Expansion of shared cycle ports optimized for businesses and society

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Background

While shared bicycles contribute to urban mobility and reducing environmental impact, operators face the challenge of balancing setup and expansion costs with revenue.

Koto Ward also seeks to enhance convenience and ensure the continued operation of the service.

Purpose

We propose a model for selecting ports to expand, taking into account changes in users' transportation choices due to the changes in the capacity of existing ports.

Data

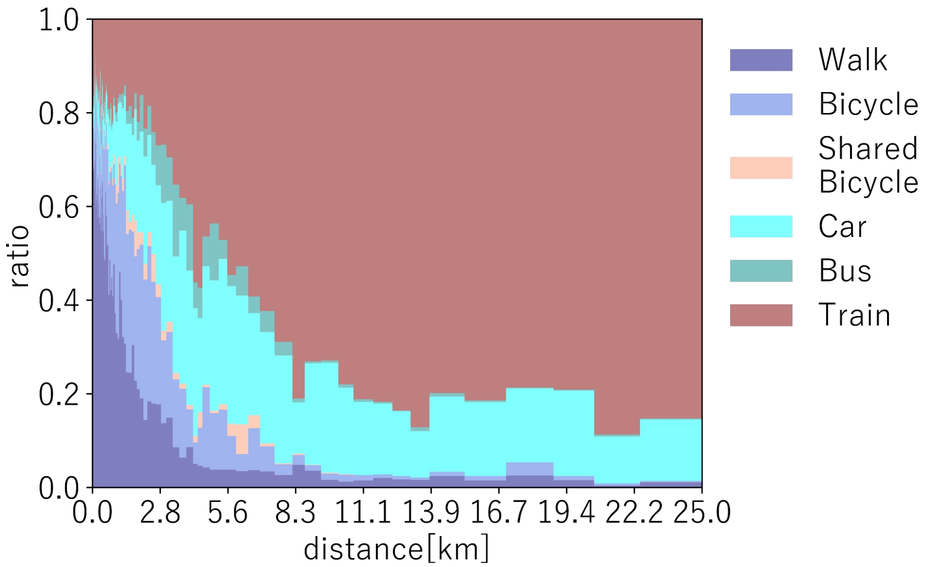
Toyosu 2019–2021 PP Data

- Focusing on Origin-Destination Data within Toyosu and Adjacent Islands
- Data Count : 43,271

Toyosu Bike-Share Port Locations and Capacity

- Port Locations, Capacity, and Rental Data for Docomo Bike Share Services

basic analysis

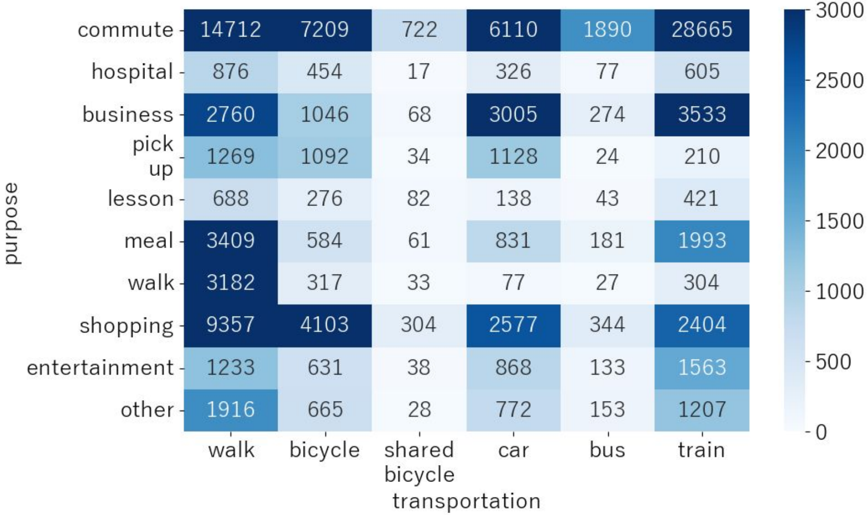


Transportation Mode Share by Travel Distance

Shared bikes have per-30-minute pricing
→Peak usage around 6km

People traveling within 6km using privately owned bikes or cars have motivation to switch to shared bikes.

basic analysis



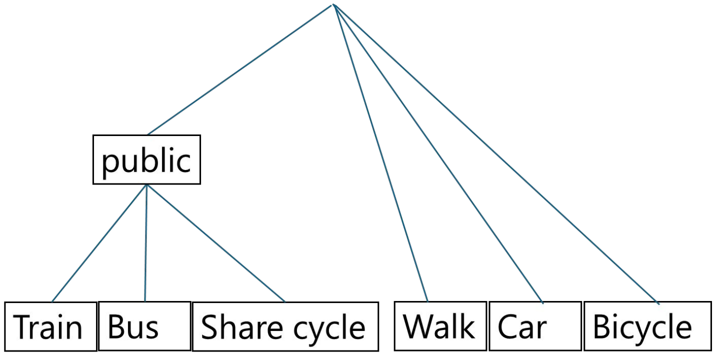
〈Results〉

- Most shared bike users travel for commuting or shopping.

〈Effective Countermeasures〉

- Adjusting capacity at stations and residential area ports during morning/evening rush hours
- Establishing new ports near commercial facilities or expanding existing port capacity

Nested logit model



T	Travel time
C	Travel expenses
N	Transfer Dummy
L_{ac}	Access distance
L_{eg}	egress distance
δ	Sex
Y	age
M	Income
tmp	Temperature
W	Weather

$$V_{\text{train}} = \beta_{\text{time}} T_{\text{train}} + \beta_{\text{cost}} C_{\text{train}} + \beta_{\text{norikae}} N_{\text{train}} + \beta_{\text{access}} L_{\text{ac,train}} + \beta_{\text{egress}} L_{\text{eg,train}}$$
$$+ \beta_{\text{sex}} \delta + \beta_{\text{age}} Y + \beta_{\text{income}} M + \beta_{\text{temp}} tmp + \beta_{\text{weather}} W + ASC_{\text{train}}$$

Maximization of corporate profits

$$\max G$$

subject to

$$G = f \times \Delta t - \sum_i c_i x_i - \sum_j \gamma_j y_j$$

$$\sum_i x_i \leq N \qquad \forall i \in O$$

$$0 \leq x_i \leq n \qquad \forall i \in O$$

$$x_i = 0 \qquad \forall i \in L$$

$$y_i \in \{0, 10\} \qquad \forall i \in \nu$$

Table1: Notation of the Corporate Profit Maximization Problem

Figure	Definition
G	corporate profit
f	shared cycle fees
Δt	increased usage time
c_i	cost required to expand Port i by 1 unit
x_i	number of additional port i unit
γ_i	new port installation cost
y_i	capacity of new port i.
N	total expansion limit of ports
n	expansion limit of 1 port
L	port set that already has sufficient capacity
O	existing port set
ν	set of potential new port sites

Social Optimization

$$\max B$$

subject to

$$B = -\Delta p \times v - \left(\sum_i c_i x_i + \sum_j \gamma_j y_j \right) a$$

$$\sum_i x_i \leq N \qquad \forall i \in O$$

$$0 \leq x_i \leq n \qquad \forall i \in O$$

$$x_i = 0 \qquad \forall i \in L$$

$$y_i \in \{0, 10\} \qquad \forall i \in \nu$$

$$f \times \Delta t - \left(\sum_i c_i x_i + \sum_j \gamma_j y_j \right) (1 - a) \geq 0$$

Table2: Notation of social optimization problems

Figure	Definitioin
B	benefit
Δp	change in time of use of individual transportation
v	time value
a	Subsidy rate for additional or new ports
c_i	cost required to extend port i by 1 unit
x_i	Number of additional port i.
γ_i	cost of setting new port i.
y_i	capacity of new port i.
N	total expantion limit of ports
n	expansion limit of 1 port
L	port set that already has sufficient capacity
O	existing port set
ν	Set of potential new port sites
f	shared cycle fees
Δt	Incresed using time

result

Expected profit per rack per year (yen)	Place
52086.5	Urban Dock Lalaport Toyosu
52086.5	Life Toyosu Store
48127.6	Hulic Toyosu Prime Square
42330.2	KDX Residence
31535.0	Toyosu Civic Center
28487.4	North side of Toyosu IHI Building
25214.0	Toyosu IHI Building (Harumi Street)

investigation

- High effectiveness of adding ports to commercial facilities is good for both users and operators because it stimulates the movement of people outside of commuting to and from work

- In the optimization process, considering the expansion cost and other costs based on the land price, it seemed difficult to make it profitable.
  - subsidy-driven public works
  - The facility management is attracting and rents are lower than expected.
  - The latent demand is large, just not taken into account.
  - Possible bias in the original data.

What was achieved and what was not achieved

- Obtaining utility function parameters using a nested logit model (completed)
- Calculating the expected increase in shared bicycle usage resulting from the rise in the “availability probability” variable for each port expansion pattern (only rack increase 1 executed)
- Calculate the expected increase in shared bicycle usage resulting from reduced “access distance” and “egress distance” due to new port construction (could not be executed)
- Convert the increase in users to increased usage revenue

Perform social optimization (could not be executed)

Perform operator optimization (only executed for rack increase 1)

Appendix

$$V_{\text{share}} = \beta_{\text{time}} T_{\text{share}} + \beta_{\text{cost}} C_{\text{share}} + \beta_{\text{access}} L_{\text{ac,share}} + \beta_{\text{egress}} L_{\text{eg,share}} + \beta_{\text{portshare}} P_{\text{share}} + \beta_{\text{sex}} \delta$$
$$+ \beta_{\text{age}} Y + \beta_{\text{income}} M + \beta_{\text{temp}} tmp + \beta_{\text{weather}} W + \beta_{\text{holiday}} D_H + \beta_{\text{rush}} D_R + ASC_{share}$$

$$V_{\text{train}} = \beta_{\text{time}} T_{\text{train}} + \beta_{\text{cost}} C_{\text{train}} + \beta_{\text{norikae}} N_{\text{train}} + \beta_{\text{access}} L_{\text{ac,train}} + \beta_{\text{egress}} L_{\text{eg,train}} + \beta_{\text{sex}} \delta$$
$$+ \beta_{\text{age}} Y + \beta_{\text{income}} M + \beta_{\text{temp}} tmp + \beta_{\text{weather}} W + \beta_{\text{holiday}} D_H + \beta_{\text{rush}} D_R + ASC_{\text{train}}$$

Appendix

Name	Value	Name	Value
ASC_BIKE	-3.99	B_SETUZOKU_BIKE	1.24
ASC_SHARE	3.02	B_SETUZOKU_BUS	1.72
ASC_TRAIN	2.83	B_SETUZOKU_SHARE	0.669
ASC_WALK	5.21	B_SETUZOKU_WALK	1.63
B_AGE_BIKE	0.332	B_SEX_BIKE	-2.87
B_AGE_SHARE	-0.346	B_SEX_BUS	-0.943
B_AGE_TRAIN	-0.386	B_SEX_SHARE	-0.659
B_AGE_WALK	-0.22	B_SEX_TRAIN	-0.711
B_COST	0.00613	B_SEX_WALK	-0.851
B_HOLIDAY	-0.178	B_TEMP_SHARE	0.0103
B_INCOM_BIKE	0.403	B_TIME_BIKE	-10.8
B_INCOM_BUS	-0.164	B_TIME_BUS	-6.45
B_INCOM_SHARE	-0.375	B_TIME_CAR	-7.6
B_INCOM_TRAIN	-0.145	B_TIME_TRAIN	-7.34
B_INCOM_WALK	-0.349	B_TIME_WALK	-7.84
B_NORIKAE	-1.43	B_WEATHER_BIKE	0.479
B_PORT_SHARE	0.642	B_WEATHER_SHARE	-0.377
B_RUSH	-0.0954	B_WEATHER_WALK	-0.151
		MU	1.35