsymbol{x}$)
  - morning in-home leisure time, rail-ride travel time, train departure time, gender, age, occupation, work-time system, changes in behavior because of chronic service delays, experiences of serious service delays, and the availability of alternative rail routes.

$$\boxed{T = \beta_1 x_1 + \beta_2 x_2 + \cdots + \varepsilon}$$

Estimation Results

	Model 1		Model 2		Model 3		Model 4	
	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
Morning in-home leisure time	0.07	2.47**	0.07	2.48**	0.07	2.53**	0.07	2.62**
Rail-ride travel time	−0.14	−2.68**	−0.14	−2.78**	−0.15	−2.92**	−0.14	−2.77**
Departure time of train	−0.31	−13.5**	−0.31	−13.4**	−0.31	−13.9**	−0.31	−13.9**
Gender	4.80	2.36**	4.82	2.37**	4.94	2.43**	4.73	2.32**
Age	−0.96	−0.37	−0.86	−0.33	−1.03	−0.40	−0.82	−0.31
Work-time system	2.15	0.92	2.21	0.94	2.19	0.94	2.38	1.01
Occupation	−1.21	−0.51	−1.10	−0.46	−1.13	−0.48	−0.73	−0.31
Changes in behavior because of chronic rail-service delays	4.81	2.50**	4.52	2.38**	4.30	2.27*		
Experience with serious rail-service delays	−1.82	−1.05	−1.93	−1.11				
Availability of alternative rail routes	−1.65	−0.96						
Constant	71.4	11.7**	70.2	11.8**	70.1	11.7**	72.3	12.2**
Log-likelihood		−1,588.20		−1,588.68		−1,589.30		−1,591.97
Number of observations		473		473		473		473

Major Findings from Estimation Results

- The individuals who allocate longer time to morning leisure tend to arrive at their workplace earlier.
- Shorter-travel-time passengers tend to arrive at their workplace earlier.
- The male worker arrives at the workplace earlier than the female.
- The individuals working under the fixed work-time system arrive at their workplace earlier.

Departure Time Choice Modeling

- A departure time choice model based on the time allocation model with the revealed-preference data of rail transit users.
  - The model formulates the departure time choice of home-to-workplace travelers.
  - The model follows the theoretical framework presented by Small (1982).
  - The model assumes a continuous time choice in which an individual maximizes his/her utility under the constraints of time budget.

Model Formulation

$$\max_{t_{Dn}} U_n = u_{MLn} + u_{RAILn} + u_{SDEn} + u_{SDLn}$$

Subutility function of the morning in-home leisure time

Subutility function of the in-vehicle rail travel time

Subutility function of the difference between arrival time from the preferred arrival schedule or schedule delay early

Subutility function of the difference between arrival time the official work start time or schedule delay late

Subject to $t_{An} = t_{Dn} + \bar{T}_{ACCn} + \tilde{T}_{RAILn} + \bar{T}_{EGRn}$ $\quad \tilde{T}_{RAILn} > 0,\ \bar{T}_{ACCn} > 0,\ \bar{T}_{EGRn} > 0$

Arrival time

Departure time

Access travel time from home to station

Rail-ride travel time

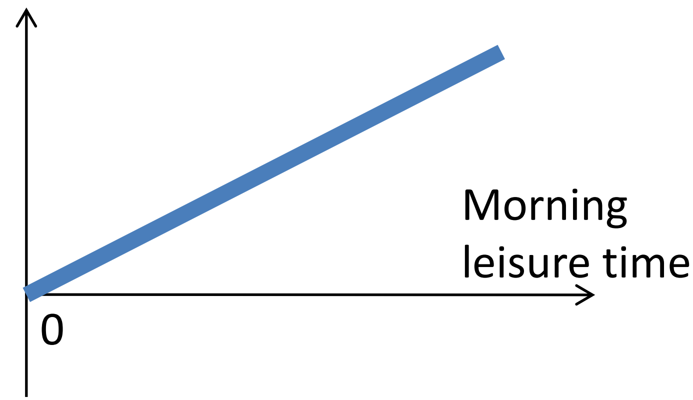
Egress travel time from station to workplace

Model Specifications

Sub-utility function pertaining to the morning in-home leisure time for individual

$$u_{MLn} = \left(t_{Dn} - \bar{t}_{WAKEn}\right) \cdot \exp\left(\mathbf{A}_{ML}\underline{\mathbf{X}_{MLn}}\right)$$

Personal attributes

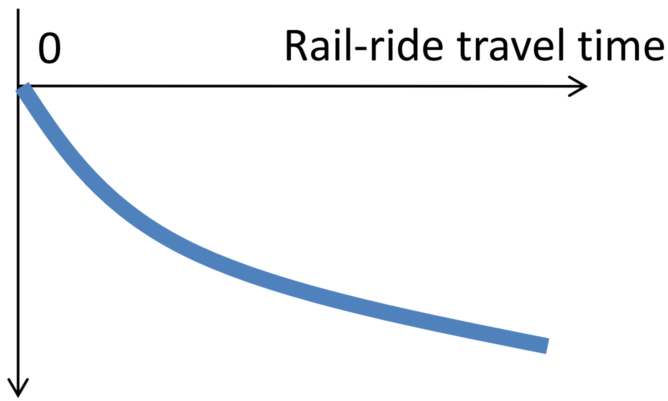


Sub-utility function of the in-vehicle rail travel time for individual

$$u_{RAILn} = -\ln\left(\underline{\bar{T}_{RAILn}} + \underline{\varepsilon_n}\right) \cdot \exp\left(\mathbf{A}_{RAIL}\mathbf{X}_{RAILn}\right)$$

Timetable-based rail travel time

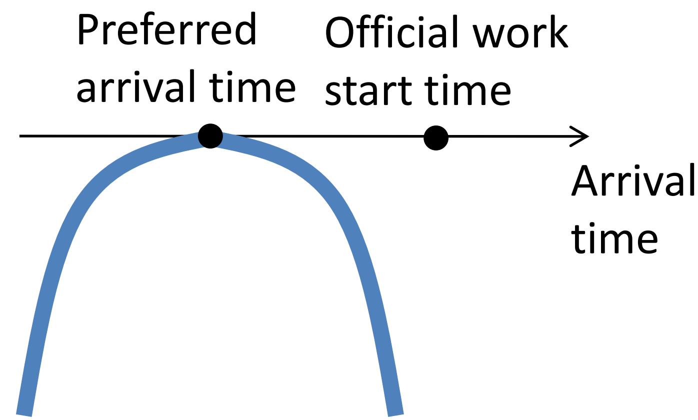
Random component of travel time caused by delay



Model Specifications (Continued)

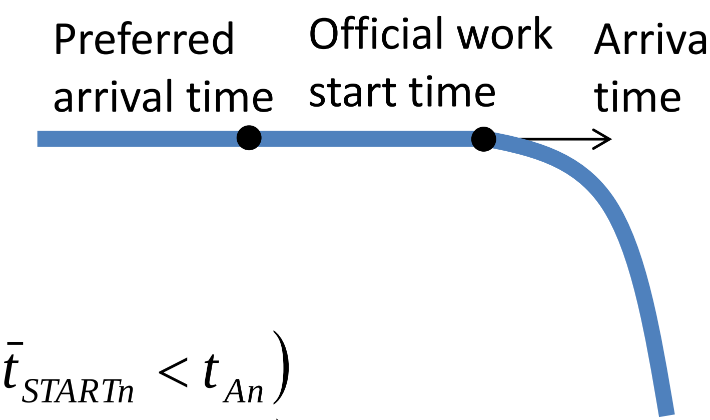
Sub-utility function pertaining to the difference between arrival time from the preferred arrival schedule or schedule delay early for individual

$$u_{SDEn} = -\left(t_{An} - \bar{t}^{\,o}_{An}\right)^2 \cdot \exp\left(\mathbf{A}_{SDE}\mathbf{X}_{SDEn}\right)$$



Sub-utility function pertaining to the difference between arrival time the official work start time or schedule delay late for individual

$$u_{SDLn} = \begin{cases} -\left(t_{An} - \bar{t}_{STARTn}\right)^2 \cdot \exp\left(\mathbf{A}_{SDL}\mathbf{X}_{SDLn}\right) & \left(if \;\; \bar{t}_{STARTn} < t_{An}\right) \\ 0 & \left(if \;\; \bar{t}_{STARTn} \geq t_{An}\right) \end{cases}$$



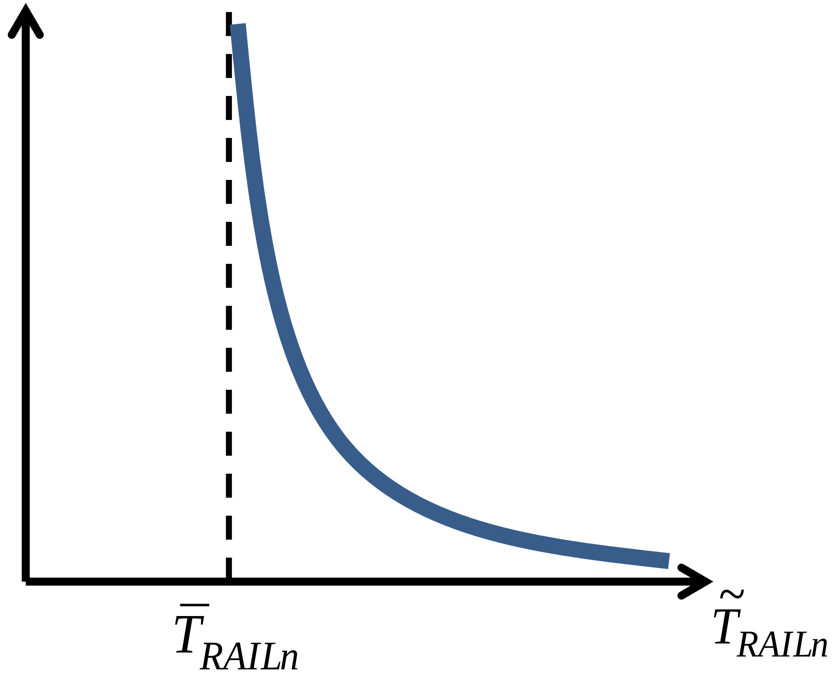
Distribution of Perceived Rail-ride Travel Time

$$\tilde{T}_{RAILn} = \underline{\bar{T}_{RAILn}} + \varepsilon_n$$

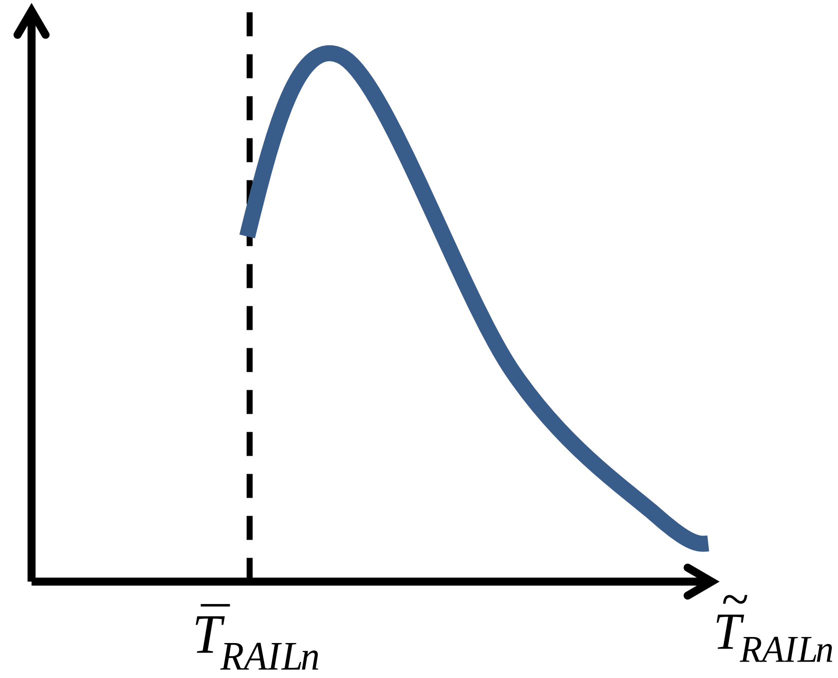
Timetable-based rail travel time

Two types of probability functions are assumed for the random component

Exponential function



Censored-normal distribution function

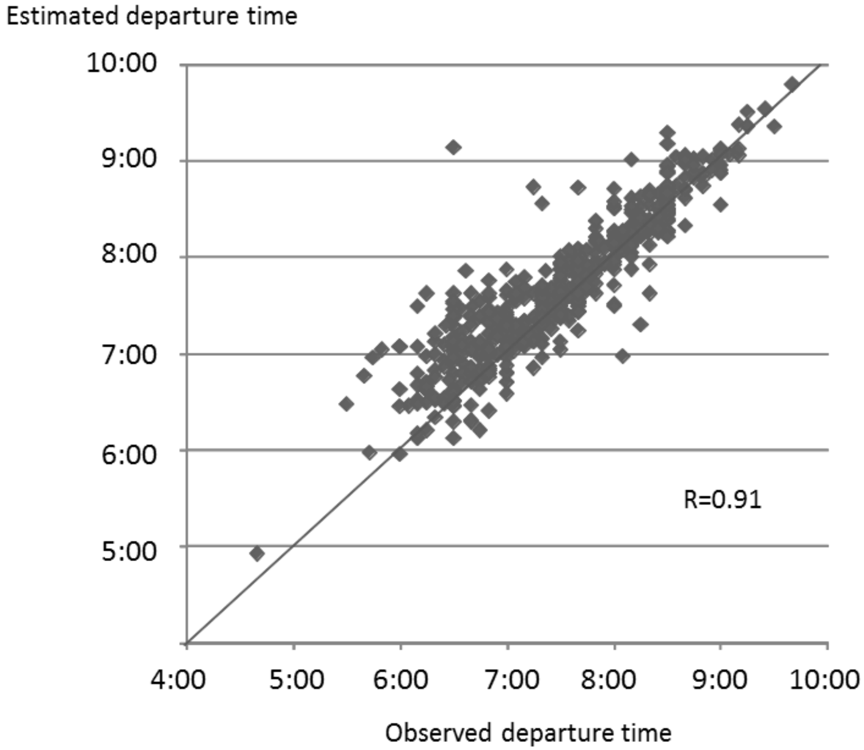


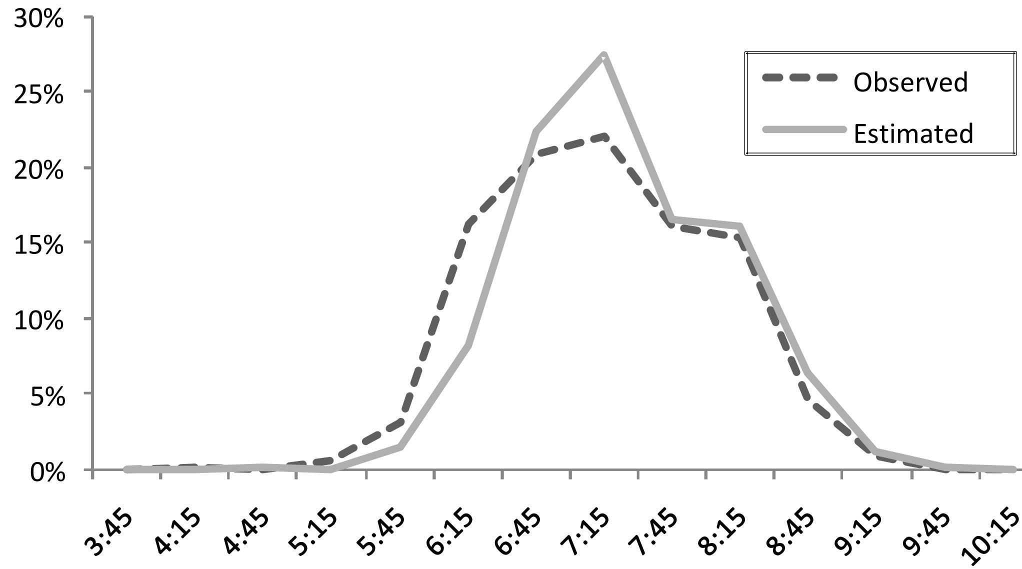
Estimation Results

Type of function for random component		Exponential function		Censored-normal distribution function					
		Model A		Model B		Model C		Model D	
Explanatory variable		Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
A_{ML}	Alternative route			−1.05	−6.84*	−1.47	−8.04*	−1.87	−3.93*
	Gender	−21.01	−0.05	−1.00	−4.19*	−0.95	−1.90	−1.69	−3.53*
	Age	−14.41	−0.15	−0.44	−2.14	−0.54	−2.44	−0.59	−2.40
A_{SDE}	Work-time system	−32.30	−0.04	−2.09	−6.69*	−2.71	−5.00*	−2.57	−5.20*
	Experience with serious delay					−1.27	−5.24*		
	Concerns with service delay			−1.30	−5.81*			−1.65	−6.08*
	Occupation			−0.68	−3.58*	−0.69	−2.15	1.34	1.48
A_{SDL}	Work-time system	−12.35	−0.25	4.75	2.26	8.85	0.51	−0.91	−2.00
	Gender			2.09	4.72*	2.16	3.13*	2.91	3.57*
	Occupation							−0.17	−0.94
	Constant	−0.41	−1.61	−5.70	−2.67*	−9.81	−0.57		
	Mean of normal dist.			2.77	6.24*	2.40	5.71*	2.58	2.38
	Variance of normal dist.			204.98	65.65*	206.45	65.65*	210.06	65.65*
	Beta	0.81	46.40						
	Initial log-likelihood	−31,859.1		−2,374,397.1		−2,374,397.1		−2,374,397.1	
	Final log-likelihood	−4,687.8		−8,792.1		−8,799.8		−8,818.5	
	AIC	9,387.6		4,731,210.0		4,731,194.7		4,731,157.3	
	Number of observations	536		536		536		536	

Observed vs. Estimated Departure Time

Observed Departure Time and Estimated Departure Time with Model B (censored normal distribution)





Estimation of Benefit from Improvement

The economic benefits stemming from improvements in transportation service are estimated with the departure-time choice model.

$$B_n = \frac{\underline{VOT_n}}{\partial U / \partial \tilde{T}_{RAILn}} \left[\underline{V_n(\mu^w, \sigma^w)} - \underline{V_n(\mu^o, \sigma^o)} \right]$$

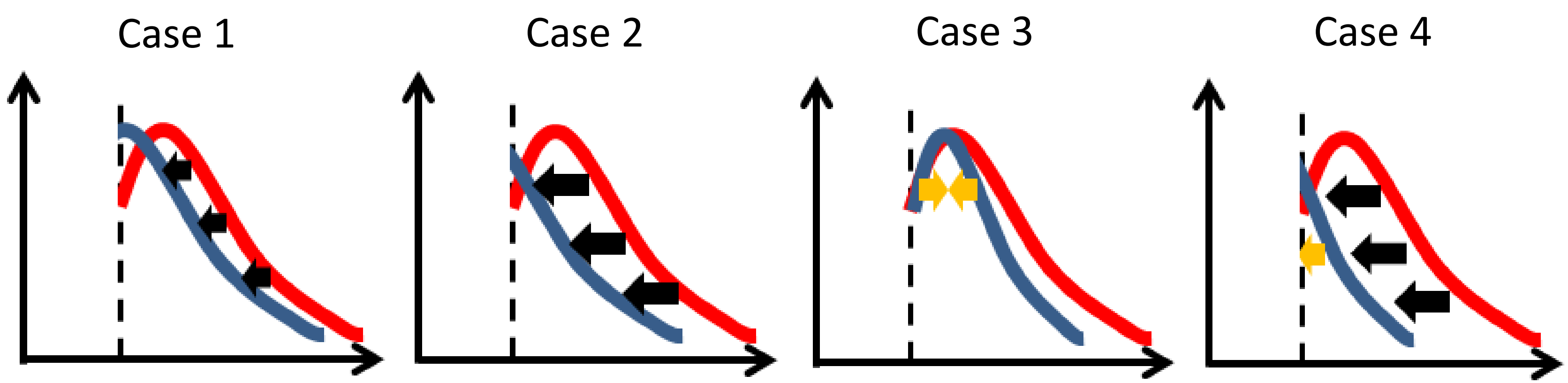
Value of in-vehicle rail-ride travel time of individual

Indirect utility function after the improvement

Indirect utility function before the improvement

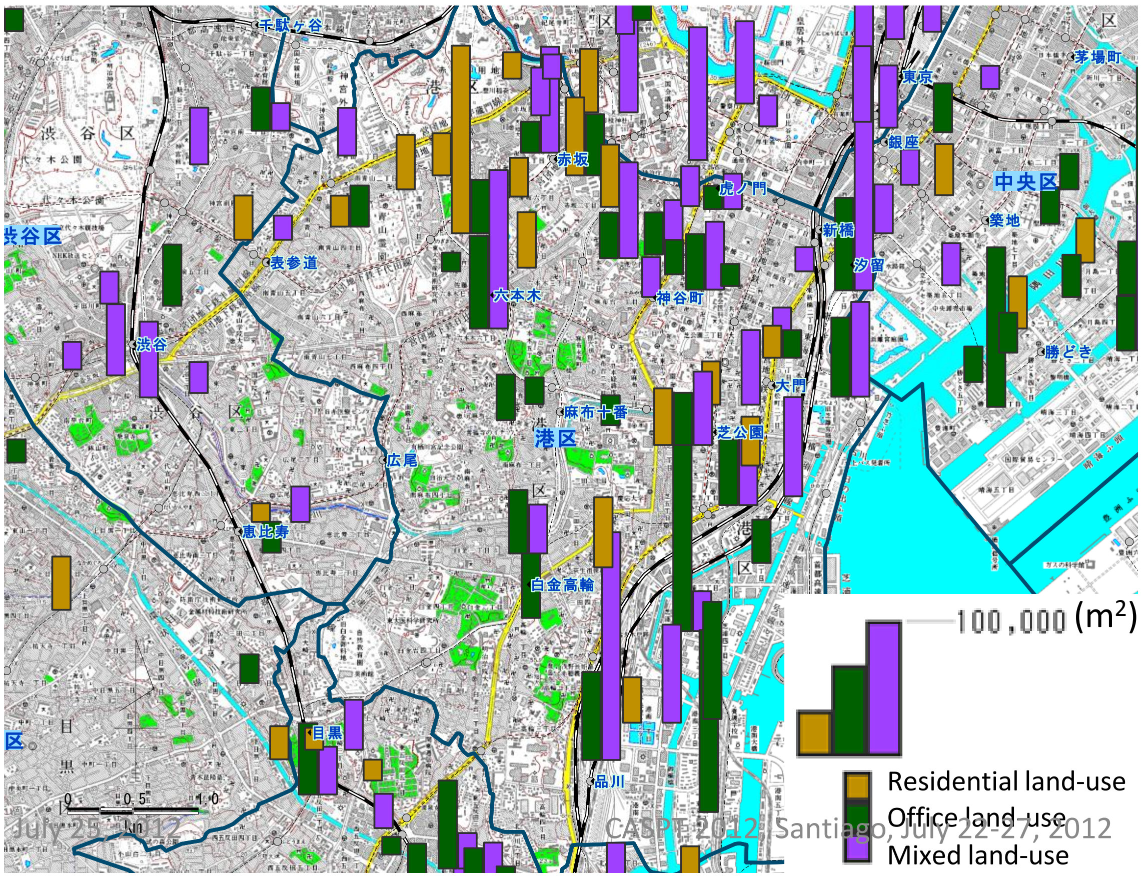
Case Studies of Benefit Estimation with Model B

	Case 0	Case 1	Case 2	Case 3	Case 4
		Reduction of mean by 1 min	Reduction of mean by 2 min	Reduction of S.D. by 2 min	Reduction of mean by 2 min and S.D. by 2 min
Mean of censored-normal dist.	7.20	6.64	6.11	6.42	5.85
S.D. of censored-normal dist.	8.02	7.77	7.52	7.52	6.75
Daily benefit in sample group		21,885	42,643	30,497	52,842

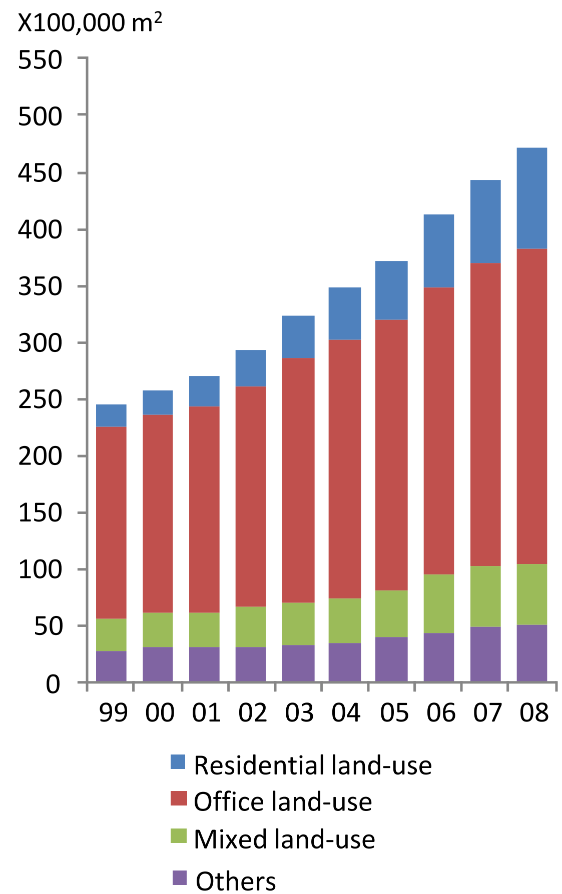


Main Factors Causing the Rail Service Delay

- Recent Urban Development in the Central Business District since early 2000s.
  - This was led by the government’s deregulation on land-use control in Tokyo.
- Higher demand at CBD causes in-station congestion.

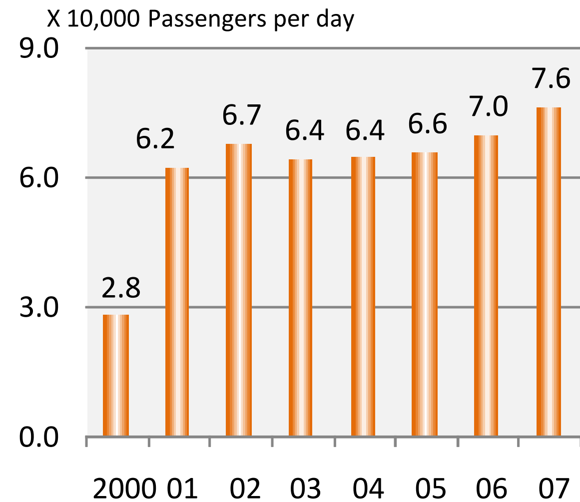


Floors of Super-high-story buildings (over 60m) in 11 wards area

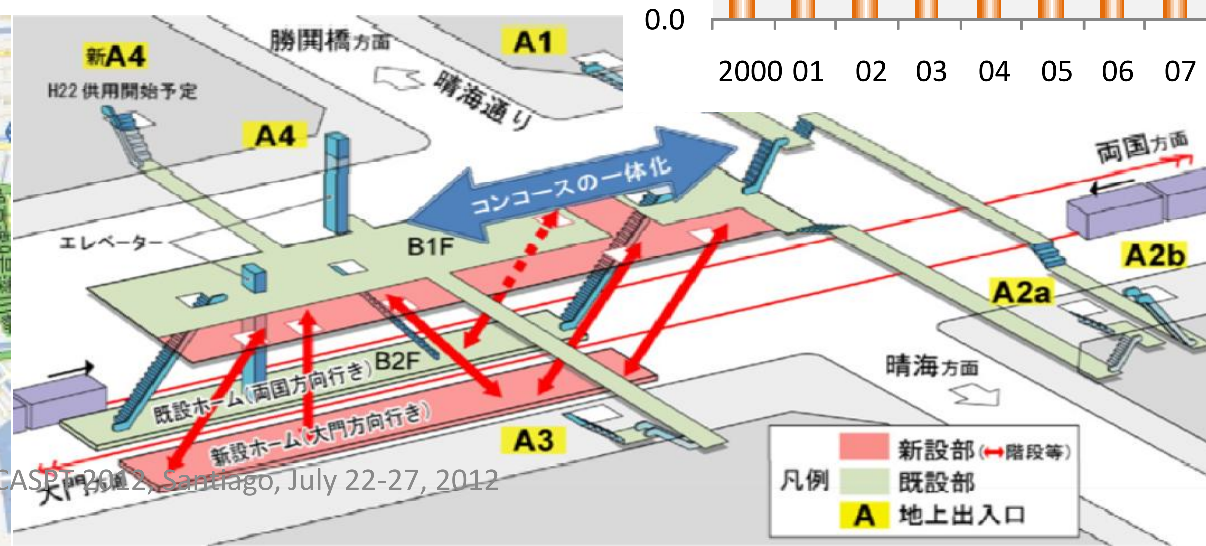


Reduction of In-station Congestion

- One of the possible solutions for service delay is the reduction of the in-station congestion at subway stations in CBD.
- Examples at Kachidoki Station
  - Installation of new platform and new exit
  - Separation of platform by direction
  - Integration of concourse floors
- Critical issue is the allocation of construction cost among stakeholders including rail operator and developers.



Kachidoki Station



Conclusions

- This study surveyed the recent service delay in urban rail network in Tokyo Metropolitan Area.
- It formulated the continuous departure-time choice under conditions of unreliable rail service and estimated the models through the use of empirical data.
- The model can estimate the benefit stemming from the changes in mean and variance of the censored normal distribution.
- Currently various countermeasures are implemented to reduce the service day in urban rail service.

Questions?

Smart Traffic Information

- Traffic information contributes to better departure time choices of rail users.
  - Mobile phones enable individuals to access traffic information even during travel.
  - The possibilities of providing dynamic traffic information through mobile phones and/or personal digital assistants should be explored.

Example of in-vehicle integrated information system for smart-phone users

Source: JR East

Type of behavior to avoid delays

Collection of traffic information before departure	195	49.4%
From TV programs	89	(45.6%)
From the internet using mobile phones	49	(25.1%)
From radio programs	16	(8.2%)
From the internet using personal computer	6	(3.1%)
Earlier departure from home everyday	262	66.3%
Earlier departure from home particularly when an important meeting is planned	212	53.7%
Others	21	5.3%