An Empirical Shipment Size Model for Urban Freight

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Contents

Background

- Shipment size prediction is required in freight transport simulations (especially for micro-simulations).

- Past research on shipment size is mostly for inter-city shipments.

- Economic Order Quantity (EOQ) model may not be applicable for intra-city shipments.

- This research:
  - **Analyzes how the characteristics of intra-city shipment play a role in the size selection.**
  - **Examines if a theoretical EOQ model is directly applicable to intra-city shipments.**

Literature Review

- Freight models that simulate logistics decisions incorporate shipment size models:
  - Wisetjindawat and Sano (2003), Wisetjindatwat et al. (2005), Roorda et al. (2010), Liedtke (2009)

- Joint models for mode choice and shipment or vehicle size:
  - Abate and de Jong (2014), Abate et al. (2018), Pourabdollahi et al. (2013), Irannezhad et al. (2017)

- Combes (2012) confirms the validity of a simple EOQ model using shipment records in France

Terminologies

Shipment:
Goods, or a bundle of goods, that is transported together at the same time between a shipper and a receiver (de Bok and Tavasszy, 2018)

Contract:
A specification of the total commodity flow (in weight) between a shipper and a receiver per time period

A shipment size model determines the **shipment size/frequency** for a **contract**.

EOQ-based Formulation

total logistics cost (TLC) for a contract i

- $$TLC_i = Transport\ Cost_i + Inventory\ Cost_i + Capital\ Cost\ during\ Transport_i$$

$$Transport\ Cost_i = Q_i / q_i \cdot o_i(q_i, d_i)$$

$$o_i(q_i, d_i) = (\beta_1 + \beta_2 \cdot q_i) \cdot d_i$$

$$Inventory\ Cost\ at\ the\ Receiver_i = q_i / 2 \cdot w_i$$

Q_i :Size of contract

q_i : Shipment size

$o_i(q_i, d_i)$: Transport cost per shipment

d_i : Shipment distance

w_i : Storage cost per unit

EOQ-based Formulation (cont'd)

- $$TLC_i = Q_i/q_i \cdot (\beta_1 + \beta_2 \cdot q_i) \cdot d_i + q_i/2 \cdot w_i$$
  $$+ other\ costs\ independ\ from\ q_i$$

Minimizing TLC with respect to q_i results in:

$$ln\, q_i = 1/2\, ln\, Q_i + 1/2\, ln\, d_i - 1/2\, ln\, w_i + 1/2\, ln\, 2\beta_1$$

Q_i :Size of contract

q_i : Shipment size

$o_i(q_i, d_i)$: Transport cost per shipment

d_i : Shipment distance

w_i : Storage cost per unit

Data for Empirical Model Estimation

- Data from 2013 Tokyo Metropolitan Freight Survey
- 20.5 thou. inbound shipments (intra-city only)
- Model estimation for each commodity - receiver func. combination

Sample Size

Commodity	Receiver function			
	Office	Factory	Shop & restaurant	Logistics facility
Agricultural	101	849	78	427
Food	176	1,003	160	1,581
Light manufacturing	587	2,744	107	1,102
Wood and paper	341	347	26	364
Minerals, ore, stone, cement, ceramics or glass	124	611	32	83
Metals or articles of metal	369	3,616	21	318
Machinery, appliances, and mechanical parts.	519	2,193	78	414
Chemicals, rubber or plastics	342	1,595	40	239

Empirical Model Specification

- Assume each shipment is associated with a "contract"

$$
\begin{aligned}
\ln s_{i^n} = {} & \beta_{const.} + \boxed{\beta_{lfship} \cdot dum_{lfship\,i^n}} + \beta_{c\_size} \cdot \ln c\_size_{i^n} \\
& + \beta_{dist.} \cdot \ln dist._{i^n} + \boxed{\beta_{lfship_{dist.}} \cdot dum_{lfship\,i^n} \cdot \ln dist._{i^n}} + \beta_{LP} \cdot \ln LP_n
\end{aligned}
$$

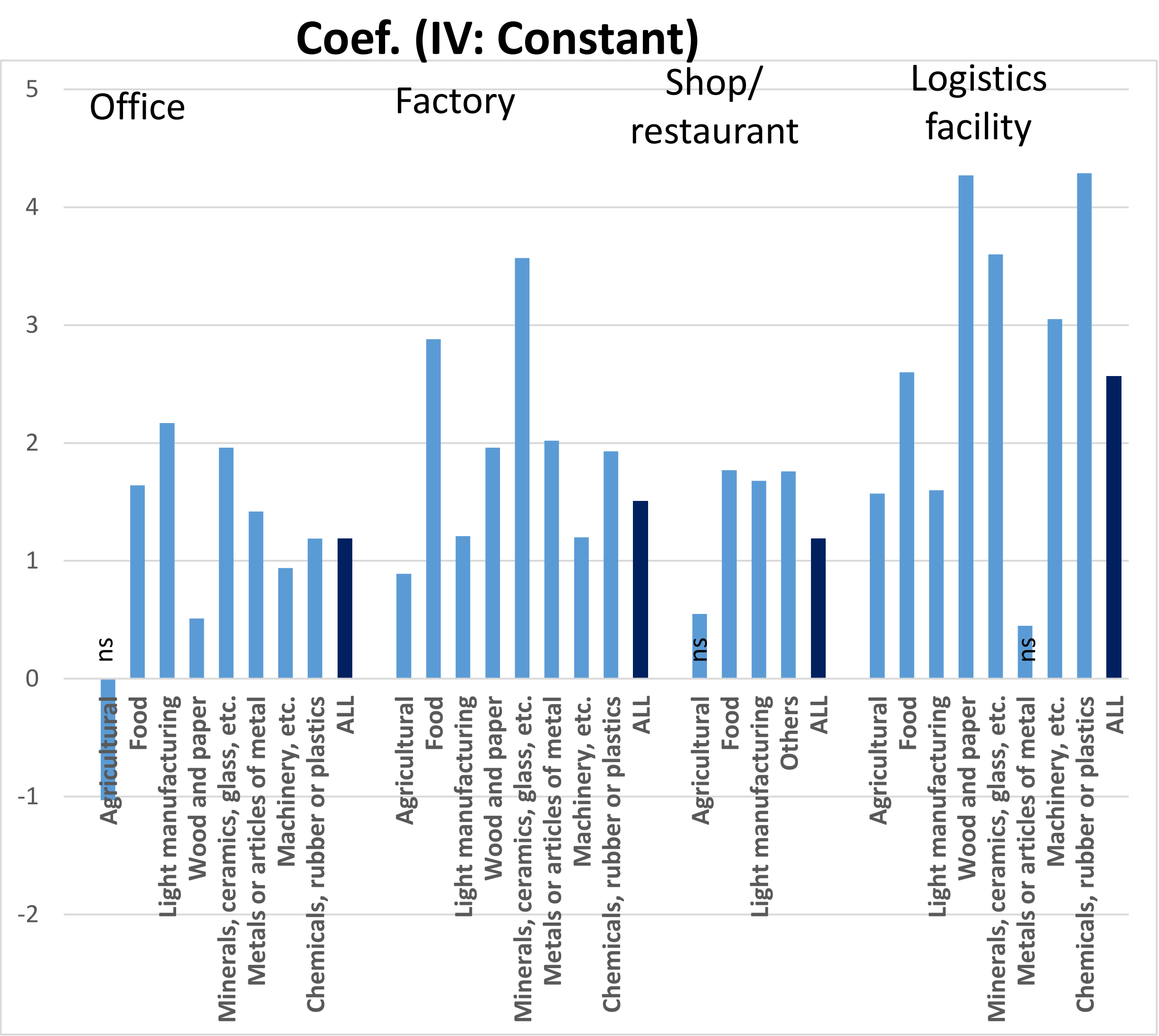
$c\_size_{\,i^n}$: Contract size (metric ton per annual)

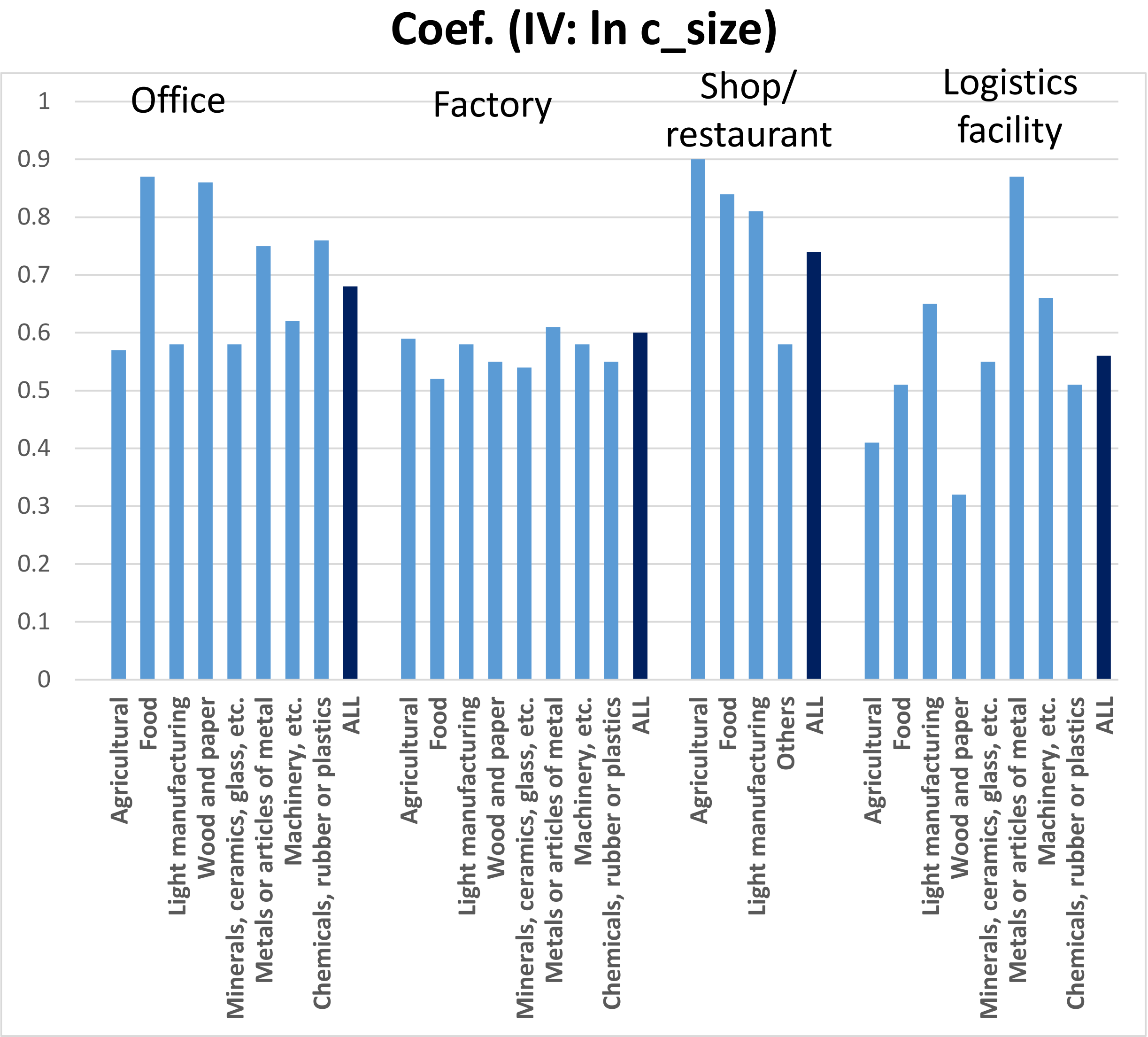
$dist._{i^n}$: Shipment distance (km)

LP_{n} : Land price at the receiver's location (mil. JPY per m²)

$dum_{lfship\,i^n}$: Dummy variable (1 if the shipper is a logistics facility)

Results



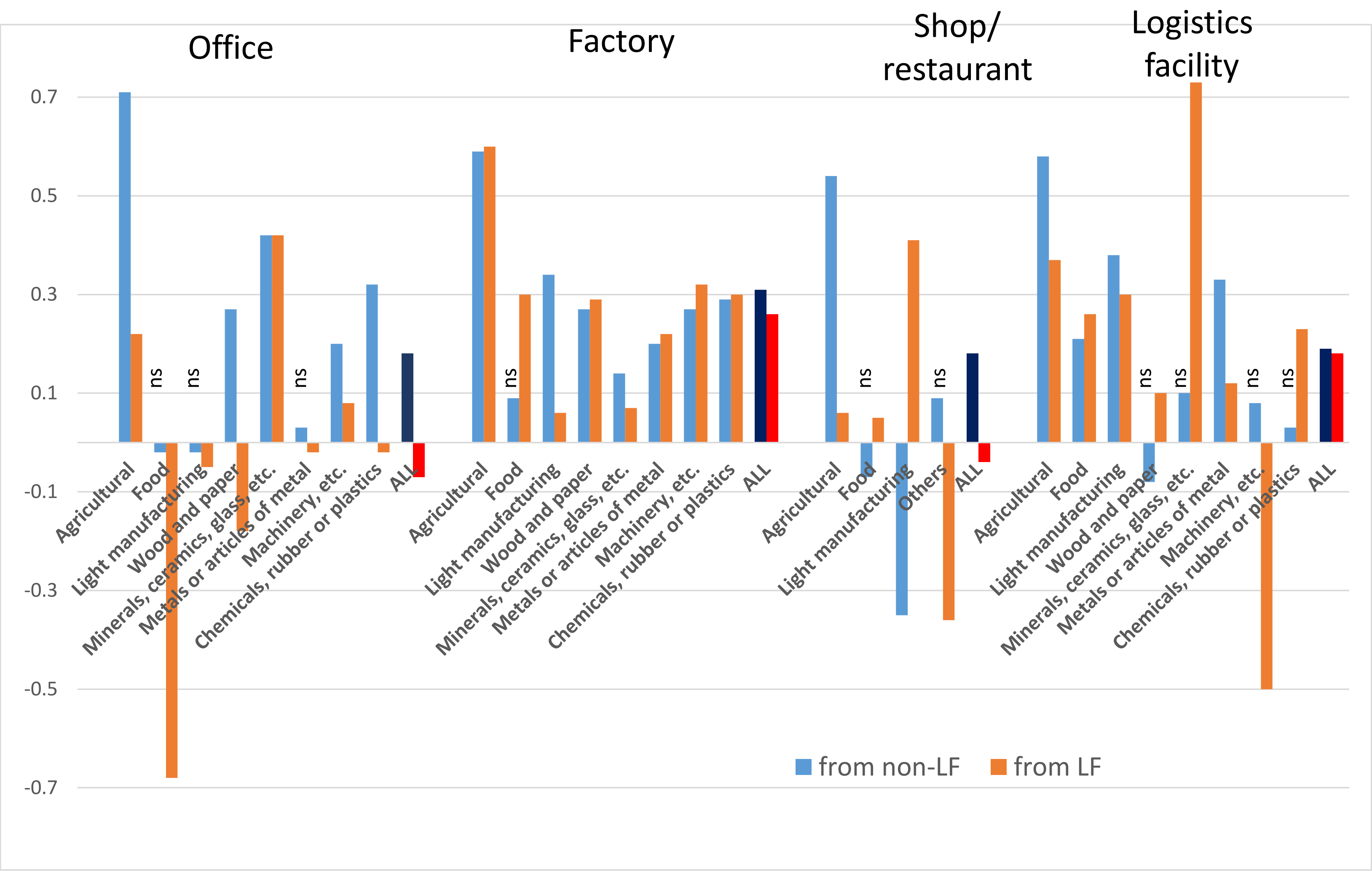


- High for logistics facilities; low for office and shop/restaurant
- Close to 0.5 for factories

Results (cont'd)

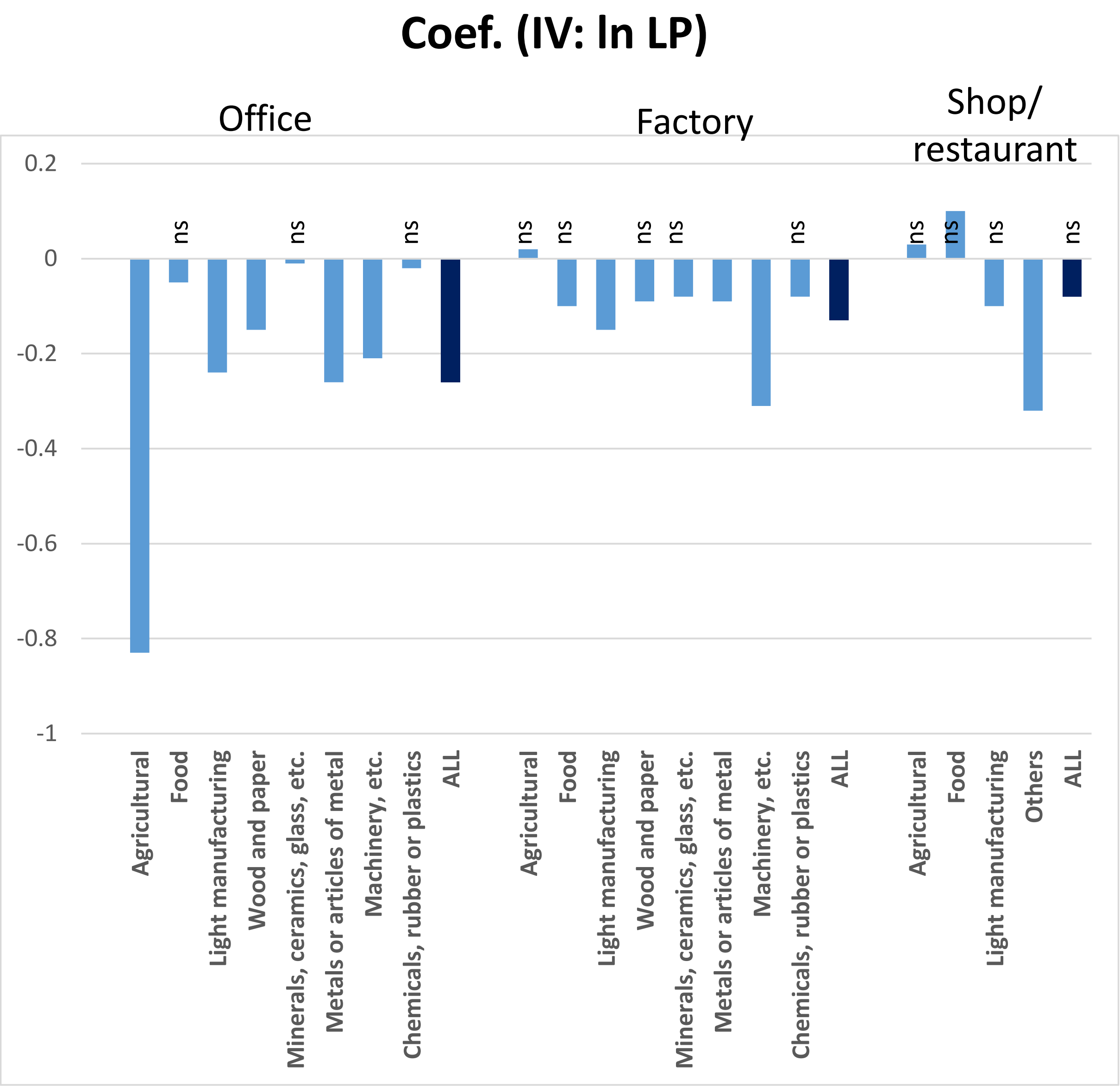
- Distance plays a greater role for shipments to factory or of agricultural products
  - **Potentially due to FTL shipping**
- For shipments from LFs, the effects decrease even to negative values.
  - **Potentially due to consolidation**

Coef. (IV: ln dist.)



Results (cont'd)

- Note: LP was not included in the models to logistics facilities
- The effects are remarkable when the receivers are offices
  - **Indicating high shadow price of storage**



Effects of Receiver / Shipper Function

- To measure the contribution of **the function type information** to the predictive performance, three segmentation methods are tested:

  (i) no segmentation
  (ii) segmentation **by shipper function**
  (iii) segmentation **by receiver function**
  (iv) segmentation **by the shipper and receiver function combination**

- Model specification:

$$ln\, s_{in} = \beta_{const.}^{c,seg} + \beta_{c\_size}^{c,seg} \cdot ln\, c\_size_{in} + \beta_{dist.}^{c,seg} \cdot ln\, dist._{in} + \beta_{LP}^{c,seg} \cdot ln\, LP_n$$

- Randomly selected 60% for training; the rest 40% for validation; repeated 100 times

Effects of Receiver / Shipper Function (cont'd)

- Comparison of predictive performance

Segmentation method	Average Mean Squared Error
No segmentation	2.548
Segmentation by shipper function	2.445
Segmentation by receiver function	2.422
Segmentation by the receiver and shipper function combination	2.403

Conclusions

- The **conceptual EOQ model** is inappropriate to use in an urban context.
- It is important to consider **both receiver function and commodity types** to capture the heterogeneity in the shipment size selection mechanism.
- The **shipper function** allows for capturing the difference in transport cost structure.
- The **contribution of the receiver & shipper function data** to the overall predictive performance might be limited, though not negligible.

Acknowledgements

This research is supported in part by the Singapore Ministry of National Development and the National Research Foundation, Prime Minister’s Office under the Land and Liveability National Innovation Challenge (L2 NIC) Research Programme (L2 NIC Award No L2 NICTDF1-2016-1.). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not reflect the views of the Singapore Ministry of National Development and National Research Foundation, Prime Minister’s Office, Singapore. We thank the Urban Redevelopment Authority of Singapore, JTC Corporation and Land Transport Authority of Singapore for their support. We also thank the Transportation Planning Commission of the Tokyo Metropolitan Region for sharing the data for this research.