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Evaluating the equity of public transport, a case study of Yokohama

Kyoto University
ITS Lab

Background

- Public transport is an important backbone of sustainable urban development, since it can provide people with mobility and access to employment, education, retail, health and recreational facilities, as well as community facilities.
- To be successful, public transport systems must have a high level of service to be attractive to non-captive users, and at the same time be affordable for low-income segments of population.
- Achieving these two targets, and still being financially viable for subsidizing local and central governments, is often difficult (Ibarra-Rojas et al. 2015).
- Spatial equity, that is, a suitable level of access and geographic coverage for everybody, is one of the most important features of popular public transport services (Murray and Wu 2003).

Background

Fare structure changes:

- In 2005, Netherlands held a fare structure change, leading to a number of complaints from commuters.
- In 2004, Seoul held a successful bus and PT fare structure reform, increasing the citizen's satisfaction from 58% to 82%, and bus users increased by 5.5%.

Especially in recent years, fare is getting more and more complicated, thanks to the smart card. But is it really "fair"? Also, is it really feasible to keep operators' revenue similar to keep their stable operation?

Objectives

- To evaluate the equity conditions in Yokohama City.
- To suggest new policy that can improve equity.
- Expect to predict changed **OD distribution, mode choice and route choice** if possible

Methodology Outline

Derived the utility function with MNL.

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Derive the generalized cost of each samples.

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Quantify the current equity with Gini coefficient

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Introduce new policy: new fare system, improvement on service frequency, etc

↓

predict the od distribution, mode choice, route choice under the new condition

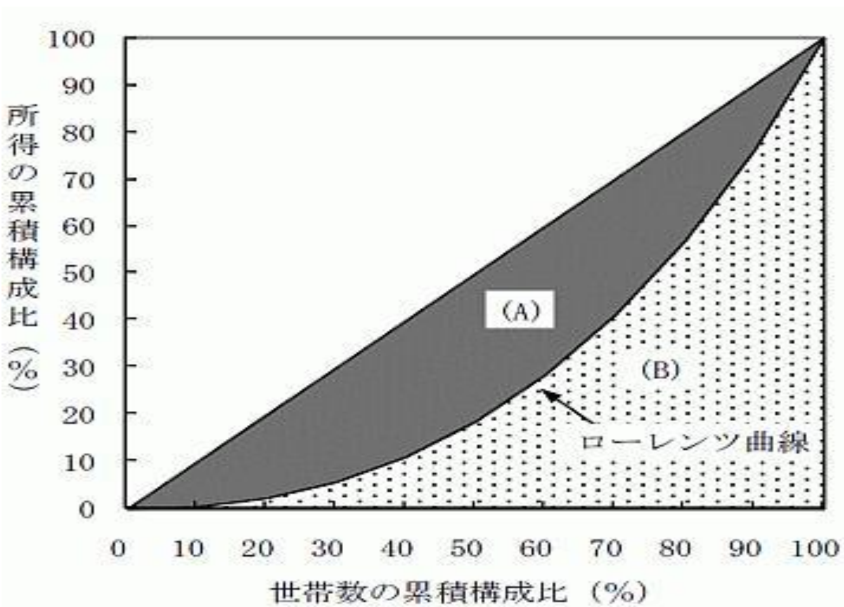
Introduction of terms

Generalized Cost

- Travel time, access and egression time and fare etc. are taken into consideration, converted into cost, and summed up.
- Usually we would consider that passengers are rational: would choose to use the mode that provides the lowest generalized cost.
- We would use it in the quantification of equity.

Gini Coefficient (ジニ係数)

- Originally: An index to quantify the inequity of income or property.
- Lorenz curve shows the proportion of overall income or wealth assumed by the bottom x% of the people.
- It is often used to represent income distribution, where it shows for the bottom x% of households, what percentage y% of the total income they have.
- In the equity evaluation on public transport, the indicator could be the proportion of overall generalized cost or accessibility



Gini coefficient$=\frac{A}{A+B}$ $(=2A)$

if 0 ⇒ Perfect equity
if 1 ⇒ Perfect Inequity

Reference: http://www.stat.go.jp/info/today/053.htm

Horizontal equity and Vertical equity

Horizontal equity (水平的公平):	Vertical equity (垂直的公平):
• To treat everybody equally, unless special treatment is justified for specific reasons.	• Progressive with respect to income or necessity.

Here we would like to spotlight on vertical equity, with respect to **needs and abilities**.

Proposal to utilize Gini coefficient for equity quantification

Vertical Equity (Progressive with respect to needs and abilities)

Should provide passengers with higher utility, who are with needs.

- Proposal of Gini coefficient

  X - axis：Cumulative population percentage with passengers sorted by the needs towards PT (from higher to lower)[%]

  Y - axis：**Disutility**[%]

  Needs of public transport at node k ： *N(k)*

$$N(k) = \frac{DU(k)}{D(k)} = \frac{-\sum_{i=1}^{n} GC_i(k)}{D(k)}$$

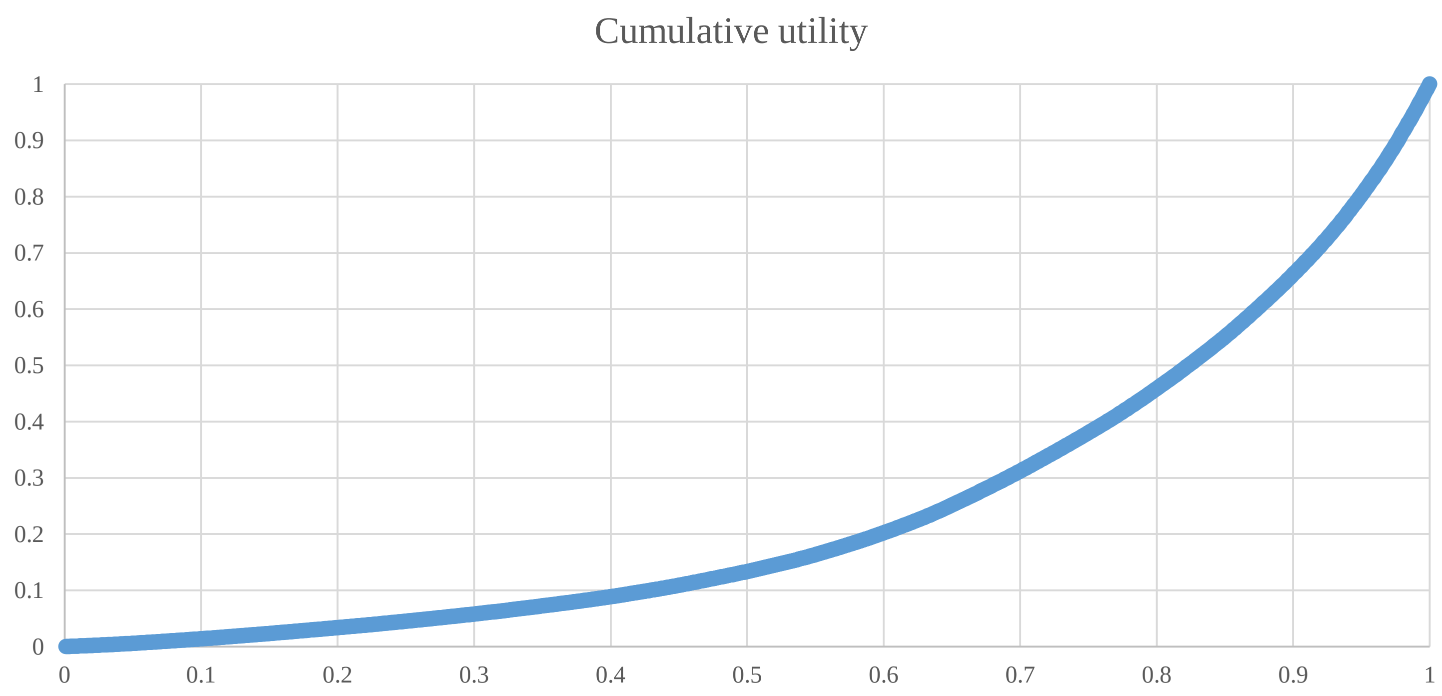
  $GC_i(k)$: Minimum generalized cost to node i from node k

  $D(k)$: Travel distance to transport center node from node k

  n : The number of all nodes

Current equity

- The current Gini coefficient is 0.52 in Yokohama City, with the Lorenz curve figure plotted as below.
- X – axis: Utility (cumulative)
  Y – axis: Population (cumulative)



Derived the utility function with MNL

Utility functions

Name	Specification
U Bus	$=ASC_B + \beta_c B *$ COST $+ \beta_t B *$ time $+ \varepsilon_1$
U Train	$=ASC_T + \varepsilon_2$ (reference)
U Walk	$=ASC_W + \beta_t W *$ time$+\varepsilon_3$
U biKe	$=ASC_K + \beta_t K *$ time$+\varepsilon_4$

Notations

ASC_B	Constant (bus)
ASC_T	Constant (train); fixed to 0
ASC_W	Constant (walk)
ASC_K	Constant (bike)
$\beta_c B$	Monetary cost of bus relative to train
$\beta_t B$	Time cost of bus relative to train
$\beta_t W$	Time cost of walk relative to train
$\beta_t K$	Time cost of bike relative to train

Derived the utility function with MNL

Utility parameters

Name	Value	Std err	t-test	p-value
ASC_B	-0.434	0.305	-1.42	0.15
ASC_K	2.29	0.206	11.13	0.00
ASC_T	0.00	fixed		
ASC_W	1.96	0.189	10.37	0.00
$\beta_c B$	0.00161	0.000497	3.23	0.00
$\beta_t B$	-0.0829	0.0140	-5.93	0.00
$\beta_t K$	-0.150	0.0118	-12.71	0.00
$\beta_t W$	-0.114	0.00868	-13.15	0.00

Number of individuals:	1010
Null log likelihood:	-1400.157
Cte log likelihood:	-1144.543
Init log likelihood:	-1400.157
Final log likelihood:	-812.370
Likelihood ratio test:	1175.574
Rho-square:	0.420
Adjusted rho-square:	0.415

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Equity Comparisons

	Current	Scenario 1	Scenario 2	Scenario 3
Details	Train - Distance Bus - Flat	Train - Flat Bus - Flat	Train - Distance Bus - Distance	Train - Flat Bus - Distance
Gini	0.52	0.66	0.49	0.61

Reference

- R. Camporeale, L. Caggiani, A. Fonzone & M. Ottomanelli (2016): Quantifying the impacts of horizontal and vertical equity in transit route planning, Transportation Planning and Technology, DOI: 10.1080/03081060.2016.1238569

- Todd Litman, Victoria Transport Policy Institute(2017). Evaluating Transportation Equity Guidance For Incorporating Distributional Impacts in Transportation Planning.