A POINT-INCENTIVE SCHEME TO SMOOTH THE EVENING DEPARTURE PEAK IN SHIBUYA

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Agenda

01	Background
02	Basic Analysis
03	Purpose
04	Hypothesis
05	Proposed Model
06	Estimation Results

Background

Shibuya, a sub-center with diverse urban functions

- Severe congestion occurs during the homebound peak

Railways

Station concourses

Surrounding commercial districts

- Two groups mix: commuters and visitors to the area

Rushing home after work

Flexible dwell time

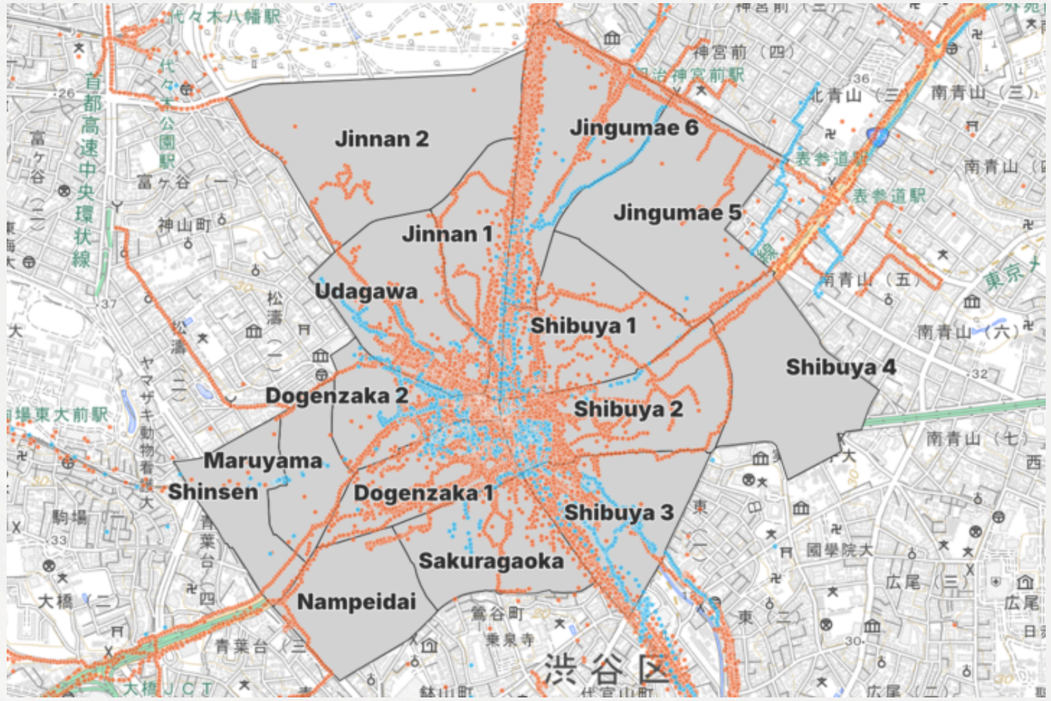
Basic Analysis

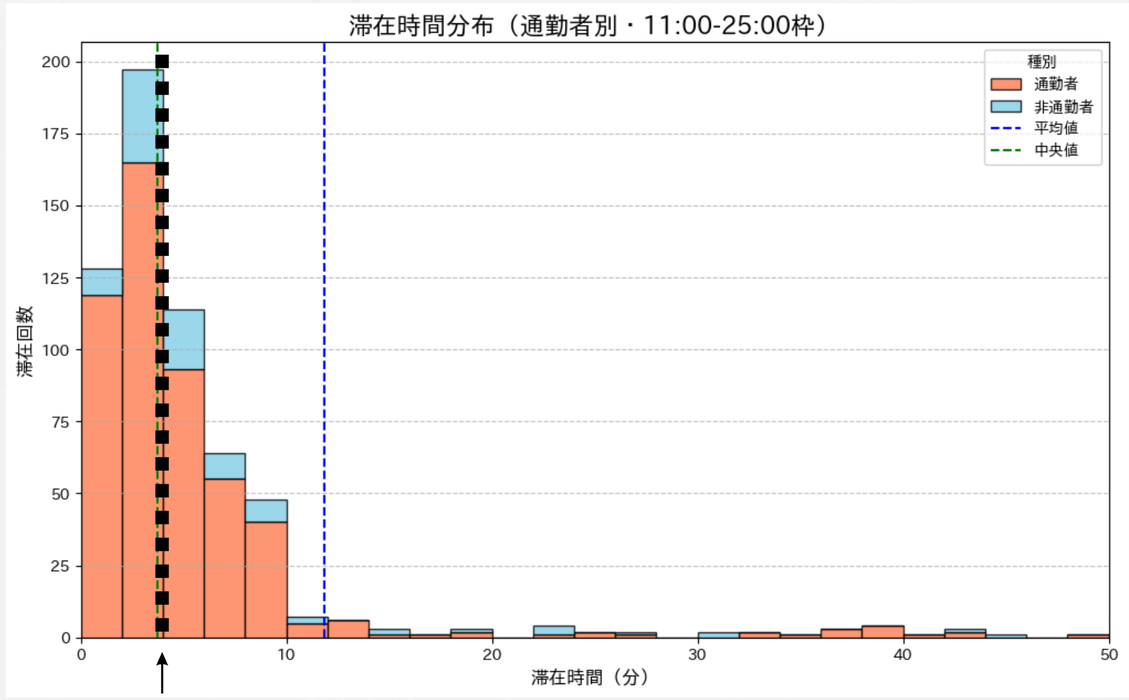
COMMUTERS VS. NON-COMMUTERS

2023 Shibuya PP
- Commuters: 325 individual daily visits
- Non-commuters: 61 individual daily visits

Commuters

Non-commuters





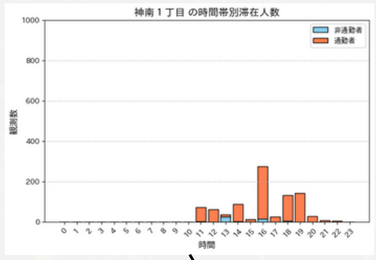
Median

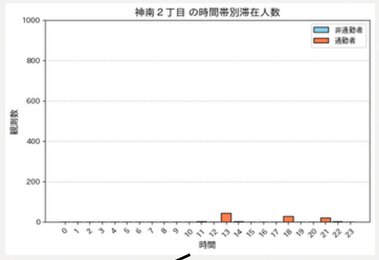
Distribution of users' dwell time

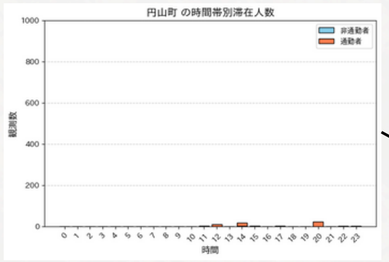
→ Tracking movement in 3-min intervals based on median stay time (3.76 min)

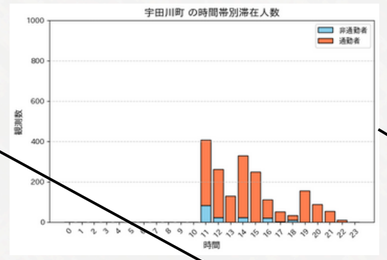
Basic Analysis

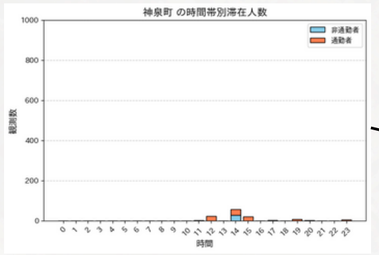
Distribution of users' dwell time

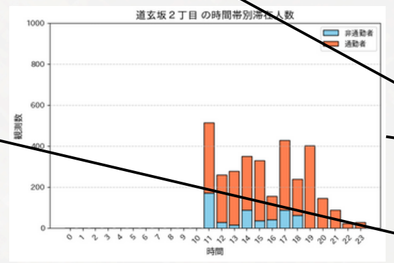


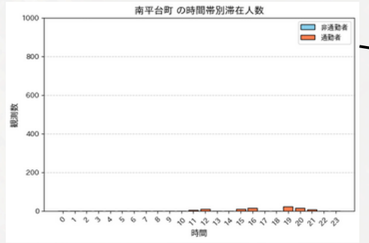


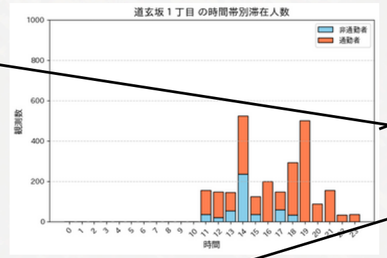


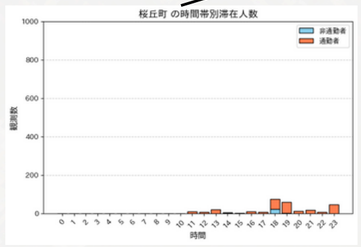


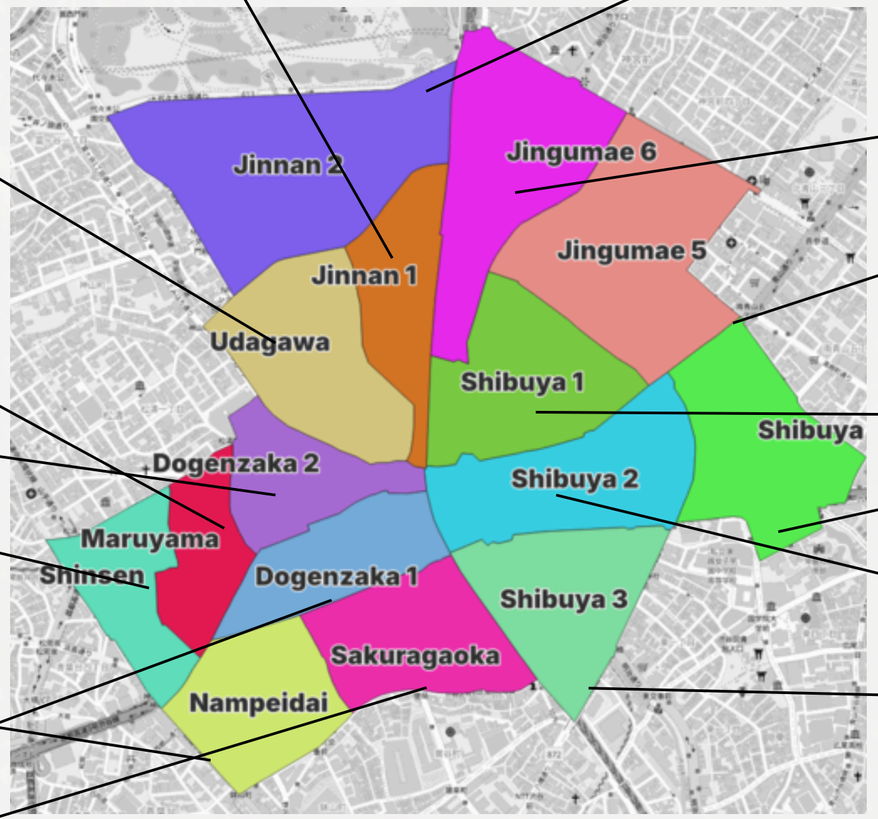


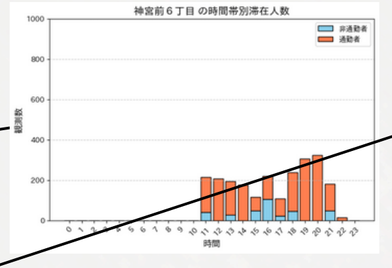


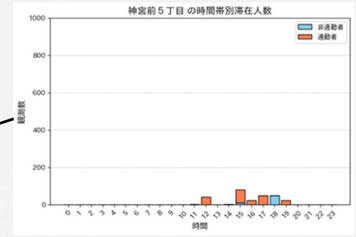


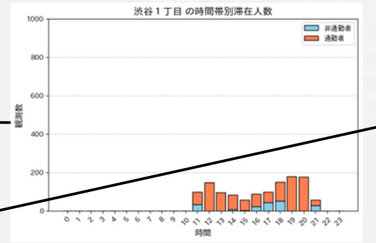


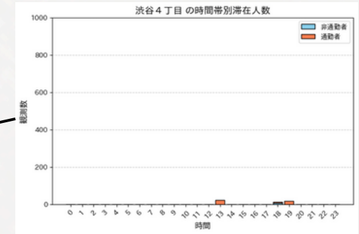


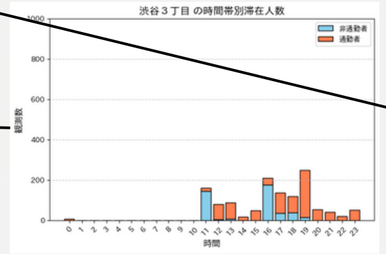


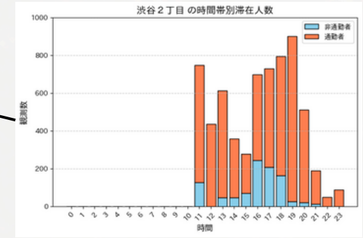












The return-home period is defined as **11:00–25:00**.

People are concentrated around the station.

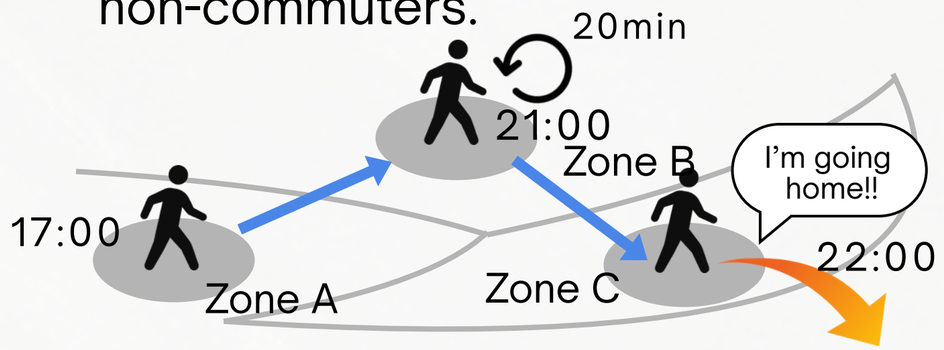
The peak time of the number of people differs by zone.

Purpose

Smoothing congestion around Shibuya Station during the evening homebound peak through point-based incentives

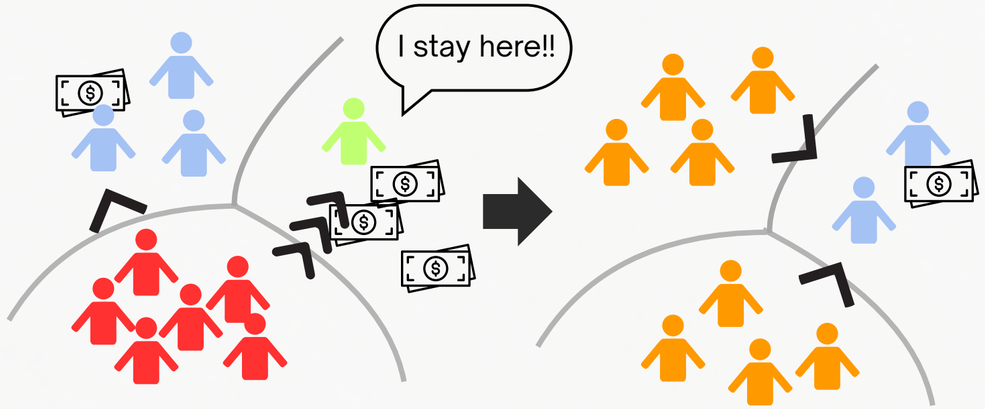
Departure-time + Circulation-zone choice model

- Estimate parameters separately for commuters and non-commuters.



Optimization of point allocation

- Search for the optimal temporal–spatial distribution of points.



Proposed Model

Nested Logit Model (Commuters)

KEEP ROAMING OR GO HOME?

Roaming/Home Choice Model

ROAMING

GO HOME

MOVE NOW OR STAY PUT?

Move-or-Stay Choice Model

MOVE

STAY

WHICH ZONE?

Zone Choice Model

Zone A

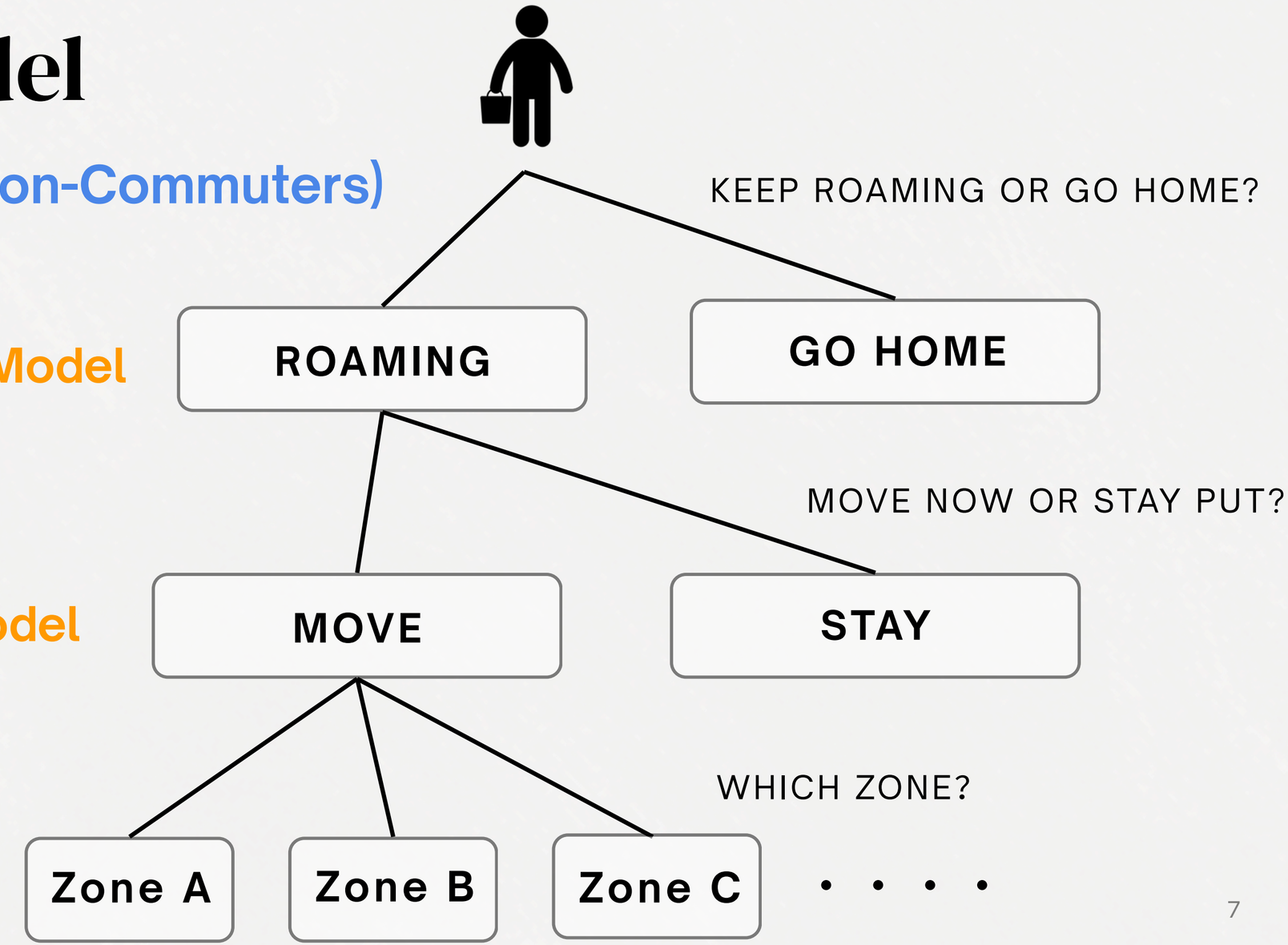
Zone B

Zone C

• • • •

Proposed Model

Nested Logit Model (Non-Commuters)



Roaming/Home Choice Model

Move-or-Stay Choice Model

Zone Choice Model

Proposed Model (Optimization)

Objective Function

$$\min f(\mathbf{x}) = w_{\text{temporal}} \cdot \Delta_t + w_{\text{spatial}} \cdot \Delta_s$$

$$\Delta_t = \max_t \left(\sum_{z=1}^{Z} D_{z,t} \right) - \min_t \left(\sum_{z=1}^{Z} D_{z,t} \right)$$

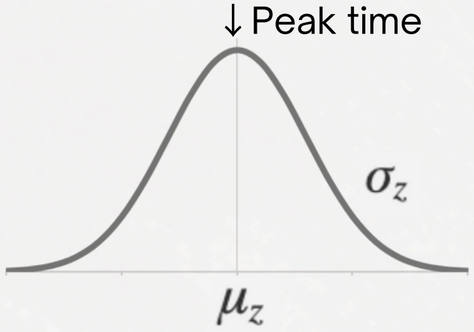
$$\Delta_s = \max_z \left(\sum_{t=1}^{T} D_{z,t} \right) - \min_z \left(\sum_{t=1}^{T} D_{z,t} \right)$$

Constraints

$$0 \le A_z \le 500 \qquad \forall z \in \{1, 2, \ldots, Z\}$$ ←Maximum point reward

$$17 \times 60 \le \mu_z \le 22 \times 60 \qquad \forall z \in \{1, 2, \ldots, Z\}$$ ←Peak time for point distribution

$$15 \le \sigma_z \le 120 \qquad \forall z \in \{1, 2, \ldots, Z\}$$ ←Temporal variance (standard deviation)



Estimation Results: Commuters

Variables	Parameters	t-values
Num of Zone Changes	-0.42	-8.01**
Current Time	0.0069	2.25*
Scale parameter_1	1.00	NaN
Nest1 (Roaming/Home Choice)		
Dwell Time	-4.14	-10.66**
Commercial Density	-2.54	-8.49**
Dist. from Station	-148.60	-3.645**
in the current zone		
Scale parameter_2	1.00	158.94**
Nest2 (Move-or-Stay Choice)		

Variables	Parameters	t-values
Dist. from Current Zone	31.51	16.20**
Commercial Density	-2.54	-8.49**
Dist. from Station	-148.60	-3.645**
Nest3 (Zone Choice)		
Samples	325	
Log-Likelyhood at 0	-2811.40	
Final log-Likelihood	-552.10	
ρ^2	0.80	
Adjusted ρ^2	0.80	

*p < 0.05, **p < 0.01

Estimation Results: Non-commuters

Variables	Parameters	t-values
Num of Zone Changes	0.0011	0.0048
Current Time	0.00020	NaN
Scale parameter_1	1.00	2.85**
Nest1 (Roaming/Home Choice)		
Dwell Time	2.45	2.29*
Commercial Density	1.67	3.52**
Dist. from Station	-2.44	-8.13**
in the current zone		
Scale parameter_2	1.00	1.28
Nest2 (Move-or-Stay Choice)		

Variables	Parameters	t-values
Dist. from Current Zone	-21.34	-1.94
Commercial Density	3.52	3.52**
Dist. from Station	-2.44	-8.13**
Nest3 (Zone Choice)		
Samples	61	
Log-Likelyhood at 0	-601.65	
Final log-Likelihood	-149.86	
ρ^2	0.75	
Adjusted ρ^2	0.74	

*p < 0.05, **p < 0.01

Conclusion

This time, the estimation by the Nested Logit (NL) model did not go well.

Possible reasons include:

- Issues with the nested structure
- Inappropriateness of explanatory variables
- Mismatch between the polygon size and the current circulation/stay patterns
- Inconsistency in the scale of the model

Future Work

新技術：組合せオークションを用いたクーポン提供による人流制御

- 最も人流分散できるクーポン獲得者の組合せを算出
  → 混雑緩和と個人満足度向上を両立

Appendix

Data Organization for Time Value Estimation:

- Target Area: Tokyo
- Fiscal Year 2022: Tokyo Metropolitan Gross Product (129.2 trillion yen)
- Population: Approximately 14.07 million (2022)
- Exchange Rate: 140 JPY/USD (assumed conversion)
- GDP per capita: 61,029 USD/person

Value of Time Savings Formula:

$$VTTS = e^{-4.191} \times (GDP\ per\ capita)^{0.696}$$

$$VTTS_{base} = e^{-4.191} \times (61,029)^{0.696} \approx 32.1\ USD/h$$

Reference: World Bank "Meta-analysis of the Value of Travel Time Savings in Low- and Middle-Income Countries" PP289

Public Transportation User Time Value (Railways, Buses, etc.)

Public Transportation User Adjustment Factor (-50%):

$$VTTS_{public} = 32.1 \times 0.5 = 16.05\ USD/h$$

Conversion:

$$16.05 \times 140 = 2,247\ JPY/h$$

$$\frac{2,247}{60} \approx 37\ JPY/min$$

Pedestrian Time Value

Pedestrian Adjustment Factor (+101% → 2.01×):

$$VTTS_{walk} = 32.1 \times 2.01 = 64.5\ USD/h$$

Conversion:

$$64.5 \times 140 = 9,030\ JPY/h$$

$$\frac{9,030}{60} \approx 151\ JPY/min$$