DAVeMoS BOKU | IVe Institut für Verkehrswesen

Operationalising Equity Measurement based on Distributional Effects of Policy Interventions

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Acknowledgement

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Outline

- ‘Fairness’ and fare design
- The impacts of three fare designs to equality levels
- How to make this equality measurement operatable
- Case study: Skip-stop experiment in Stockholm
- Summary

Fairness of public transport fare is a matter of public debate

- When the flat change the common debate would be who benefit more and who benefit less (“would I loose anything with this changes?)
- **Sometime the answers are far from clear, in particular when the changes were politically motivated**
- **But also when we had access to reasonable data:** the outputs highly depend on how we define the system and the definition of ‘what is fair’

Common operational approach of creating ‘fair’

- *A fare scheme usually follows how the production costs are distributed* - which then usually lead to a lowering demand for trips with high production costs and an increasing demand for trips with low production cost and increasing revenues.
- Opposition to proposed differentiations tends to center around the fairness of the proposed changes since differentiation will advantage some groups of travelers and disadvantage others (e.g. groups living far from the CBD)
- Balancing between ‘mission’ and both sides’ believe gives us different type of fare schemes

When a simplified science exercise become a ‘religion’

“The political sides have for more than a decennium fought about whether to have zonal or flat fares in the county of Stockholm. The red-greens (left of center coalition) thinks that flat fare is fair, that it makes the county more connected, that it ensures that low-income residents in the periphery can use public transport. The right-of-center parties believe that it is unfair that passengers should pay the same amount for a single stop in the subway as for traveling 100 km with the public transport system (from the south to the north of the county)”

(translation from Dagens Nyheter, 2015)


DAGENS NYHETER.

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But, is this really the case?

The points of this work:

- To show: (1) how systematic quantitative analysis of travel patterns and distributional impact can support an evidence-based professional and public debate on fare scheme choices, and, (2) to support the design of win-win schemes with regard to efficiency and equity

- Aims:
    1. to propose a framework for investigating equity impacts of different fare systems
    2. to demonstrate one of possible ways to implement the measurement in a tangible way

Accessibility as the key to achieve equity

- Access to activities is a core need for all, and the fair distribution of accessibility is directly impacting society's capacity to reach several of the UN SDGs
- A fundamental measure of transportation quality is the *accessibility*.
- There is an implicit assumption for most of existing equity measurements/discussions is that the measured distribution of accessibility should be compared with ideals of giving all citizens the same accessibility (combined with eventual compensation to certain groups defined as vulnerable or with particular needs).
- Providing public transport with the same accessibility and performance for all citizens is practically *infeasible*. In all actual cities, land use patterns, network geometry, and economies of scale make it very expensive to provide the same level of accessibility to all. *It is even questionable if this is a desirable goal to have, given the significant differences in production cost per accessibility unit in different parts of the network.*
- Substantial factors: concentration of attractive destinations and population density

Exploring different fare designs to equality

distance base vs zone base vs flat fare setting

Stockholm County

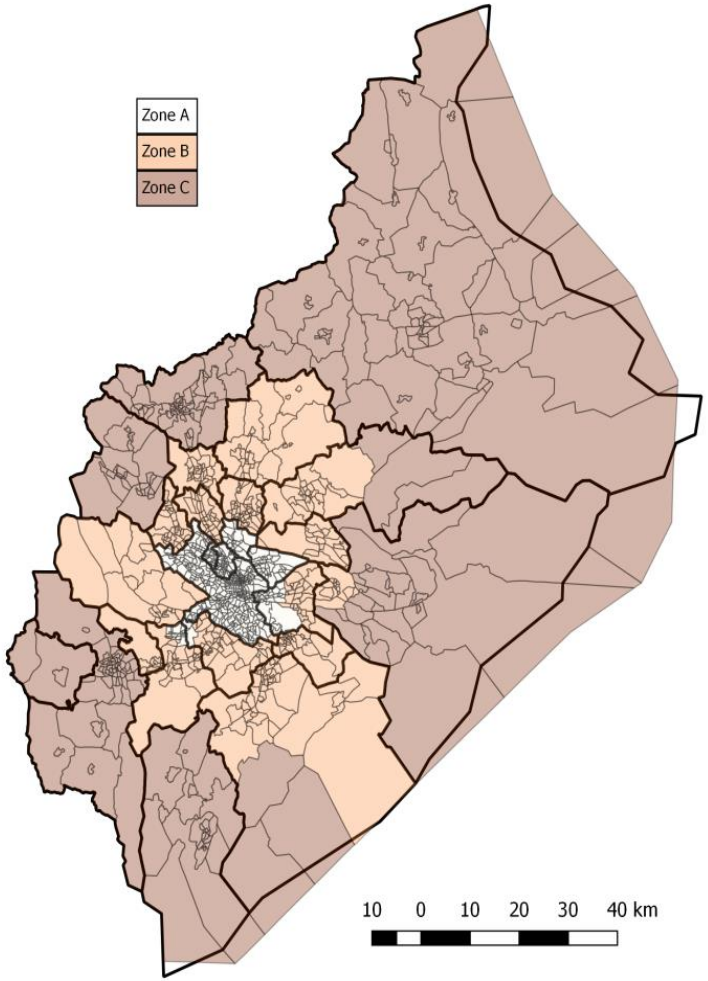
PT OD & distance matrixes, Sampers, Horizontal and Vertical Indices, Gini and Suit indexes

Stockholm County

26 different municipalities,
2.3-2.4 million people
6.519 km2

The city of Stockholm hosts approximately 40 percent of the County population.

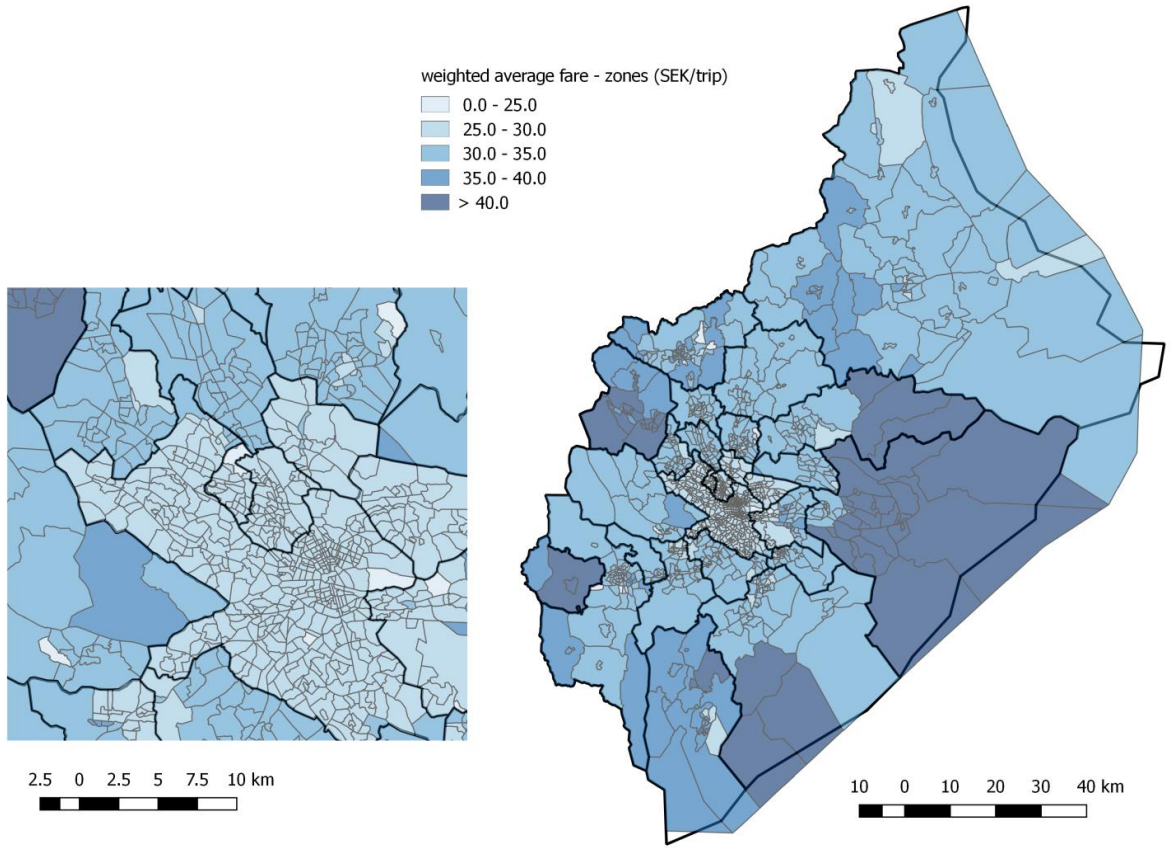
The Public transport system of Stockholm is comprised of four different modes with 2.9 million boardings on an average winter workday: Metro (1.3 million boardings), Bus (1.1), Commuter train (0.3) and Light rail (0.2).



Traveling through	Fare (SEK)
one zone	25
two zones	37.7
three zones	50

Weighted average fare – zone based

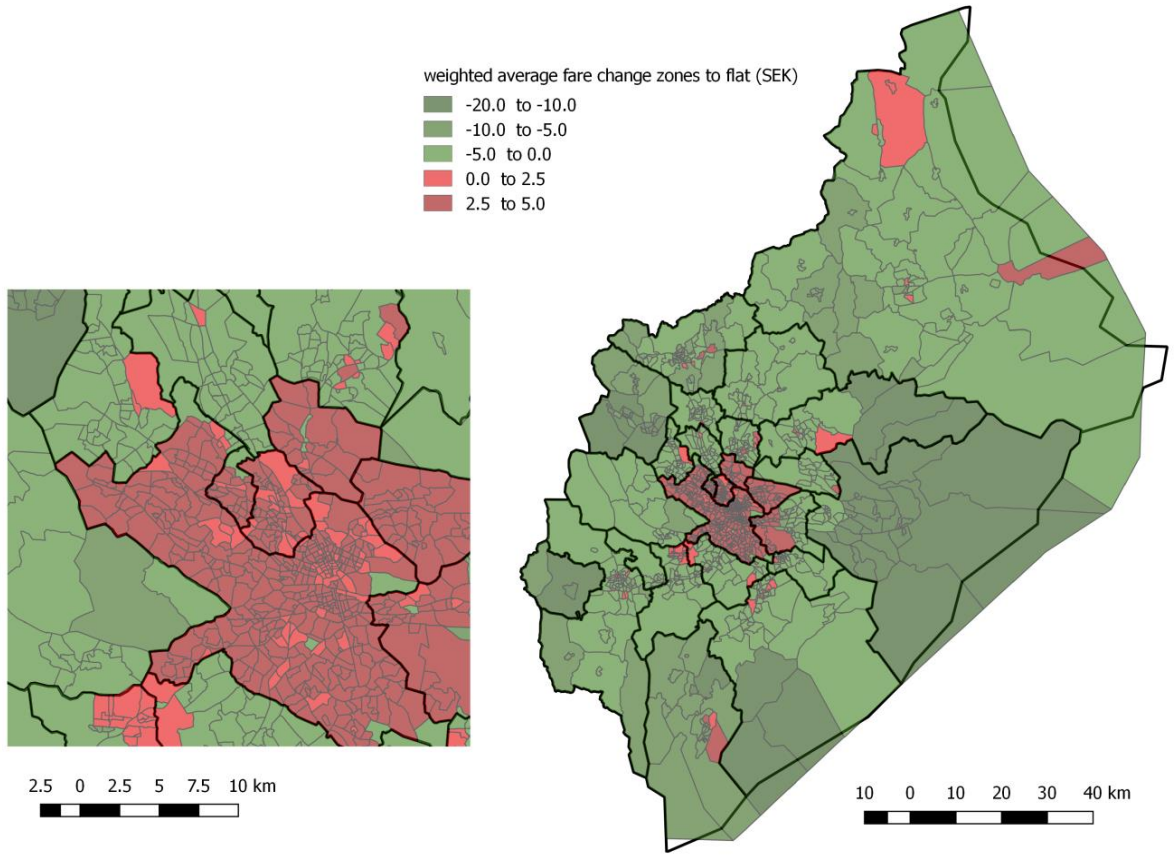
$$\overline{f_i} = \frac{1}{\sum_j d_{ij}} \sum_j d_{ij} f_{ij}$$



Weighted average fare – flat fare

$$\overline{f_i} = \frac{1}{\sum_j d_{ij}} \sum_j d_{ij} f_{ij}$$

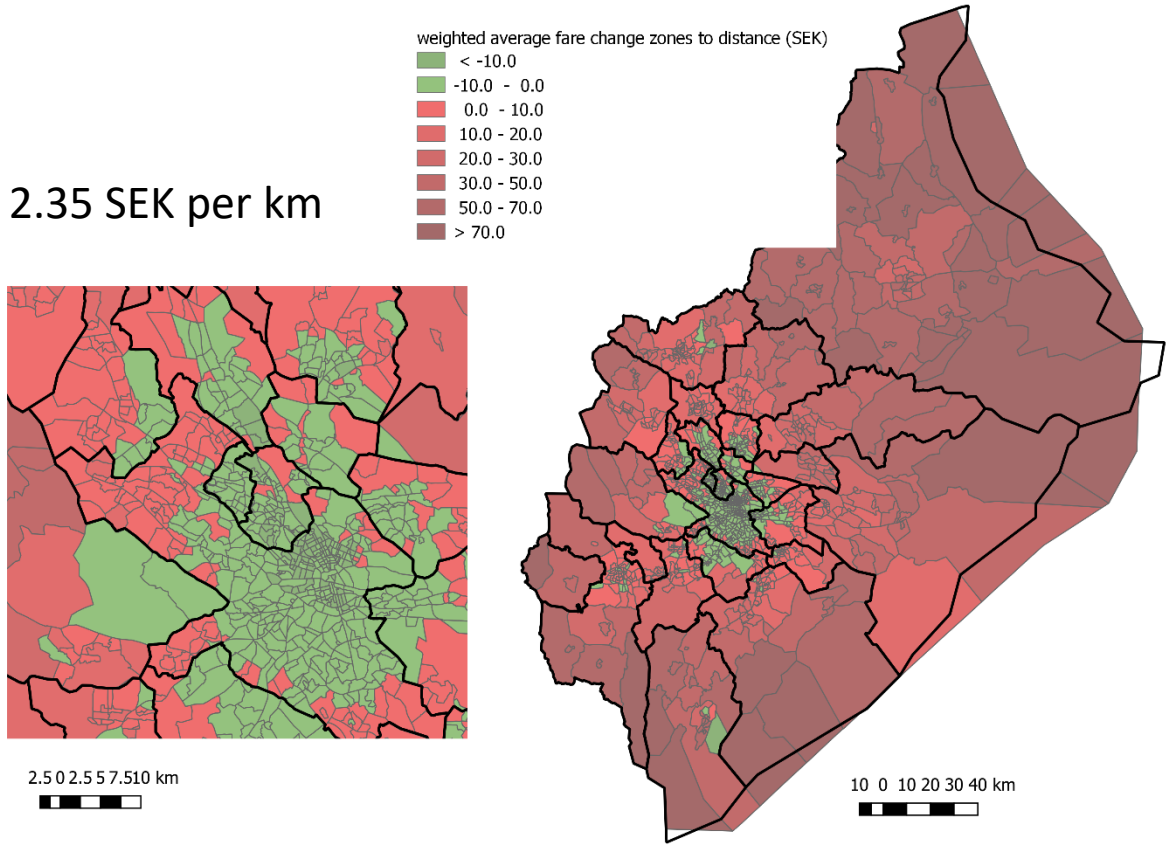
With a flat fare of 30 SEK



Weighted average fare – distance based

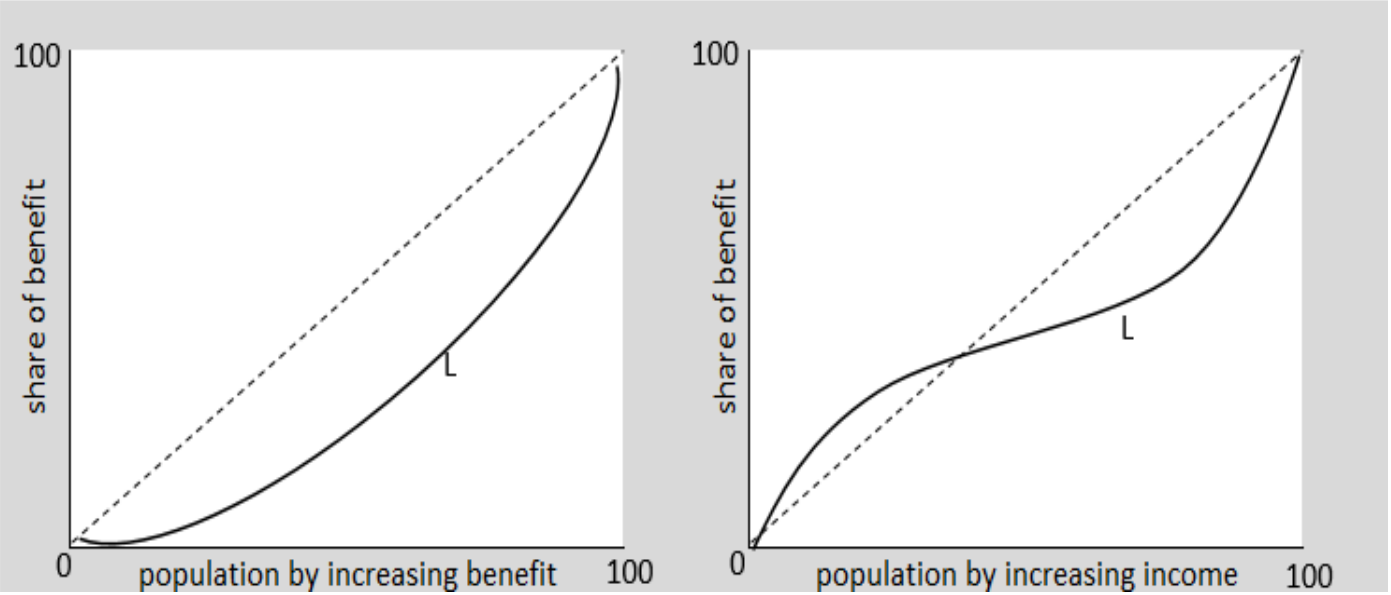
$$\overline{f_i} = \frac{1}{\sum_j d_{ij}} \sum_j d_{ij} f_{ij}$$

The distance fare is set to 2.35 SEK per km



Measuring equality

Horizontal Equity



Vertical Equity

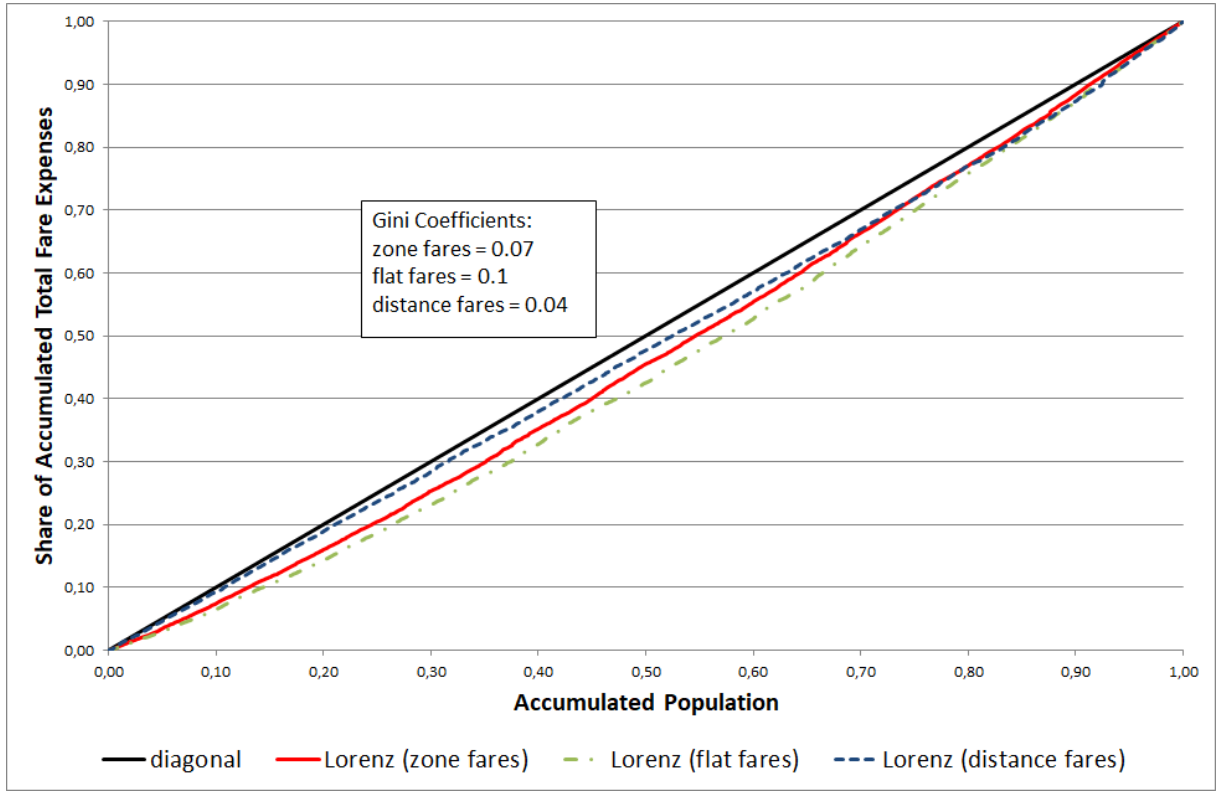
Gini Index (0 .. 1)

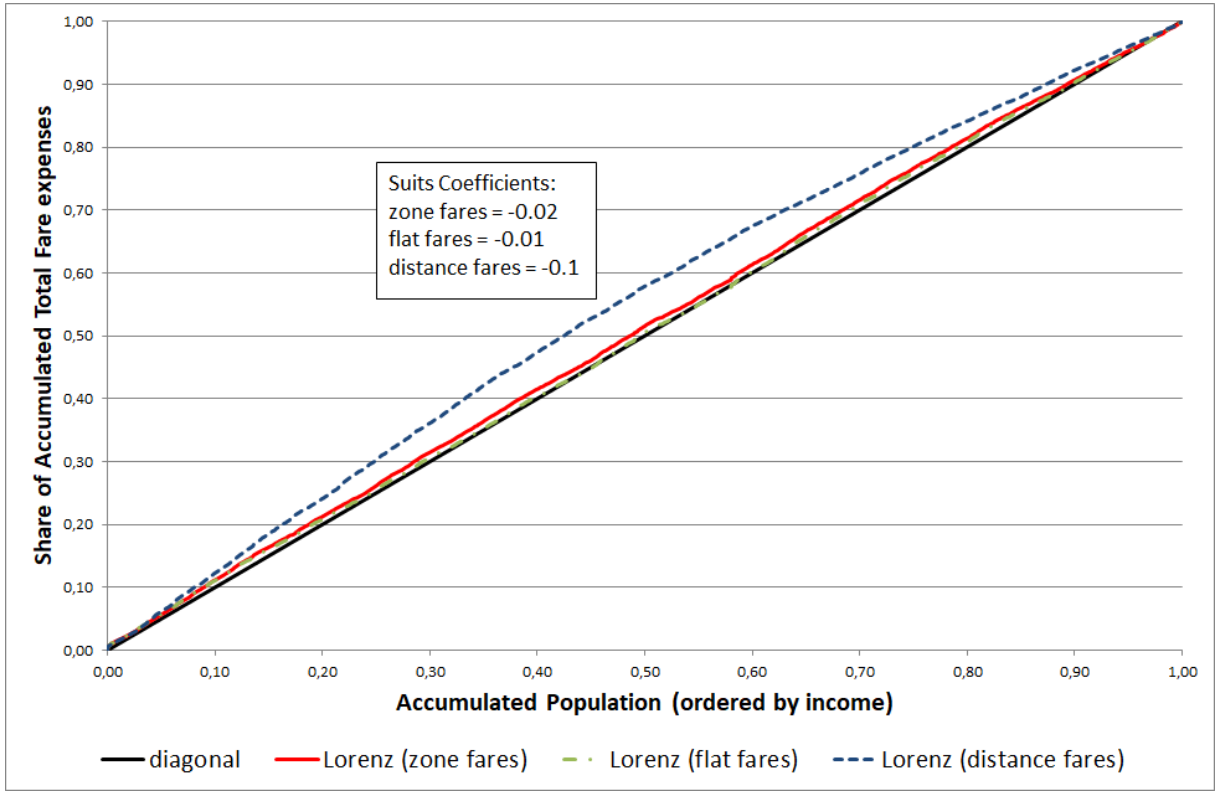
The Gini coefficient can vary from perfect horizontal equality, 0 to extreme inequality, 1

Suit Index (-1 .. +1)

For Suits: zero indicates proportionality, -1 corresponds to an extreme policy where the individual with the lowest income pays all fares and 1 implies extreme reverse unevenness where the wealthiest individual pays all fares.

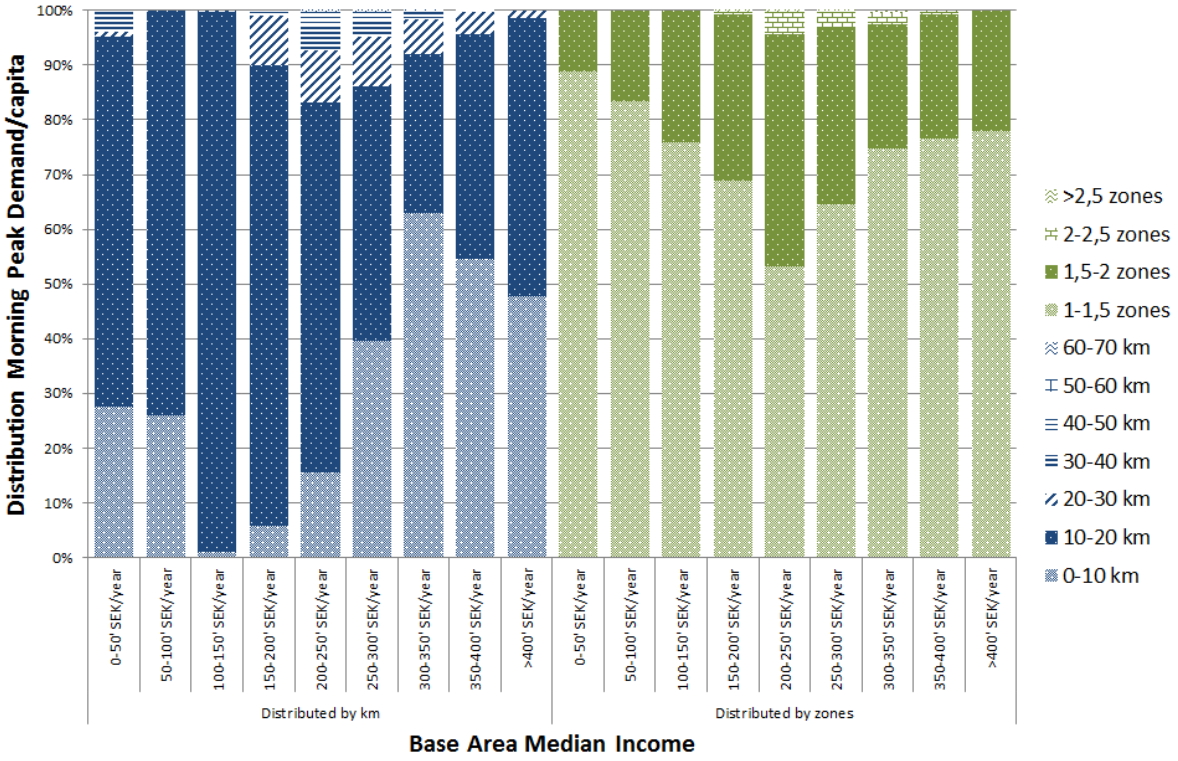
Horizontal and Vertical Equity of different fare schemes

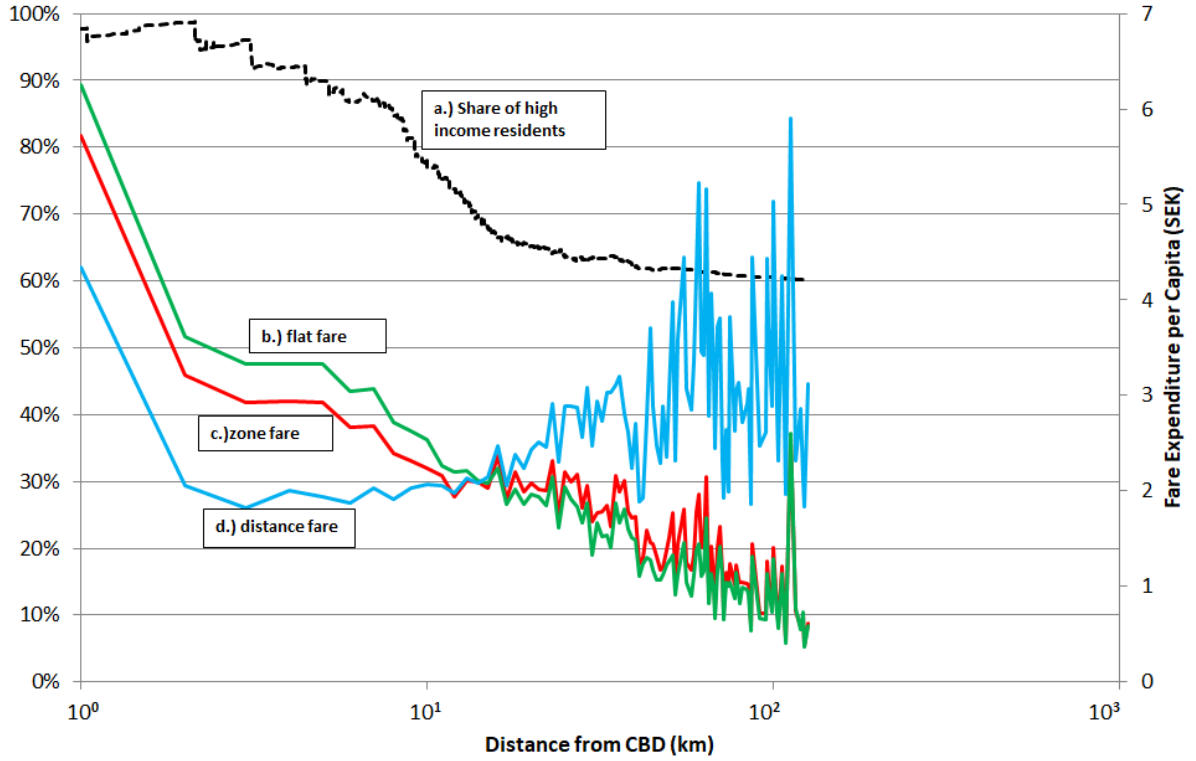




Keep in mind that in this analyses we assume that money has the same value for all groups

Why are distance fares vertically inferior, compared with zone fares, for low-income residents?





Why are distance fares vertically inferior, compared with zone fares, for low-income residents?

Fare-policy	Increasing distance dependence	Increasing Usage Fairness	Increasing Horizontal Equity	Increasing Vertical equity
Flat Fares	↓	↓	↓	↑
Zone Fares				
Distance fares				

"[…]a large body of research has shown that most long-distance and peak time travel is taken by higher income individuals. So in reality distance-based and time-of-day pricing may shift the burden of higher cost trips from low income to high income people."

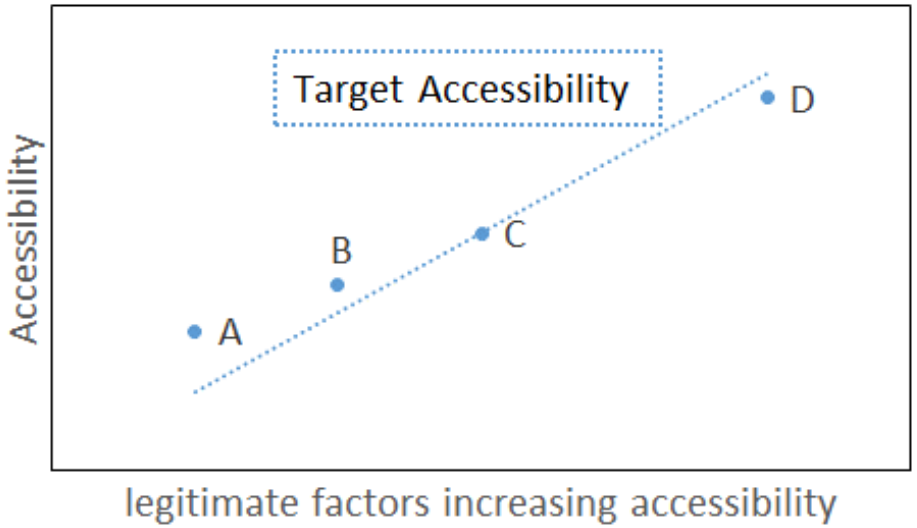
How to make this equality measurement operationable for stakeholders and operators?

What operators/policy makers need?

- *Equity is not the sole concern*. There are also other quality and performance factors involved in the provision of accessibility and its distribution. How should the public transport system work, and *what targets* should it meet?
- Apart from providing horizontal and vertical equity, the transportation system *should operate efficiently with an acceptable level of farebox recovery*
- It should also offer a *reliable alternative for car traffic* in the most congested parts during peak hours
- Proposed policy shifts *should be recommendable from a CBA point of view* as well as from an equity point of view

What did we do?

1. **Created a quantifiable target accessibility based on the existing stakeholders' machine**. We compared actual accessibility with a sought after state, which we refer to as *target accessibility* where only a few selected, legitimate, factors impact accessibility.
2. Simultaneously, we measure the accessibility with *logsums* from a trip destination choice-model, taking generalized travel costs, and the quality and distribution of destinations into account.
3. We constructed the target accessibility as a function of *origin population density* and *closeness to the center of gravity* of the urban agglomeration



Logsum as measures of accessibility

- *Logsums are the sum value of the utilities associated with a set of choices available to the decision maker.* If the choice set consists of all possible destinations, the Logsum may express the accessibility with public transport (the sum value of choices among all possible destinations). The logsum offers an important advantage for planners being a byproduct of the standard four-step transport model. That means that if a planning agency has access to such a transport demand forecast model, then the logsums are directly extractable
- The MNL model is used to obtain the probability of choosing a destination from a set of destinations based on generalized travel costs and relative attractiveness of the destinations, and E(CS) can be interpreted as a measure of accessibility. This logsum can be expressed in monetary terms if divided by the marginal utility of money (De Jong et al., 2007)

$$x_{rij} = transport\ utility\ components\ (cost, time\ etc)\ between\ zones\ i\ to\ j$$

$$S_j = attractiveness\ of\ destination\ j$$

$$V_i = \sum_j V_{ij} = \sum_{rj} \beta_r x_{rij} + ln(S_j)$$

$$V_j = utility\ of\ choice\ j$$

$$C = unknown\ constant$$

$$E(CS) = \left(\frac{1}{\alpha}\right) ln\left(\sum_j e^{V_j}\right) + C$$

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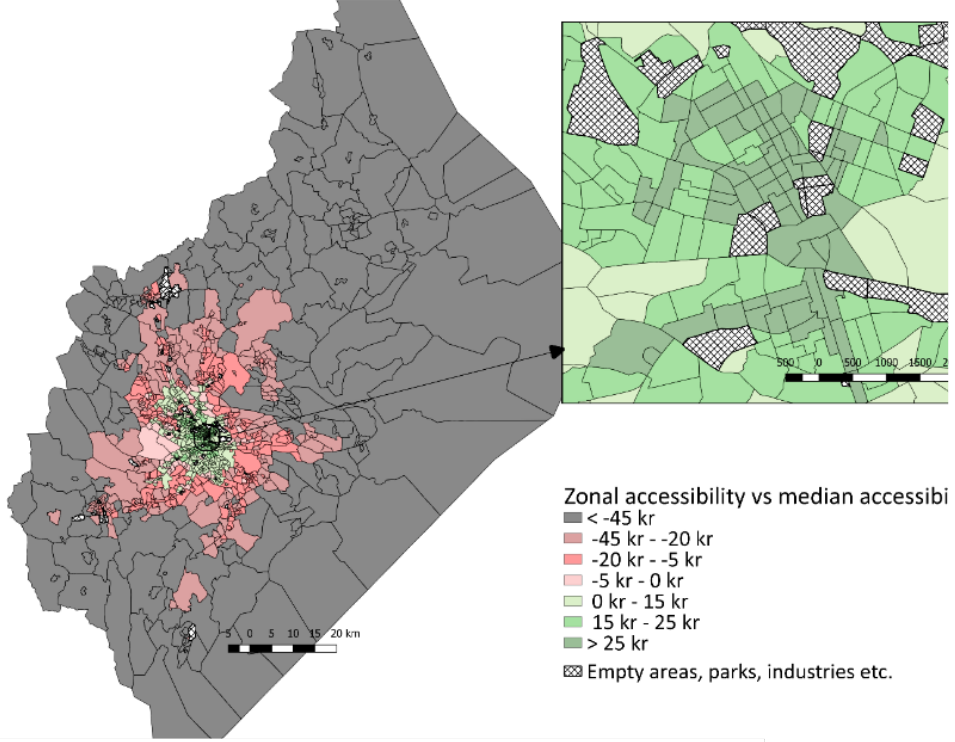
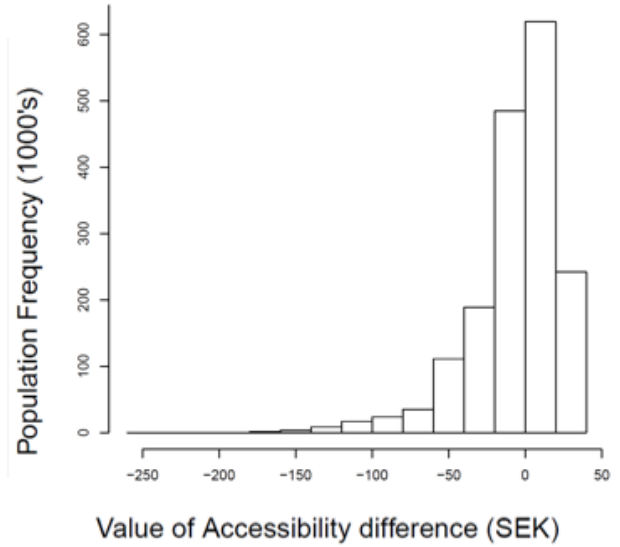
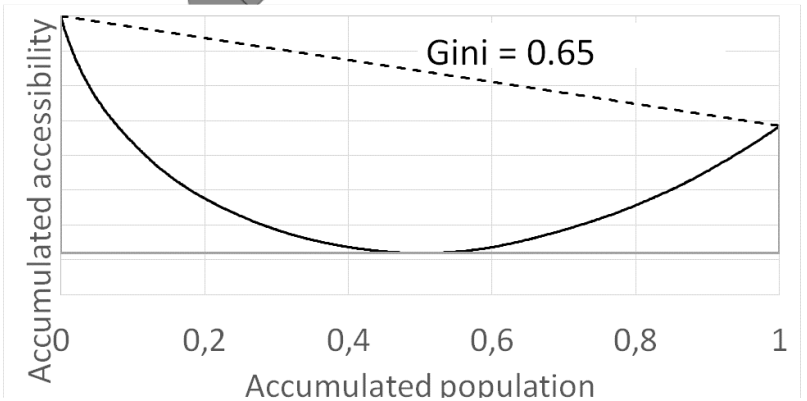
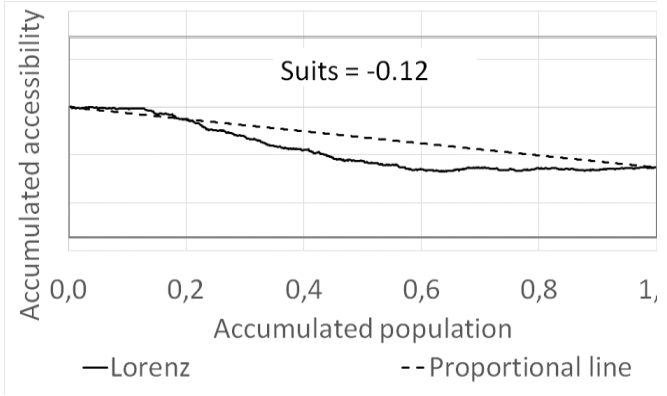
4. The specific formulation of the target accessibility is achieved by performing a linear regression of the logsum accessibility as the dependent variable and the two chosen factors as independent variables.
5. We then study the residual between actual and target accessibility as the distribution of unwarranted inequality.
6. We assess horizontal and vertical inequities,

- Distribution of public transport accessibility in Stockholm County



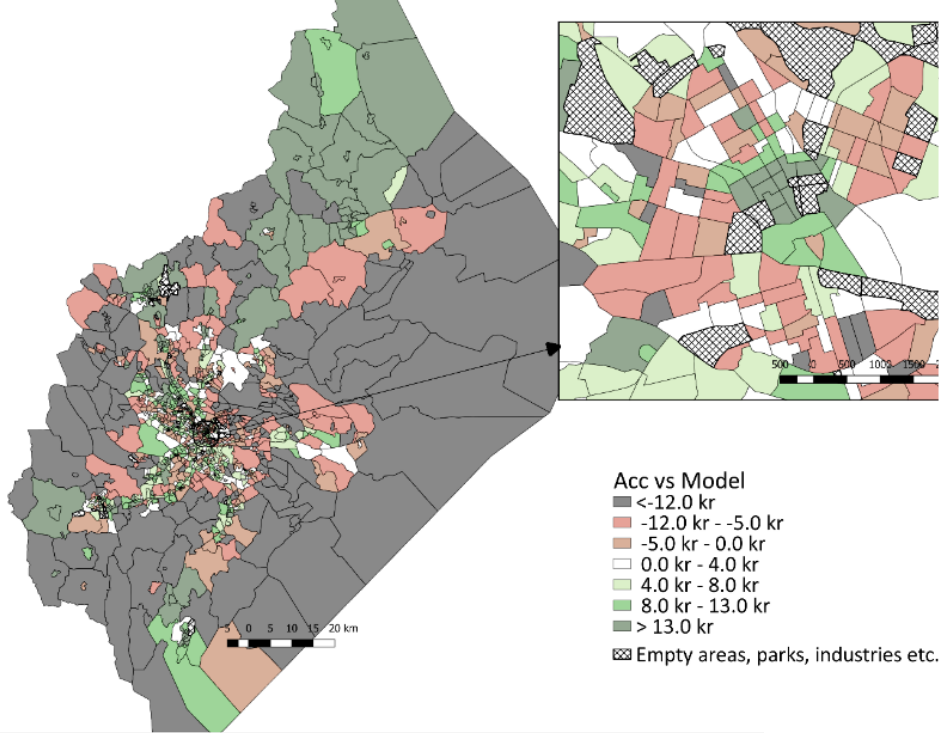


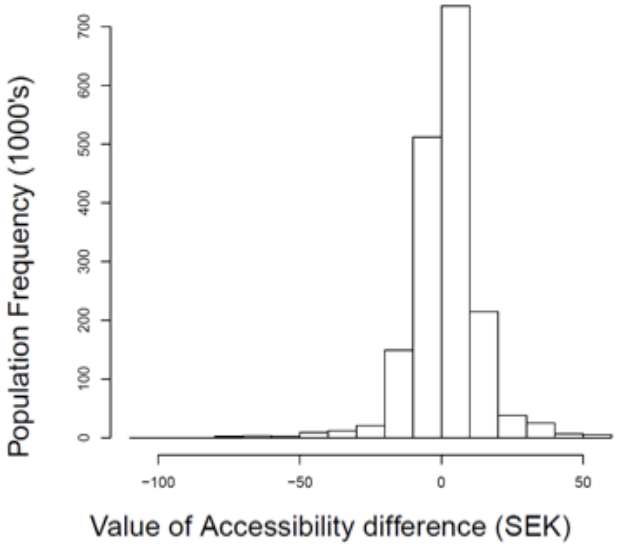


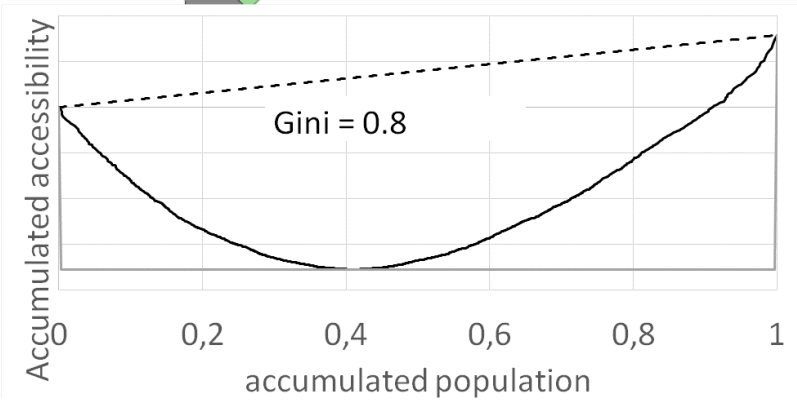


- Surplus and deficit accessibility compared to target accessibility as a function of distance to center and population density

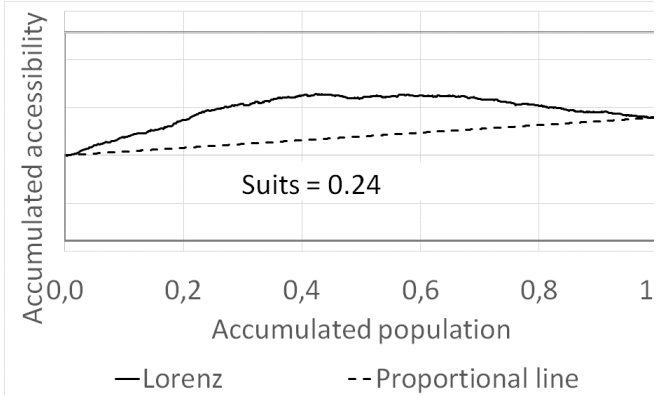
	Coefficients	*Stand. Err.*	*t-stat*	*p-value*
Constant	1.1E+01	0.01	782.16	0.00
Population density (pop/km2)	1.3E-05	0.00	9.82	0.00
Distance to central station (km)	-3.2E-02	0.00	-65.01	0.00
Multipel-R	0.90			
R-square	0.81			
Adjusted R-square	0.81			
Standard Err.	0.27			
Observations (N=number of zones)	1,364			







Horizontally inequitable
- 40% have lower accessibility than target



Vertically equitable
- The poorest 40% higher accessibility than target
- The richest 60% have lower accessibility than target

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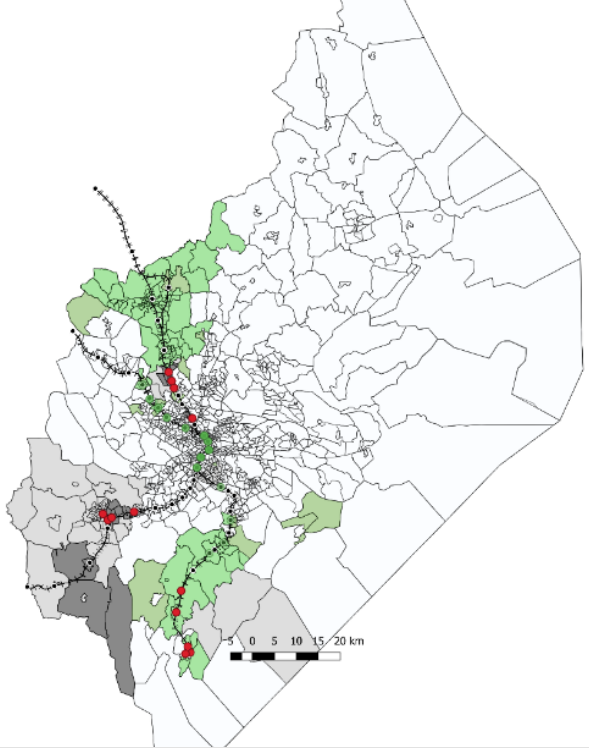
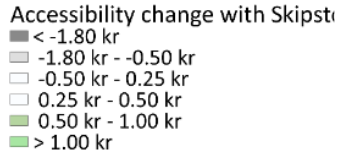
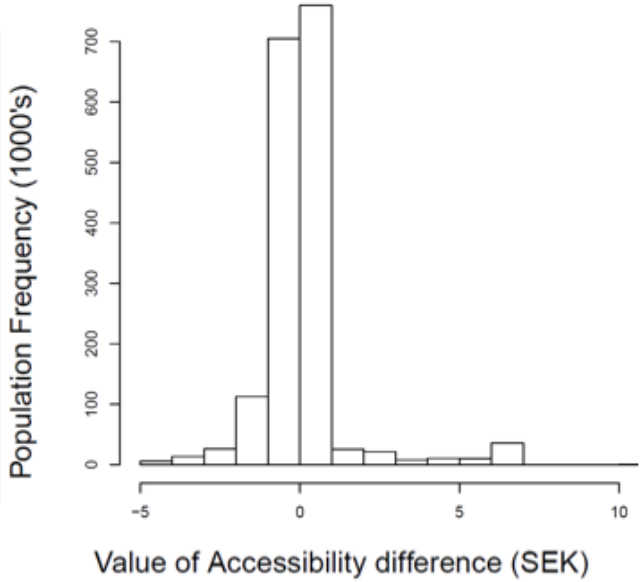
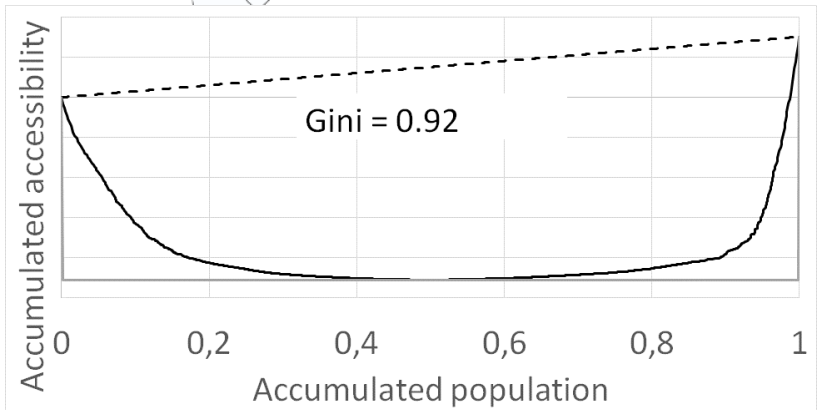
5. We then study the residual between actual and target accessibility as the distribution of unwarranted inequality.
6. We assess horizontal and vertical inequities,
7. We demonstrate our approach by evaluating an introduction of skip-stop services on the Stockholm commuter train network

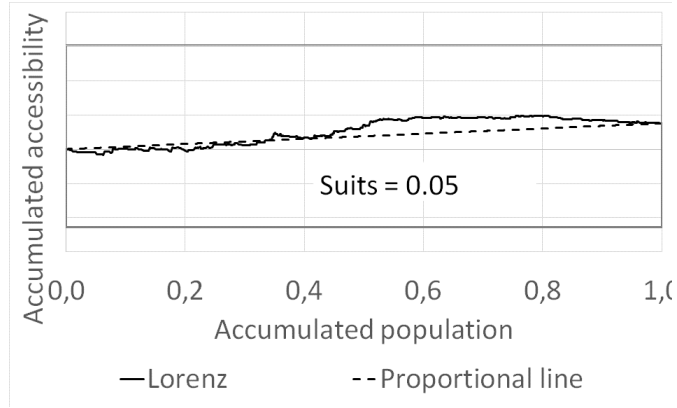
- Change in accessibility when changing to skip-stop on commuter train











About 20% of the population seeing more substantial decreases or increases

Summary

- We set out to define a system goal for public transport regarding accessibility equity where residents living in equally dense and central home areas should receive equal amounts of public transport accessibility
- Equity of accessibility is easy to measure, but it is hard for the policymaker to decide on the goal for accessibility
- With this methodology, two questions can be answered for all proposed policies: will it bring us closer to the goal or farther away from it? And, will it increase or decrease the accessibility for those with lower incomes?
- The proposed measure has the advantages of being economically feasible, concrete, and useful for assessing the overall situation and looking at individual policy implementations.
- This methods also would help us to illustrate concrete impacts to people who asking “would I loose anything with this changes?” in a much simpler manner

Relevant publications

1. Rubensson, I., Cats, O. and Susilo, Y.O. (2020) Fair accessibility – operationalizing the distributional effects of policy interventions. *Journal of Transport Geography*, 89, 102890, doi: 10.1016/j.jtrangeo.2020.102890
2. Rubensson, I., Cats, O. and Susilo, Y.O. (2020) Is Flat Fare Fair? Equity Impact of Fare Scheme Change. *Transport Policy*, 91, pp. 48-58, doi: 10.1016/j.tranpol.2020.03.013.

Thank you!

Any questions?

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