Effect of Introducing Subscription-based MaaS to Tokyo

The University of Tokyo A

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Background and Motivation

- 定額型MaaS (Mobility as a Service) の出現
  Appearance of subscription-based MaaS.
  - **定額**で、一定エリアの**公共交通が乗り放題**になるサービス
    A service that allows unlimited rides on public transportation in a certain area for a subscription fee.

- 日本においてもMaaS導入の動きが見られる
  MaaS adoption is gaining momentum in Japan.

- 公共交通事業者が乱立する東京において、定額型MaaSのインパクトは大きいと考えられる
  In Tokyo, where public transport operators are in disarray, the impact of fixed-price MaaS is expected to be significant.

仮説　Hypothesis

- 消費行動の変化・拡大
  Change and expansion of consumer behavior
- 満足度の高い交通体系の実現
  Realization of a highly satisfactory transportation system

Ex. whim, Finnish mobility application

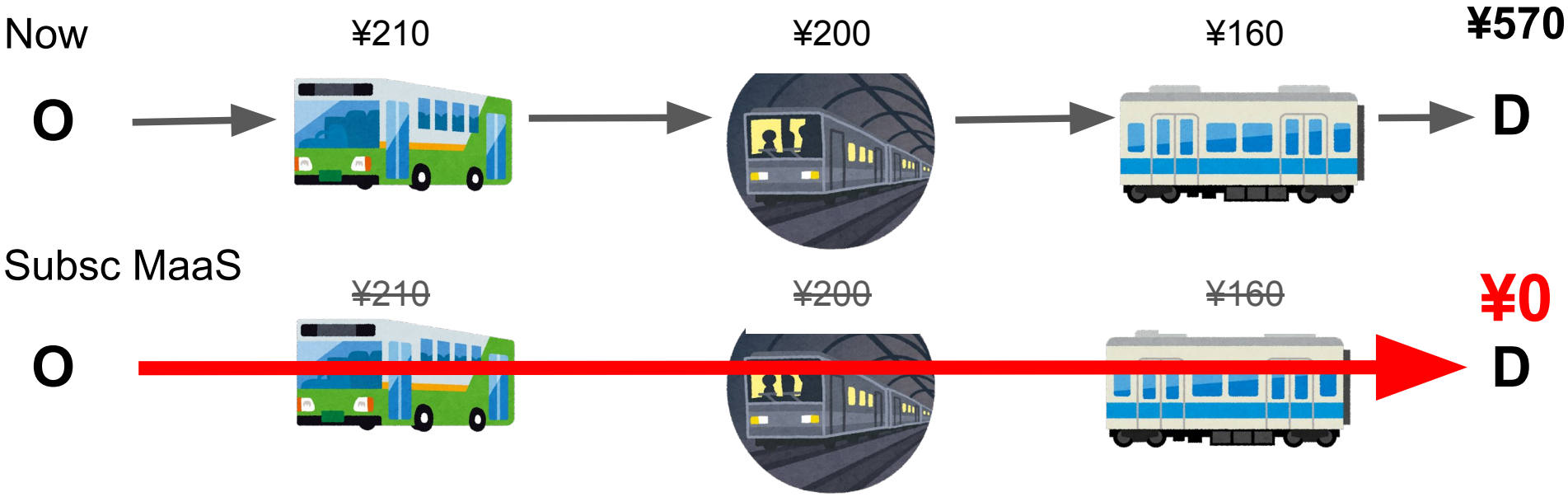
出典：whim, https://whimapp.com/jp/package/whim-japan/

Ex. 複雑に入り組んだ地下鉄　/ The intricate subway system.

出典：都営地下鉄路線図、東京都交通局　，
https://www.kotsu.metro.tokyo.jp/subway/line.pdf

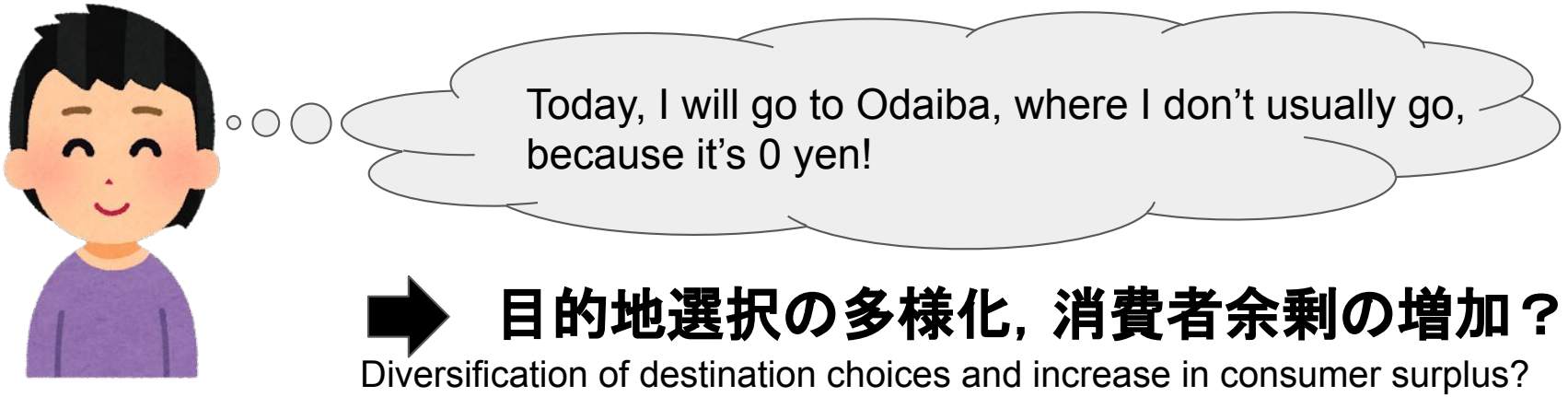
Mobility as a Service

定額型MaaS　Subscription-based MaaS (Subsc MaaS)



定額料金を支払えば、都内の公共交通乗り放題

Unlimited use of public transportation in Tokyo for a flat rate



➡ **目的地選択の多様化，消費者余剰の増加？**

Diversification of destination choices and increase in consumer surplus?

Framework

目的：MaaS導入による余暇トリップの目的地の変化・効用の変化を予測し，政策評価を行う

Goal: Predicting change in destination and utility of leisure trips by MaaS, and conducting policy evaluation

Data
・Toyosu PP 2019, 2020
→Trips of leisure purpose from Toyosu
n=1231 (2019), 1064 (2020)

Modelling = Nested Logit model
・Upper nest is destination choice, lower nest is mode choice

Estimation
・User classification with **EM algorithm**

Some may evaluate **cost**, and the others **attractiveness of destination**.

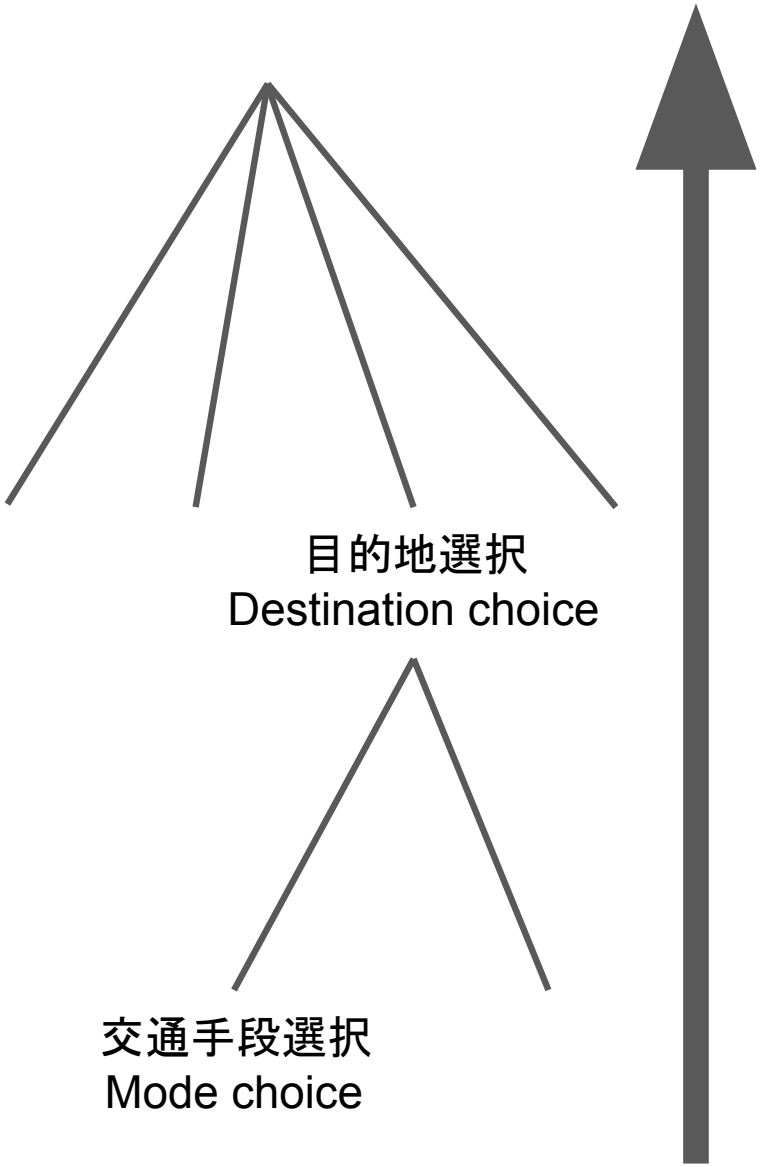
Parameters

MaaS simulation
・Probability of subscribing MaaS
・Trip distribution

Evaluation of the effect of MaaS
・Calculate benefit
・relation b/w benefit and monthly fee

NL model (Estimation)

- NLモデルによる目的地・交通手段選択　Choice of destination and mode by NL model



活動の選択確率　Probability of activity choice

$$P(d,m) = P(m|d)P(d)$$

条件付き確率　Conditional probability

$$P(m|d) = \frac{\exp\{\mu(V_m + V_{dm})\}}{\sum_{m'} \exp\{\mu(V_{m'} + V_{dm'})\}}$$

周辺確率　Marginal probability

$$P(d) = \frac{\exp\{\mu^d(V_d + V'_d)\}}{\sum_{d'} \exp\{\mu^d(V_{d'} + V'_{d'})\}}$$

ログサム変数　Calculation of logsum

$$V'_d = \frac{1}{\mu^{dm}} \ln \sum_m \{\mu^{dm}(V_m + V_{dm})\}$$

Specification of Utility Function (Estimation)

潜在クラス分け(EMアルゴリズム)を用いた定式化
Formulation with latent classifiers (EM algorithm)

- 目的地d, 移動手段m の効用関数(クラスk)
  utility function (destination d, mode m and class k)

$$= V_d^k + V_{dm}^k + V_m$$

目的地の魅力度
- **店舗数**
- Google検索結果の件数
- 駅乗降客数

Attractiveness of the destination
- **Number of stores**
- Number of Google search results
- Number of passengers getting on and off the station

手段mでの
目的地dへの運賃
Fare to destination d by mode m

手段mでの目的地dまでの
所要時間
Time required to destination d by mode m

手段mの定数項
Constant term of mode m

- 目的地d, 移動手段m の選択確率
  Probability of choosing destination d and mode m

$$P_{dm} = \sum_k s^k P_{dm}^k$$

クラスk帰属時の選択確率
Choice probability when belonging to class k

クラスkへの帰属確率
Attribution probability to class k

Specification of Utility Function (Simulation)

効用関数(クラスk) utility function (class k)

- 定額型MaaSに**登録する**場合s　registered case s

$$V_d^k + V_{sdm}^k + V_m^k + V_s^k$$

V_d^k	V_{sdm}^k	V_m^k	V_s^k
目的地の魅力度 Attractiveness of the destination	**運賃0** **Fare is zero** 所要時間 Time required	定数項 Constant term	**MaaSの定額料金** Flat rate of MaaS

- 定額型MaaSに**登録しない**場合s'　unregistered case s'

$$V_d^k + V_{s'dm}^k + V_m^k + V_{s'}^k$$

V_d^k	$V_{s'dm}^k$	V_m^k	$V_{s'}^k$
目的地の魅力度 Attractiveness of the destination	**通常運賃** **Standard fare** 所要時間 Time required	定数項 Constant term	**0**

NL Model (Simulation)

MaaS登録有無選択
Whether to register to MaaS

Tトリップ分の
目的地・交通手段選択
Choice of destination
and mode of n trips

活動の選択確率　Probability of activity choice

$$P(s,d,m) = P(d,m|s)P(s)$$

条件付き確率　Conditional probability

$$P(d,m|s) = \frac{\exp\{\mu(V_m + V_{sdm})\}}{\sum_{m'}\exp\{\mu(V_{m'} + V_{sdm'})\}} \cdot \frac{\exp\{\mu_d(V_d + V_d')\}}{\sum_{d'}\exp\{\mu_{d'}(V_{d'} + V_{d'}')\}}$$

周辺確率　Marginal probability

= MaaS登録確率　Probability of regestering to MaaS

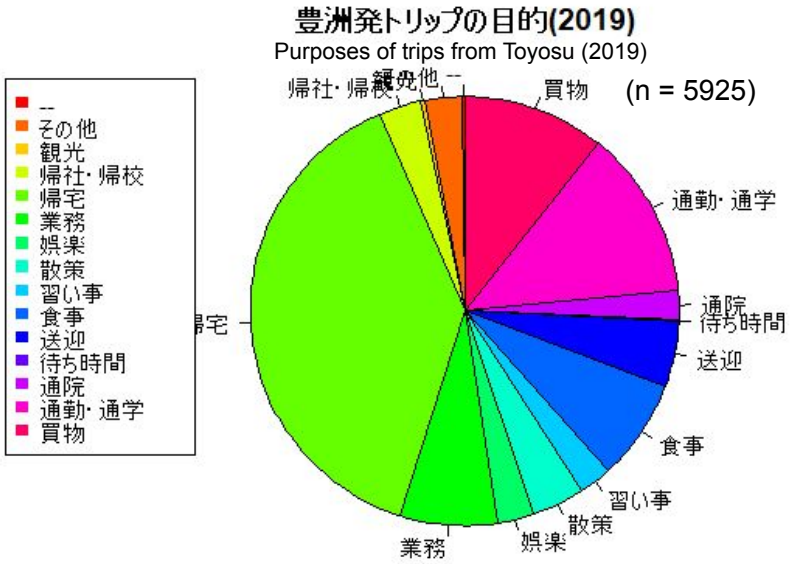
$$P(s) = \frac{\exp\{\mu_s(V_s + V_s')\}}{\exp\{\mu_s(V_s + V_s')\} + \exp\{\mu_s(V_s' + V_{s'}')\}}$$

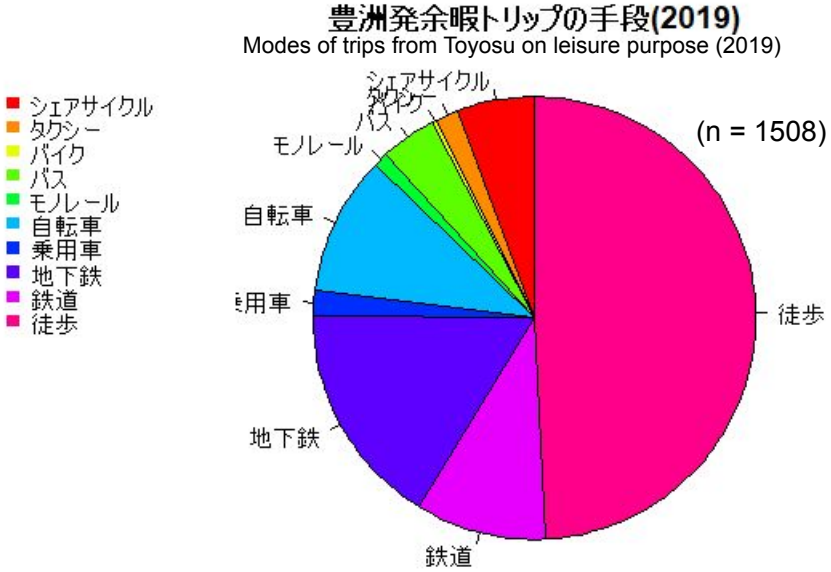
ログサム変数　Calculation of logsum

$$V_s' = \frac{T}{\mu_d}\ln\sum_d \exp\left[\frac{\mu_d}{\mu}\ln\sum_m \exp\{\mu(V_{sdm} + V_m)\} + \mu_d V_d\right]$$

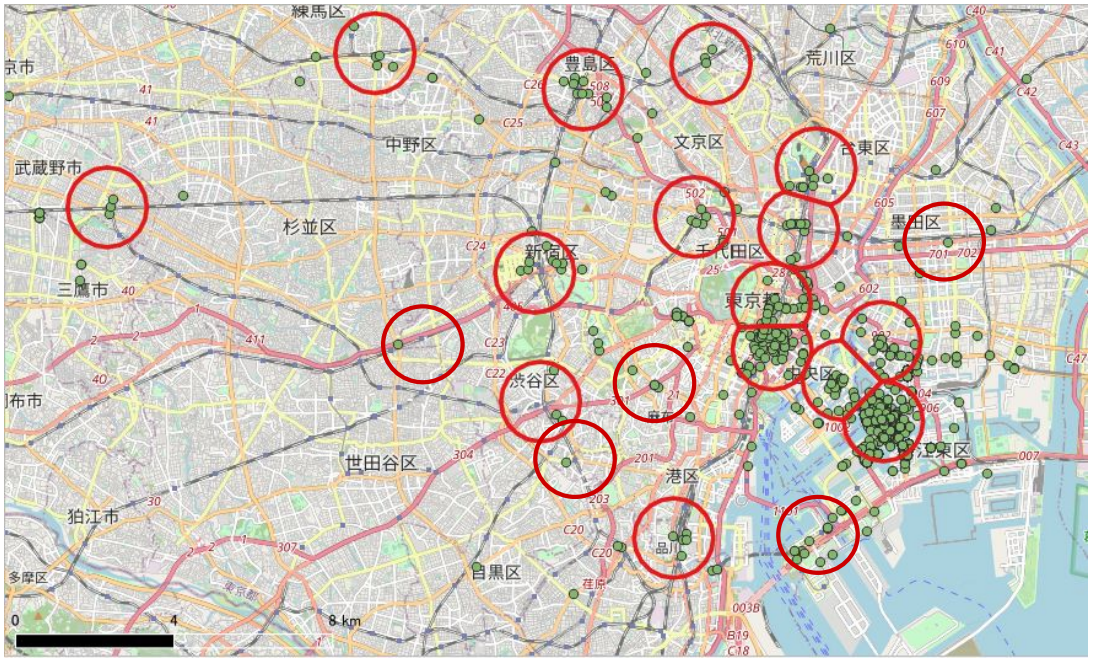
Basic Research

使用したデータ：豊洲2019PP・豊洲2020PP Data used: Toyosu 2019 PP, Toyosu 2020 PP





豊洲発余暇トリップの目的地（2019）Destination of trips from Toyosu on leisure purpose (2019)



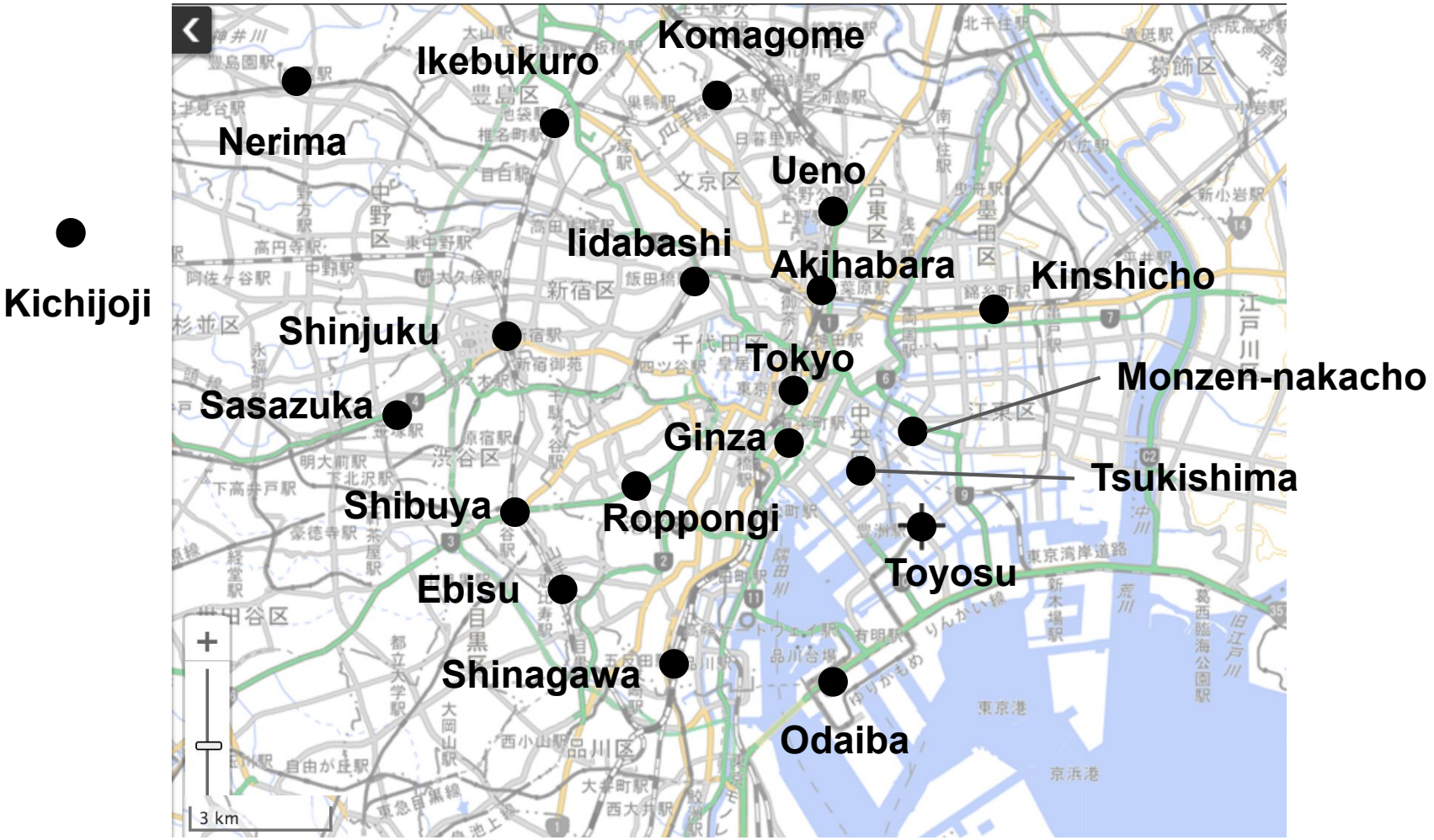
- 豊洲発のトリップは，通勤通学と同等に買物や他の娯楽も多い
  Trips originating from Toyosu are often accompanied by shopping and other entertainment, just like commuting to and from work.

- 目的地が豊洲近傍に集中し，そのため手段も徒歩が多い
  Destinations concentrated in the vicinity of Toyosu, so almost half people walk.

Destination Choice Set

豊洲発の余暇トリップで選択されることの多い20駅を抽出

We chose 20 stations as destinations that are often selected for trips of leisure purpose from Toyosu.



EM-NL Estimation Results

	2019				2020			
	class1		class2		class1		class2	
	parameter	t-value	parameter	t-value	parameter	t-value	parameter	t-value
帰属確率	0.81	-	0.19	-	0.73	-	0.27	-
fare/100	-2.69	-9.76**	-0.50	-3.23**	-4.25	-2.75**	-1.20	-5.58**
time(h)	-18.24	-7.17**	-6.34	-7.57**	-17.22	-10.08**	-10.09	-10.19**
number of shops/1000	-7.82	-4.69**	0.74	5.39**	-20.72	-4.70**	0.46	7.47**
Const_train	-0.51	-1.53	-0.51	-1.53	-0.55	-1.04	-0.55	-1.04
Const_bus	-1.35	-4.26**	-1.35	-4.26**	-1.72	-3.57**	-1.72	-3.57**
Const_car	-6.48	-13.76**	-6.48	-13.76**	-6.56	-19.79**	-6.56	-19.79**
Const_bike	-4.02	-10.32**	-4.02	-10.32**	-3.92	-15.72**	-3.92	-15.72**
Scale parameter ※(1/(1+exp(x)))で推定	0.91	-1.71	0.56	-0.46	0.67	-0.06	1.00	-2.25
number of observations		1213				1064		
LL(0)		-5668.96				-4899.90		
LL(β)		-2323.03				-1471.39		
likelihood ratio		0.59				0.70		
fixed likelihood ratio		0.59				0.70		

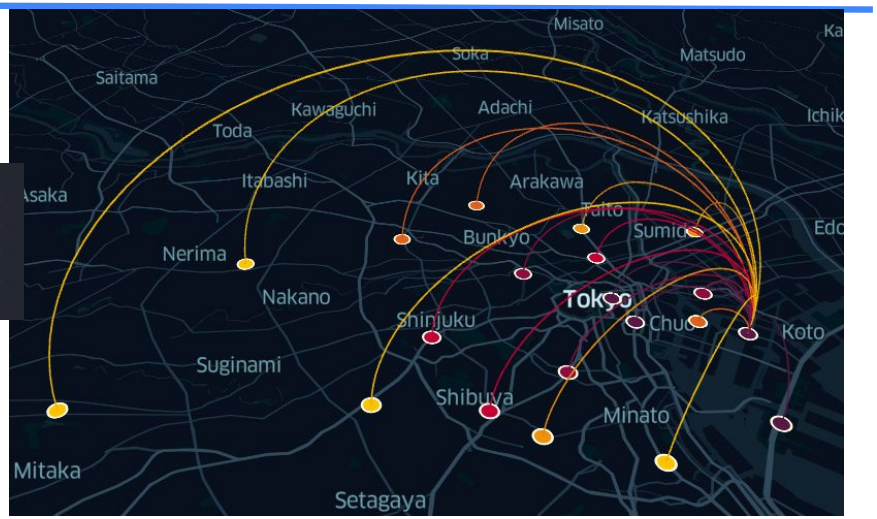
* p < 0.05
** p < 0.01

Simulation and Evaluation: Change of Destination

配分結果　Distribution results

- MaaS(2000円/30日)導入前後でのトリップ割合の変化を示した。
  the change in trip ratio before and after the introduction of MaaS (2000 yen/30 days).。

- MaaSの導入により、遠い地点の選択確率が上がっている
  The introduction of MaaS has increased the probability of selecting distant locations.

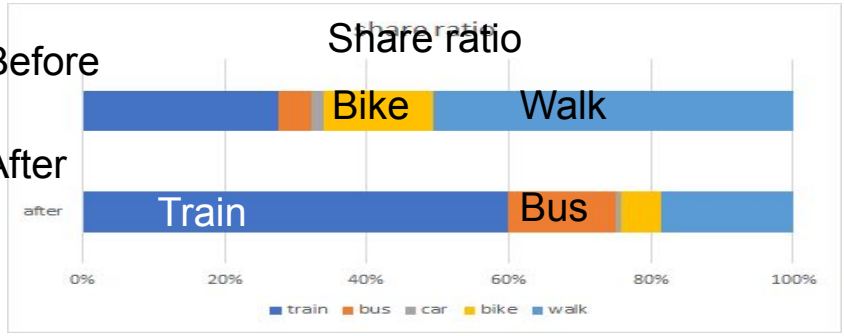


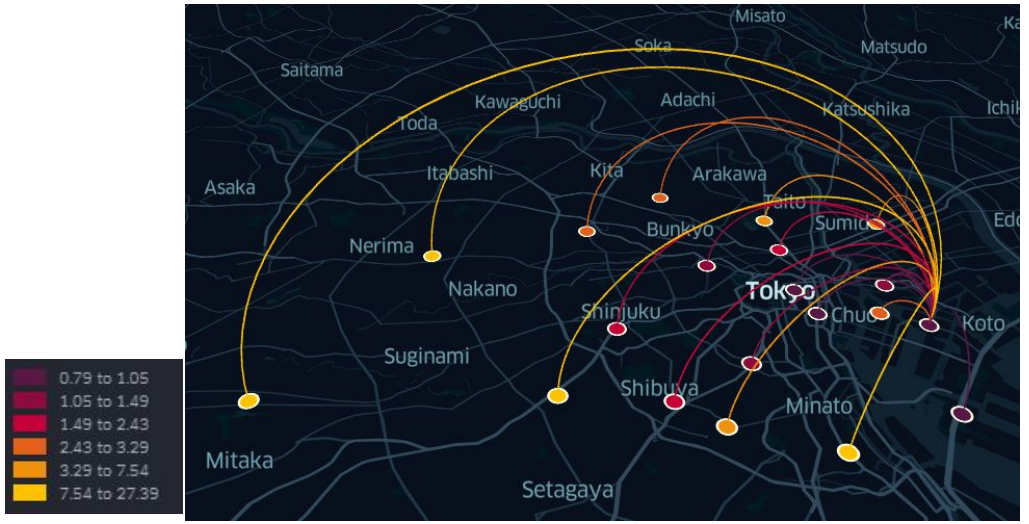
MaaS導入前後でのトリップ数の変化(導入後/導入前, 2019)
Change in the number of trips before and after the introduction o
MaaS (post-implementation/pre-implementation, 2019)

表　MaaS導入前後の平均移動距離

Table　Average distance traveled before and after the introduction of MaaS

	2019	2020
導入前(Before)	1.447km	0.762km
導入後(After)	1.691km	1.179km





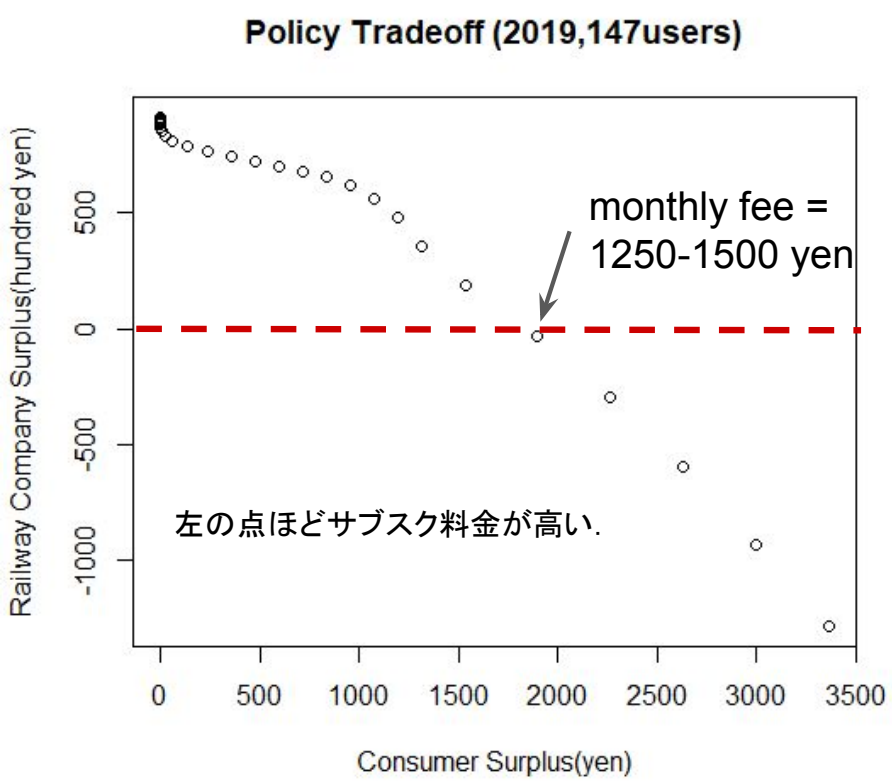
MaaS導入前後でのトリップ数の変化(導入後/導入前, 2020)
Change in the number of trips before and after the introduction of
MaaS (post-implementation/pre-implementation, 2020)

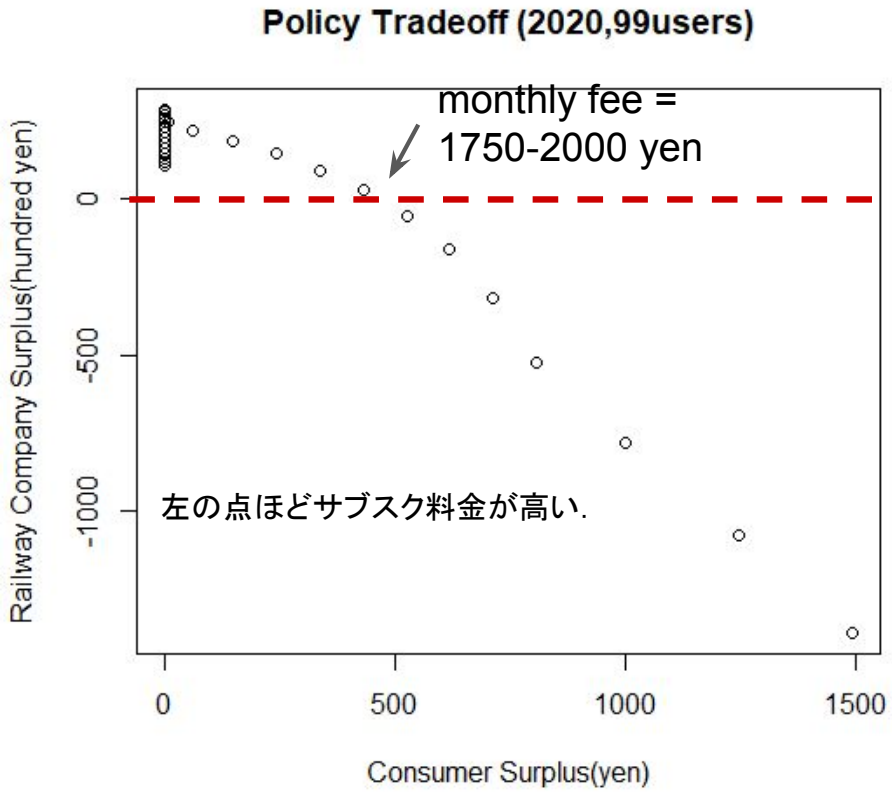
Simulation and Evaluation: Tradeoff of Interests

消費者の余剰と鉄道会社の収益余剰とのトレードオフ関係

A trade-off between consumer surplus and railroad company profits surplus.

- バランスするサブスク料金はいくらか？？
  How much is the best for a monthly fee?





- 最適な料金設定は，鉄道会社の収益が0円以上の範囲で消費者余剰を増加の効率性をみて決定される
  Optimal fee should be determined by looking at the efficiency of increasing the consumer surplus within the range where the railroad company's profit is above zero.

Summary

結論　Conclusions

- 定額型MaaSの導入により、行動範囲の拡大・多様化が喚起される
  By introducing subscription-based MaaS, action ranges get bigger and more diverse.

- 定額型MaaSの導入により、満足度がより高い交通体系が確立される。ただし、料金設定によってその上がり幅は大きく変化するため、注意が必要
  The introduction of subsc MaaS will establish a transportation system with a higher level of satisfaction. However, it is important to note that the range of increase varies greatly depending on the rate setting.

- 消費者余剰の増減と公共交通事業者の収入の増減は、トレードオフの関係にあり、適切な料金設定が必要。
  There is a trade-off between change of consumer surplus and railway surplus, so you have to be careful when setting the fee .

今後の課題　Future work

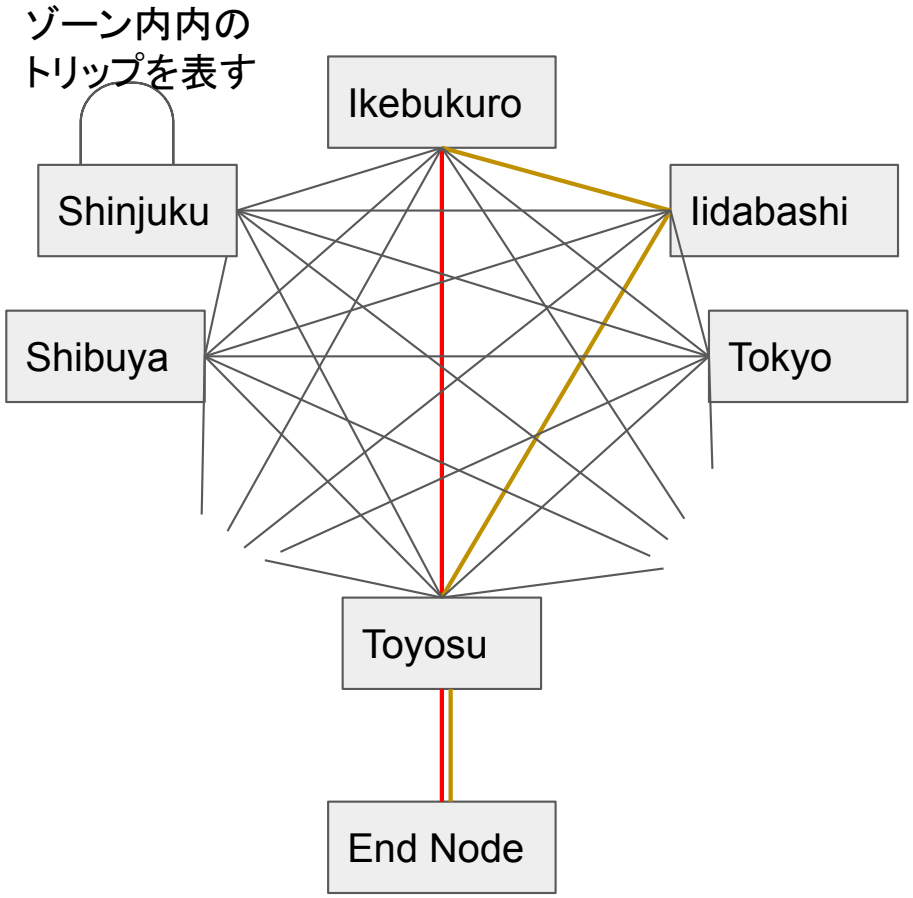
- 誘発需要の発生や、アクティビティパターンの変化の考察
  Considering induced demand and change of activity pattern.

Appendix

Increase in the number of trips associated with MaaS

- 外出をする/しないという選択は、教師データ不足のため、推定できず

- MaaSにより一度外出した人が寄り道をして帰るためにトリップ数が増えるという現象は、RLモデルで再現可能



- 左図のような、20駅がノードとして並び、相互にリンクでつなぐ仮想ネットワークを想定
- 図の赤線は、池袋から豊洲まで直接行くことを表し、茶色線は飯田橋で途中下車し、寄り道することを表す。
- 効用は運賃、時間、魅力度、交通手段ごとの定数項
- ODが決まった「寄り道」を評価できるはずだが・・・
- 時間内に計算結果が出ず

Increase in the number of trips associated with MaaS

- 朝の段階で出ていた暫定推定値で配分を行いました。
- トリップ数1.16倍
- 特に遠距離のトリップが増える
- 徒歩トリップも増えている(MaaSにより期待効用が上がるため)