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Transport infrastructure investments, job accessibility, equity and regional growth

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- Case study 1: ex ante evaluation of rail investments in the Netherlands
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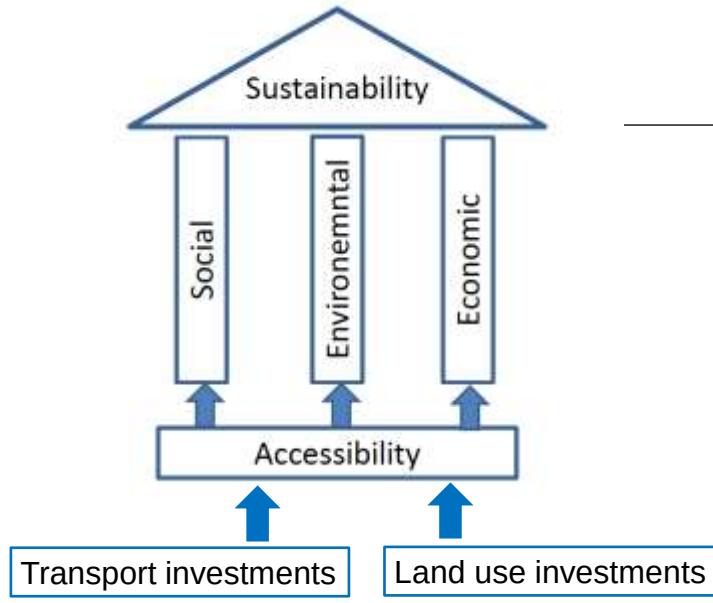
- Conclusions



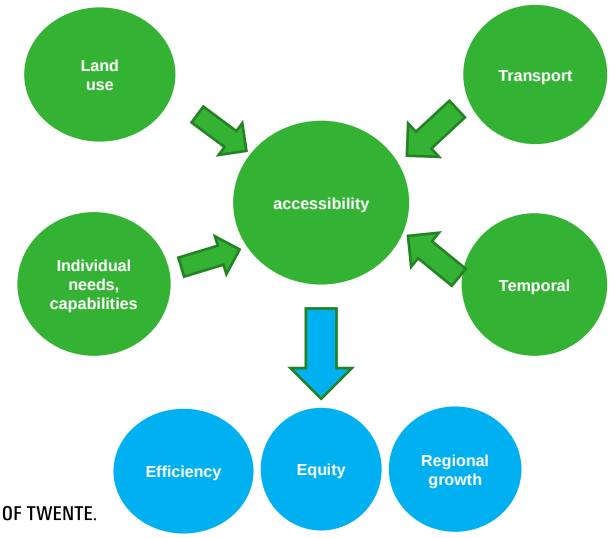
Accessibility (and Equity)

Can be measured in many different ways - > definition and operationalization affects results and conclusions

Spatial and temporal inequalities in accessibility varies strongly across cities as a result of socio-economic and spatial-infrastructural contexts

A great topic for research (> 25 publications; PhD, >15 journal papers, 2 edited books)

Accessibility, equity and regional growth



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Components and perspectives

Geurs, K. T., van Wee, B., 2004. Accessibility evaluation of land-use and transport strategies: Review and research directions. *Journal of Transport Geography 12, 127-140.*

Components / Perspectives	Transport component	Land use component	Temporal component	Individual component
Infrastructure-based perspective	Transport engineering and planning			
Location-based perspective		Urban planning Geography		
Person-based perspective			Time geography	
Utility-based perspective	Economic geography Spatial economics			

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Case study 1- Ex ante economic appraisal of public transport investments

Geurs, K., Bok, M. d., & Zondag, B. (2012). Accessibility benefits of integrated land use and public transport policy plans in the Netherlands. In K. T. Geurs, K. Krizek, & A. Reggiani (Eds.), Accessibility Analysis and Transport Planning: Challenges for Europe and North America (pp. 189-216). Edward Elgar.

Background

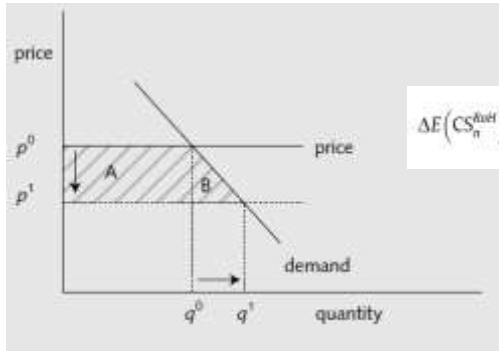
- Attention for synergy between PT-investments and spatial planning is lacking in (Dutch) economic appraisals of transport investments.
- Policy Question: does spatial planning improve efficiency of public transport investments?
- Methodological questions:
  - How to measure separate project effects (urbanisation, transport) and synergies between projects in integrated planning?
  - How to measure accessibility benefits?

Case study Almere

- Urbanisation variants for Almere and rail investments in corridor Schiphol-Amsterdam-Almere
- (S)CBA conducted by Bureau of Economic Policy Analysis and Netherlands Environmental Assessment Agency
- Regional transport model used in CBA to estimate travel time savings
- National Land-use/transport-interaction model TIGRIS XL
  - Population and employment projections
  - Accessibility benefits from land use changes

Standard approach to measuring accessibility benefits

- Transport model simulates changes in travel costs and travel behaviour
- Rule-of-half (ROH) measure of accessibility benefits (consumer surplus)



$$\Delta E\left(CS_n^{RoH}\right) = -0.5 \sum_{z=1}^{Z} \sum_{j=1}^{J} (GC_{zj}^1 - GC_{zj}^0)(A_{zj}^1 + A_{zj}^0)$$

- Practical approximation; easy to compute, linear demand function assumed
- Shown to accurately measure user benefits from transport infrastructure investments, assuming perfect competition in all transport using sectors of the economy
- Assumption that all accessibility benefits are attributable to generalized cost changes within the transport network -> which is not the case when land use changes

Accessibility and land-use/transport interaction model TIGRIS XL

Zondag, B., de Bok, M., Geurs, K. T., & Molenwijk, E. (2015). Accessibility modeling and evaluation: The TIGRIS XL land-use and transport interaction model for the Netherlands. *Computers, Environment and Urban Systems, 49(1), 115-125.*

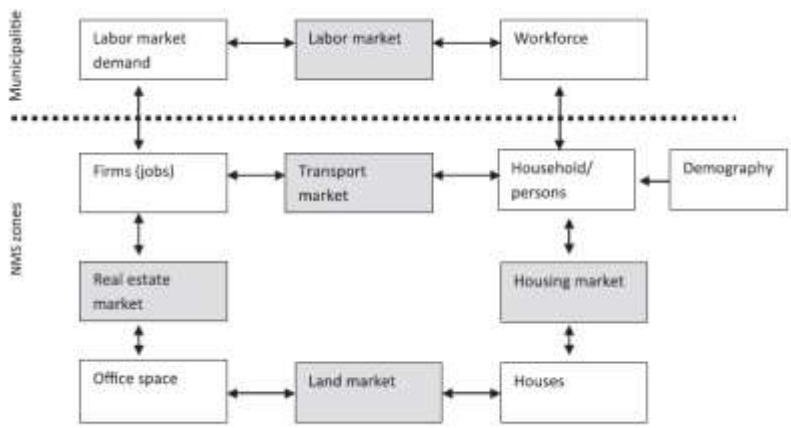
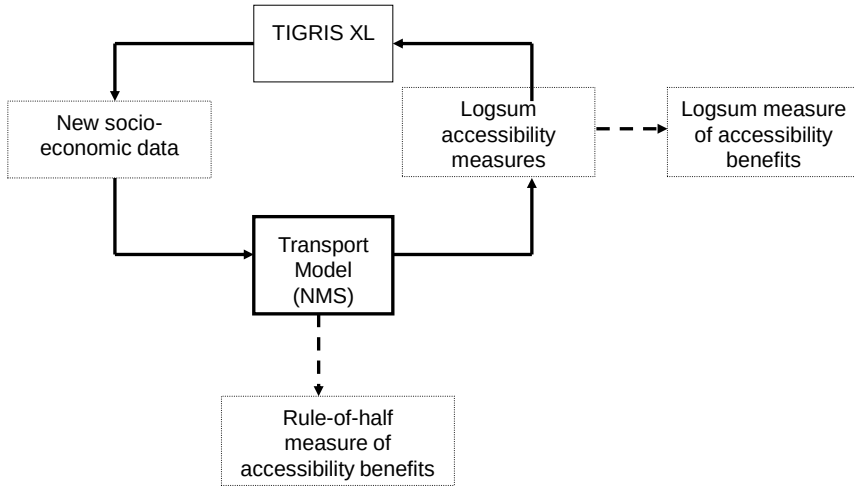


Fig. 1. Functional design of the TIGRIS XL model.

Accessibility and land-use/transport interaction model TIGRIS XL



Logsum measure derived from the Dutch National Model System

Geurs, K., B. Zondag, B., G. de Jong, G., M. de Bok, 2010, Accessibility appraisal of integrated land-use/transport policy strategies: more than just adding up travel time savings. *Transportation Research D* 15, 382-393.

- Utility functions accounts for changes in both (generalised) transport cost and changes in **destination utility** -> effects of changes in the spatial distribution of activities are included

$$V_{zijp} = \beta_p T_{zj} + \chi_{ph} \ln(C_{zj}) + \delta_p D_{pj} + \cdots$$

- Accurate estimation: uses non-linear demand curve; disaggregate estimation consistent with travel model (490 person types, 4 trip purposes)

- Attractive measure of accessibility benefits when a disaggregate MNL transport model is available

Transformation of logsum in monetary values

Assuming utility is linear in income -> accessibility benefits are computed as the difference in conditions before and after a change:

$$\Delta E(CS_n) = (1/\alpha_n)\left[\ln\left(\sum_{j=1}^{J1} e^{V^1_{nj}}\right) - \ln\left(\sum_{j=1}^{J0} e^{V^0_{nj}}\right)\right]$$

α_n is the marginal utility of income

Assuming utility is linear with income, α transforms utility into money. Cost coefficients (by income category) are used as α.

In NMS, however, cost enter utility function in logarithmic form, VOT coefficients are used

Three urbanisation variants

(spatial variation of 30 thousand inhabitants; 15-20 thousand jobs)

Almere Water Town

Almere Polder Town

Almere Town of Water and Green

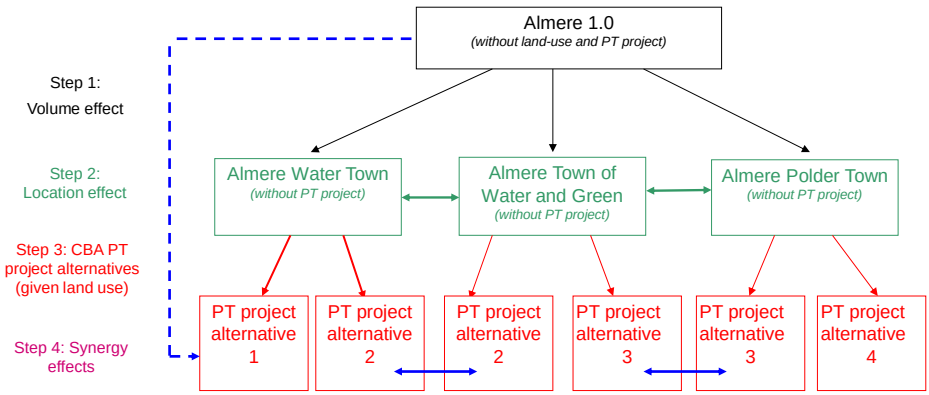
Reference scenario

- Growth of 30 thousand dwellings in Almere
- Already major improvements in public transport service quality with investments planned up to 2015 (frequency doubling)
- Improvements in road infrastructure between Amsterdam-Almere
- National road pricing scheme assumed

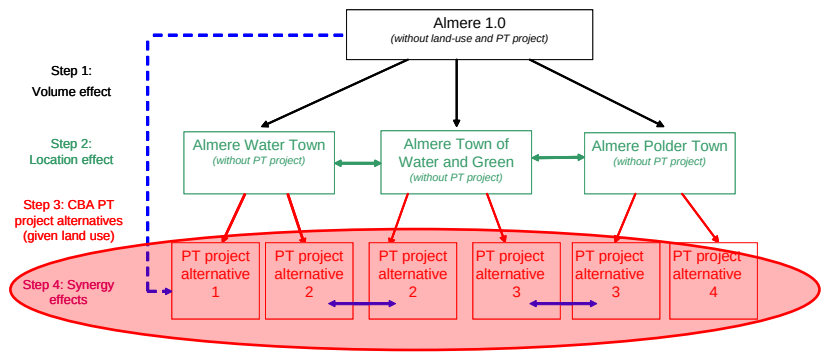
Rail project alternatives examined in CBA

- 6 project alternatives for Almere Water Town
  - New IJmeer rail link (regional rail, metro, maglev)
  - Upgrade existing link
- 4 project alternatives for Almere Town of Water and Green
  - New IJmeer rail link
  - Upgrade existing link
- 1 project alternative for Almere Polder Town
  - New 'Stichtselijn' railway link + capacity expansion motorway
- Investment cost range from 2-3 (upgrade) to 6-7 billion Euro (new links)

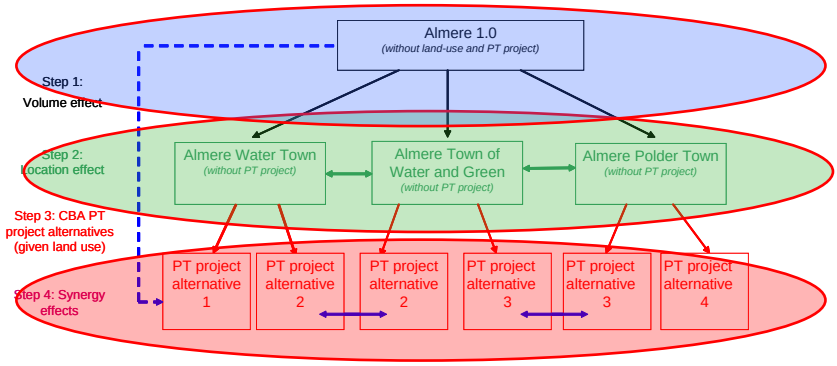
How to measure project and synergy effects in integrated planning projects?



Rule-of-half accessibility benefits

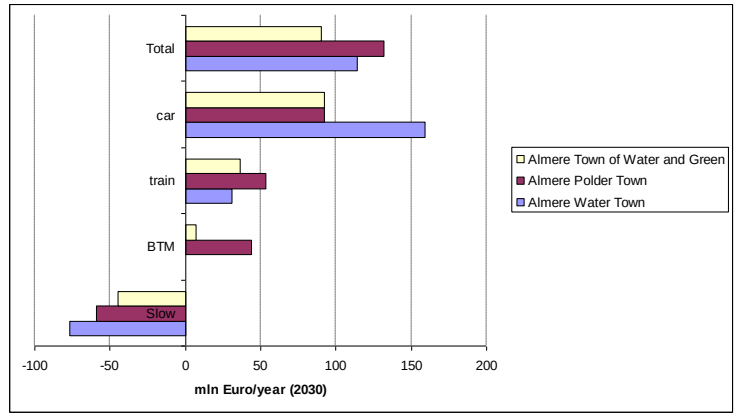


Logsum accessibility benefits

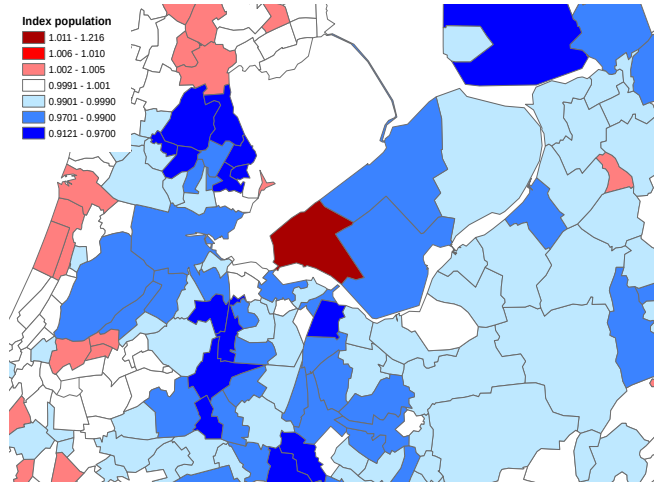


Step 1/2: Accessibility benefits of urbanisation scenarios

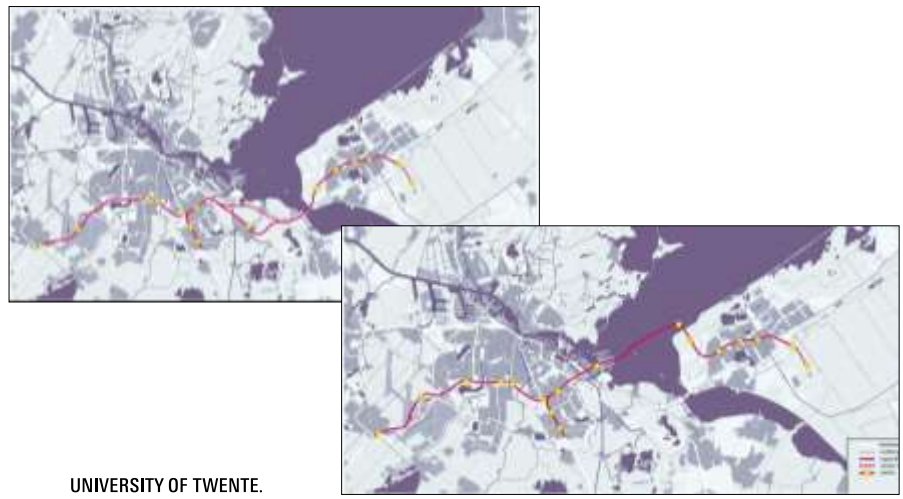
Accessibility benefits of spatial planning variants (logsum), relative to reference scenario (Almere 1.0)



TIGRIS XL results: regional impact of housing programme (population)



Step 3: Effects of rail investments



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Impacts on population and employment

Zondag, B., de Bok, M., Geurs, K. T., & Molenwijk, E. (2015). Accessibility modeling and evaluation: The TIGRIS XL land-use and transport interaction model for the Netherlands. *Computers, Environment and Urban Systems, 49(1), 115-125.*

Table 7
Population and employment effects of public transport measures, 2030.

	Population in Almere 2030	Additional population in PT run	Employment in Almere 2030	Additional employment in PT run
Almere in 2010	190,000		61,000	
Almere 2030				
Reference	248,000		84,000	
Water Town	323,000		108,000	
+new IJmeer rail link		-245		+1000
Polder Town	323,000		107,000	
+new HB and SL rail links		+1115		+1615
Town of Water and Green	323,000		107,000	
+new HB rail link		-730		+410

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5 jan 2010

Accessibility benefits of PT investments (in € m /year)

Public transport project	Scenario	Rule of half	Logsum
		Train	Train
New IJmeer rail link	Water Town	55.9	72.9
HB regiorail and new Stichtse rail link	Polder Town	55.8	67.6
Upgrade existing rail link	Town of Water and Green	32.2	33.1

NB. Car travel time savings are insignificant because of inaccuracy of assignment model

Step 4: Synergy between urbanisation and PT
Accessibility benefits (in € m /year)

Project alternative	Reference	Rule-of-half		Logsum
		Regional transport model[1]	TIGRIS XL	TIGRIS XL
New IJmeer rail link in Water Town	Water Town reference	55.4	55.9	72.9
New IJmeer rail link in Town of Water and Green	Town of Water and Green reference	44.4	n.a.	n.a.
New IJmeer rail link	Reference scenario	n.a.	27.7	48.8
Upgrade existing rail link in Water Town	Water Town reference	25.3	n.a.	n.a.
Upgrade existing rail link in Town of Water and Green	Town of Water and Green reference	23.3	n.a.	n.a.

Step 4: Synergy between urbanisation and rail investment 'Volume' effect

- Adding 30,000 dwellings and 22,000 jobs in new quarters near the new rail stops increases accessibility benefits of IJmeer rail link substantially (50 to 65%)

Almere Water Town

Step 4: Synergy between urbanisation and rail investment - location effects

- IJmeer link in Water Town creates 25% higher accessibility benefits than in Town of Water and Green (15,000 people and 7,000 jobs in new quarter)
- No location effect for the upgrade of the existing rail link

Almere Town of Water and Green

Almere Water Town

But: benefits and synergies are small compared to investment costs ….

Source: CPB/PBL Cost benefit analysis

Conclusions

- Spatial planning does affect efficiency of PT project. Adding dwellings and jobs to locations near railway stations can significantly increase accessibility benefits for public transport users.
- In our case study, this does not affect the outcome of the cost-benefit analysis.
- Logsum benefits of rail projects, given a land-use scenario, are higher than ROH benefits (20 to 30%) => more detailed computation and changes in all mode and destination alternatives are weighed simultaneously

More information:

- Geurs, K., Zondag, B., De Jong, G., & de Bok, M. (2010). Accessibility appraisal of integrated land-use/transport policy strategies: more than just adding up travel time savings. *Transportation Research Part D, 15, 382-393.*
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Case study 2: Ex post analysis of Cipularang toll road

(I.G. Andani, L. La Paix, I. Syabri, K.T Geurs, S.Y. Rachmat, An ex-post evaluation of the job accessibility and spatial equity impacts of a toll road in the Jakarta – Bandung region, Indonesia. Submitted to Transport Geography)

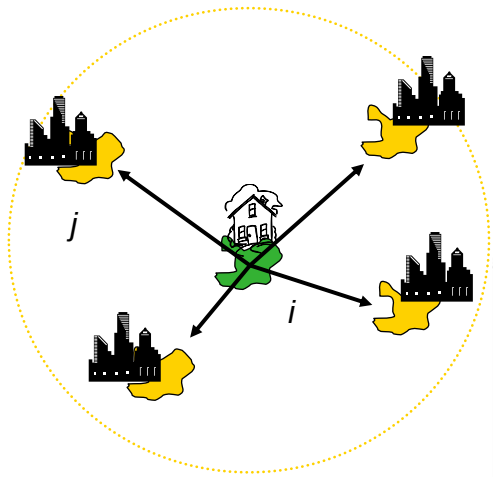
- Case study on Cipularing, opened in 2005 (2 hr travel time reduction)
- ArcGIS transport network, with and without the toll road.
- 4-step transport model extension Traffic Analyst for ArcGIS; calibrated on toll road traffic flows and google traffic travel times
- SC survey among 1500 respondents (VOT estimation)

Accessibility indicators

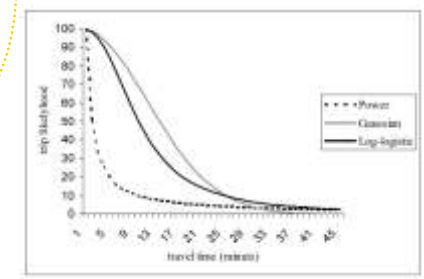
- Centrality/connectivity indicators; travel time and travel cost
- Potential job accessibility
- Shen index

Potential accessibility measure

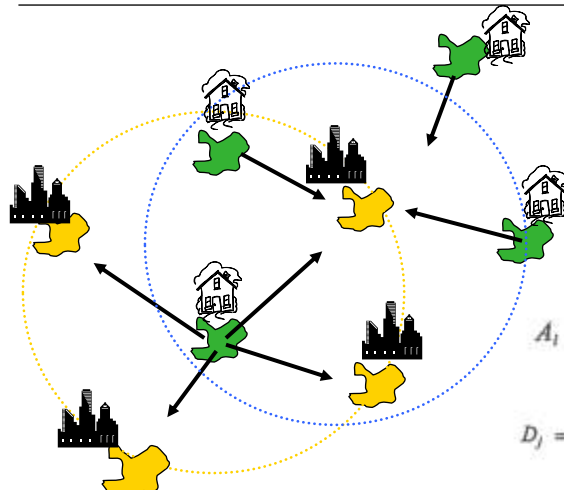
Hansen, W.G., 1959. How accessibility shapes land use. Journal of American Institute of Planners 25, pp. 73-76



$$A_i = \sum_{j=1}^{n} D_j e^{-\beta c_{ij}}$$



Shen index: potential accessibility with competition



$$A_i = \sum_j \frac{O_j\, f(C_{ij})}{D_j},$$

$$D_j = \sum_k P_k\, f(C_{kj})$$

Shen, Q. (1998). Location characteristics of inner-city neighborhoods and employment accessibility of low-wage workers. Environment and Planning B: Planning & design, 25(3), 345-365.

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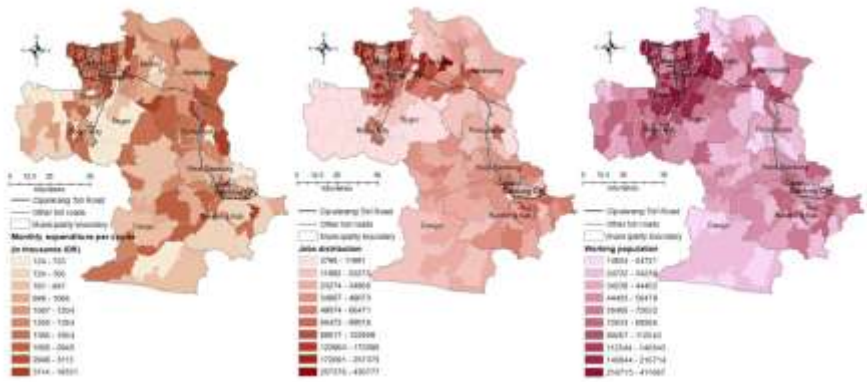
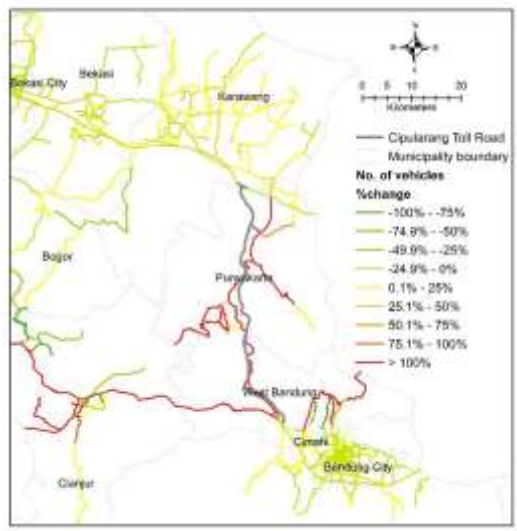
MEASURING EQUITY

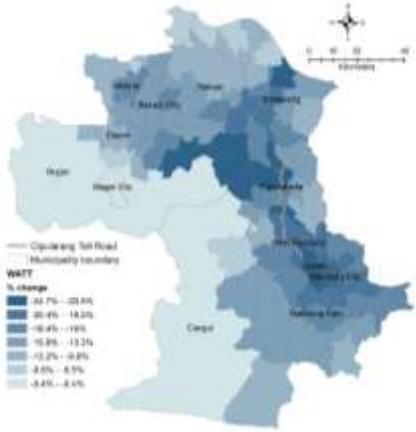
- **Gini index and Lorenz curve**; equal to the area below the line of perfect equality (0.5 by definition) minus the area below the Lorenz curve, divided by the area below the line of perfect equality. Between 0 (perfectly equal) and 1 (inequal). The smaller the index, the larger the inquality
- **Palma ratio** – originally the ratio of national income shares of the top 10% of households (richest) to the bottom 40 (poorest). The larger the ratio, the greater the inequality.
- Here: ratio of average accessibility weighted by population for the zones belonging to Decile 10 (with monthly expenditure as income proxy) and for those belonging to Deciles 1 to 4. (Guzman, L. A., & Oviedo, D. (2018). Accessibility, affordability and equity: Assessing 'pro-poor' public transport subsidies in Bogotá. Transport Policy, 68, 37-51)

Job/working population accessibility and monthy expenditure



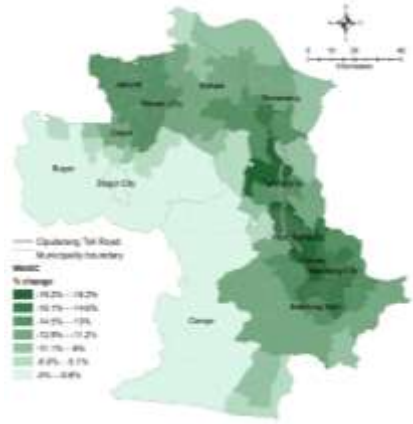
IMPACT ON TRAFFIC FLOWS





Relative changes* in weighted average travel time

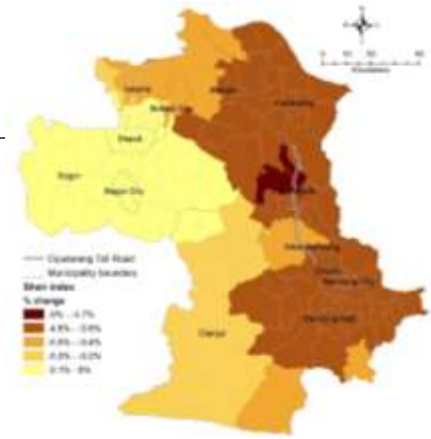
*in comparison with the situation without the Cipularang toll road



Relative changes in weighted average generalised cost

Accessibility impacts

Accessibility measures	Scenario	Impedance	
		Time	Generalised cost
Working population accessibility	With the toll road	18,586,991	29,638,231
	Without toll road	17,407,302	29,490,331
	Relative change**	6.9%	0.5%
Shen index	With the toll road	0.25	0.25
	Without toll road	0.27	0.26
	Relative change	-6.1%	-0.5%
Potential job accessibility	With the toll road	5,181,060	7,733,655
	Without toll road	4,882,929	7,697,805
	Relative change	6.9%	0.5%



Relative changes* in Shen index with the toll road

*in comparison with the situation without the Cipularang toll road

Equity (income): rather small impacts

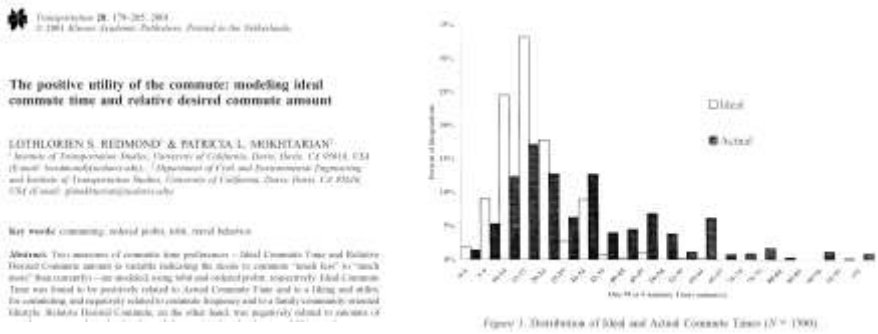
Accessibility measures	Scenario	Palma ratio	Gini coefficient
Shen index	with the toll road	2.12	0.42
	without the toll road	2.11	0.41
Potential job accessibility	with the toll road	1.98	0.49
	Without the toll road	1.99	0.46

middle-income areas benefit more from the introduction of the toll road than low-income areas

Conclusions

- the construction of the Cipularang toll road has significant impacts on traffic flows and travel time - reduced the average travel time in the Jakarta-Bandung area by 13%.
- Areas along the toll road and close to the toll gates are the most affected by the construction of the Cipularang toll road.
- The choice of the accessibility indicator affects the conclusion.
  - Potential job accessibility: significant increase (7%)
  - Shen index: decrease in job/worker ratio; the toll road increases job competition as more workers can access jobs available in the job-poor area in between Jakarta and Bandung
  - Inequalities by income group hardly affected. By job/worker type?

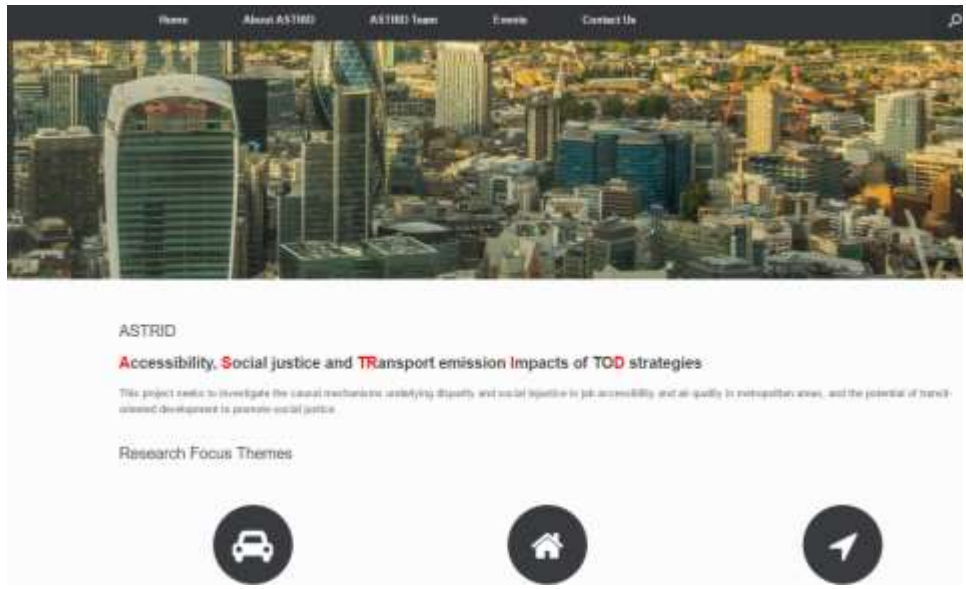
Case study 3: The importance of commuting preferences on job accessibility



The positive utility of the commute: modeling ideal commute time and relative desired commute amount

LOTHLORIEN S. REDMOND & PATRICIA L. MOKHTARIAN

To what degree does the land-use/transport system allow workers to achieve preferred commuting times?



MORE INFO: [HTTPS://WWW.ASTRIDROJECT.COM/](https://www.astridroject.com/)

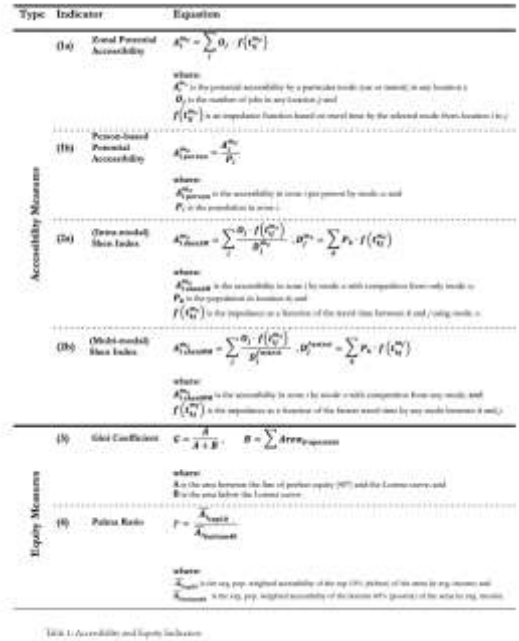
Table 2: Population and Jobs of City-Regions

	SP	GL	NLR
Zone Types	Origin–destination subzones	Transport for London zones	4-digit postcodes
Zones (n)	1,308	3,289	1,031
After listwise deletion[a]	1,286	3,134	972
Total Area (km^2)	1,521 km^2	1,572 km^2	5,327 km^2
Total Population (16–64)[b]	7,805,636	5,440,207	5,305,710
Total Jobs[c]	4,729,358	3,917,847	3,582,596

JOB ACCESSIBILITY AND EQUITY ANALYSIS

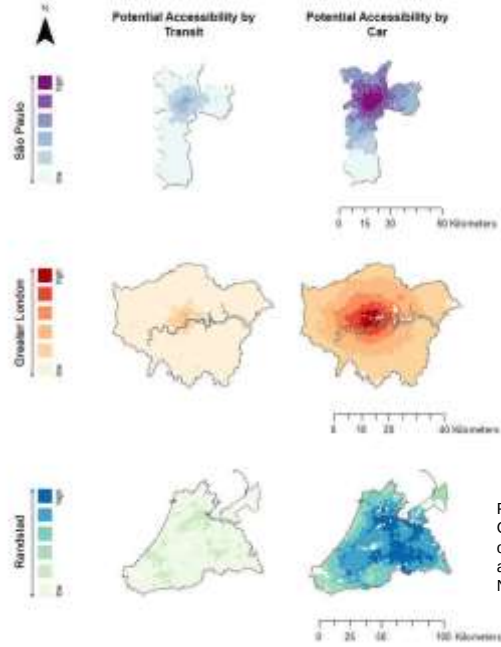
- **Land use component**: jobs and workers at high spatial resolution (NL PC5);
- **Transport component**: door to door approach to measuring travel times by car, bike-and-ride, walk-and-ride, bike
- **Temporal dynamics**: TomTom data, GTFS data
- **Individual component**: detailed survey conducted in NL (Randstad; n=1613), London (N=1002), Sao Paulo (N=1183) on perceptions/barriers to accessibility, housing market, perception of air pollution; stratified by income/HDI group (10/40/40/10)

Pritchard, J. P., Tomasiello, D., Gianotti, M., & Geurs, K. T. (2019). An international comparison of temporal and spatial inequalities in job accessibility – London, Sao Paulo and the Netherlands Randstad Area *Transport Findings.*



Type		Indicator	Equation
Accessibility Measures	(1a)	Total Potential Accessibility	$A_i^{Pot} = \sum_j O_j \cdot f\left(t_{ij}^{mo}\right)$ where: A_i^{Pot} is the potential accessibility by a particular mode (car or transit) at any location i; O_j is the number of jobs in any location j and $f\left(t_{ij}^{mo}\right)$ is an impedance function based on travel time by the selected mode from location i to j
	(1b)	Person-based Potential Accessibility	$A_{i\,person}^{Pot} = \frac{A_i^{Pot}}{P_i}$ where: $A_{i\,person}^{Pot}$ is the accessibility in zone i perceived by people at and P_i is the population in zone i
	(2a)	(Inter-modal) Shen Index	$A_{i\,Shenm}^{mo} = \sum_j \frac{O_j}{B_j^{mo}} \cdot \frac{f\left(t_{ij}^{mo}\right)}{B_j^{mo}} \cdot B_j^{mo} = \sum_k P_k \cdot f\left(t_{ik}^{mo}\right)$ where: $A_{i\,Shenm}^{mo}$ is the accessibility in zone i by mode o with competition from only mode o; P_k is the population in location k; and $f\left(t_{ik}^{mo}\right)$ is the impedance as a function of the travel time between k and i using mode o
	(2b)	(Multi-modal) Shen Index	$A_{i\,Shenm}^{mo} = \sum_j \frac{O_j}{B_j^{mo+mo}} \cdot \frac{f\left(t_{ij}^{mo}\right)}{B_j^{mo+mo}} \cdot B_j^{mo+mo} = \sum_k P_k \cdot f\left(t_{ik}^{mo}\right)$ where: $A_{i\,Shenm}^{mo}$ is the accessibility in zone i by mode o with competition from any mode; and $f\left(t_{ij}^{mo}\right)$ is the impedance as a function of the lowest travel time by any mode between k and i.
Equity Measures	(3)	Gini Coefficient	$G = \frac{A}{A+B}; \quad B = \sum_{cum} Area_{Lorenz\,curve}$ where: A is the area between the line of perfect equity (45°) and the Lorenz curve; and B is the area below the Lorenz curve
	(4)	Palma Ratio	$P = \frac{A_{top\,10\%}}{A_{bottom\,40}}$ where: A_{top10} is the avg. pop.-weighted accessibility of the top 10% richest, of the area in avg. income; and $A_{bottom40}$ is the avg. pop.-weighted accessibility of the lowest 40% (poorest) of the area by avg. income.

Table 1: Accessibility and Equity Indicators



Pritchard, J. P., Tomasiello, D., Gianotti, M., & Geurs, K. T. (2019). An international comparison of temporal and spatial inequalities in job accessibility – London, Sao Paulo and the Netherlands Randstad Area *Transport Findings.*

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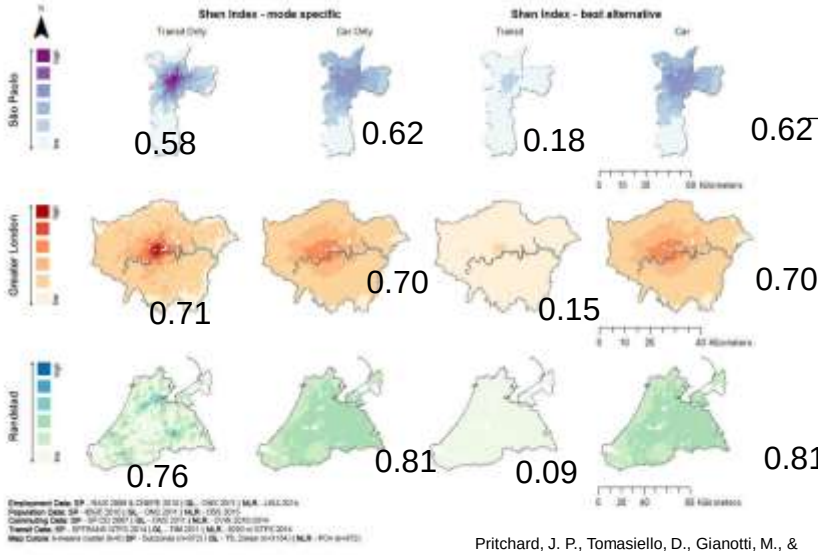


Figure 2: (Pseudo) Shen Accessibility

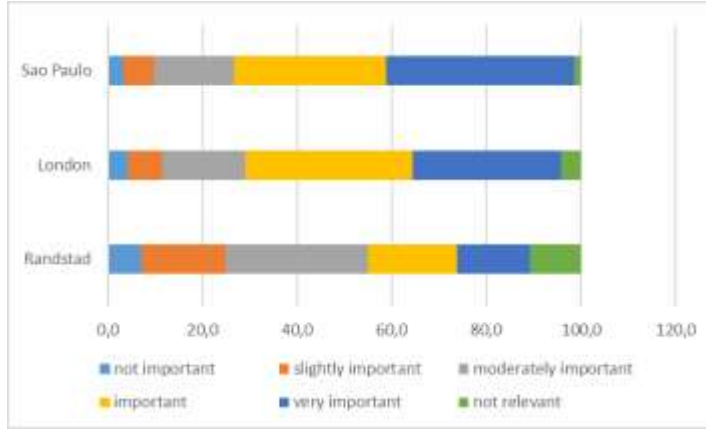
Pritchard, J. P., Tomasiello, D., Gianotti, M., & Geurs, K. T. (2019). An international comparison of temporal and spatial inequalities in job accessibility – London, Sao Paulo and the Netherlands Randstad Area *Transport Findings.*

IMPORTANCE OF COMMUTING TIME IN JOB SEARCH

(n=1183)

(n=1002)

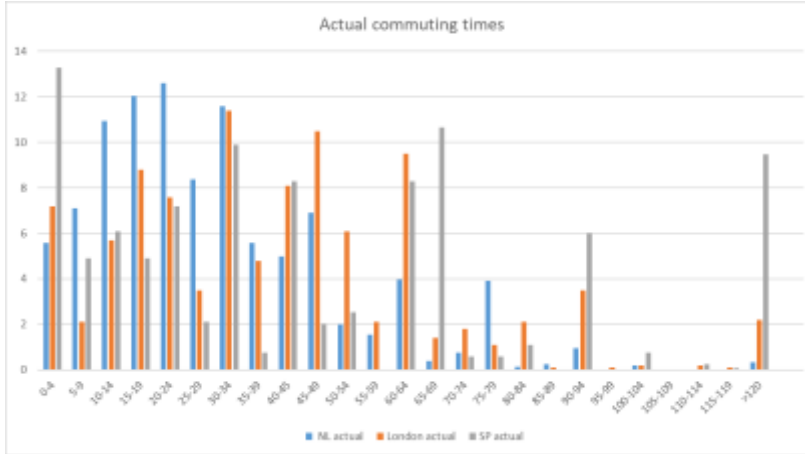
(n=1613)



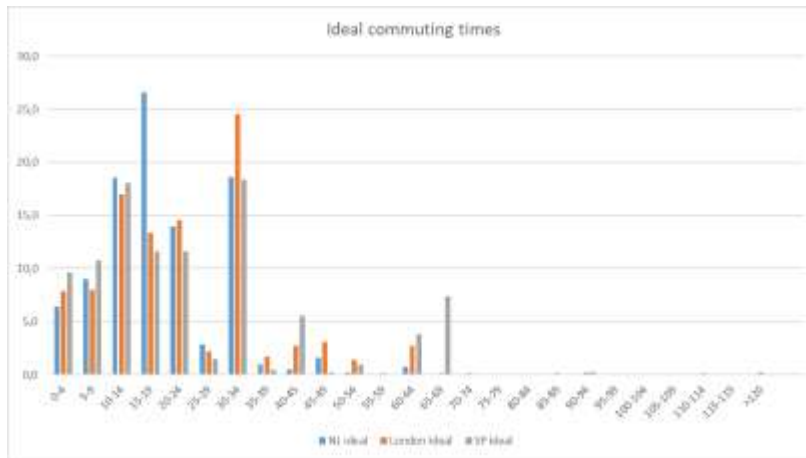
NEGATIVE IMPACTS OF COMMUTING

- 15% of the (Dutch) sample reported that the commuting negatively impacted lives
  - Well distributed amongst all areas; no clear pattern based on residential location
- negative impacts on
  - participation in leisure (48%)
  - family life (38%)
  - other necessary activities (15%)

ACTUAL COMMUTING TIMES



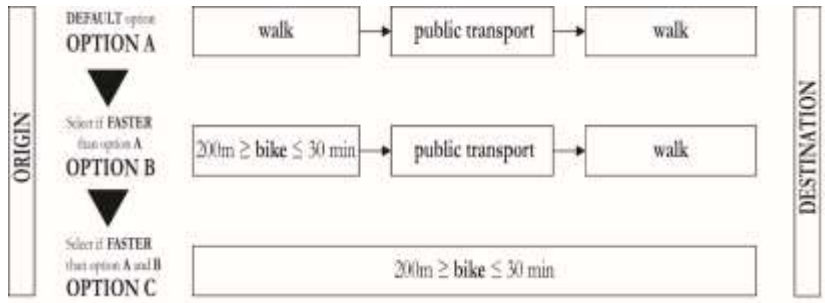
IDEAL COMMUTING TIMES



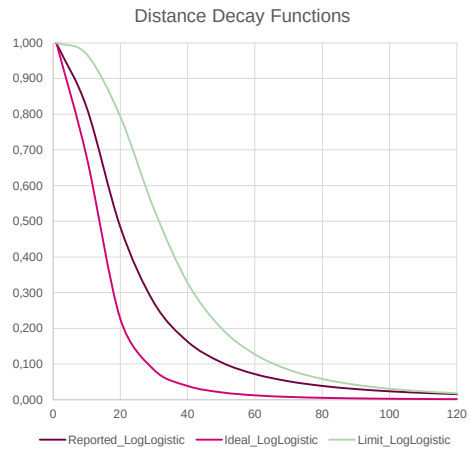
Commuting Patterns

	Randstad	London	Sao Paulo
actual commuting time	28	39	46
ideal commuting time	17	21	23
maximum accepted commuting	39	46	54
actual/ideal	1,6	1,8	2,0
actual/max	0,7	0,9	0,9

PUBLIC TRANSPORT ACCESSIBILITY MODEL
BASED ON OPEN GENERAL TRANSIT FEED SPECIFICATION (GTFS) DATA



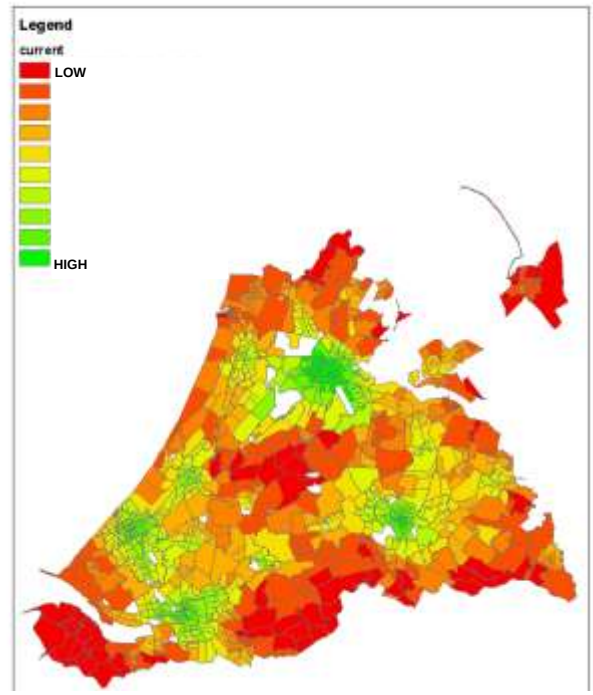
DISTANCE DECAY FUNCTIONS



- All groups would like to commute less but are willing to commute longer
- Best fit is still Log Logistic in all cases

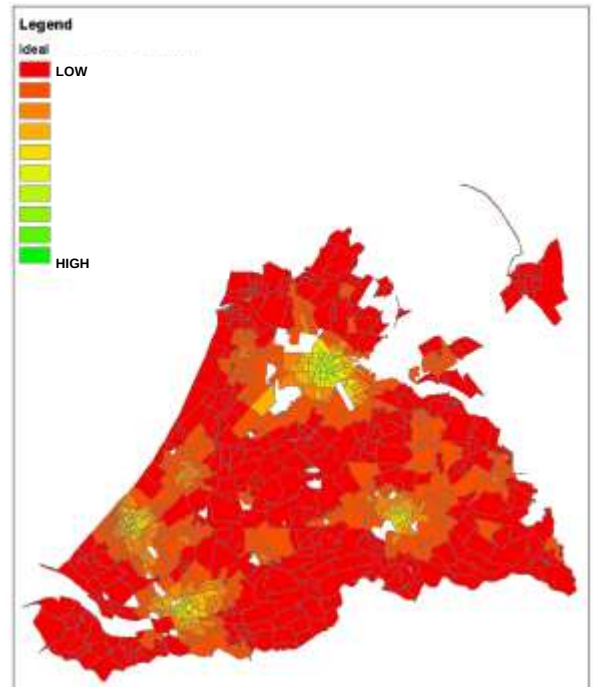
POTENTIAL ACCESSIBILITY TO JOBS (BIKE AND RIDE)

Based on the reported commuting time



POTENTIAL ACCESSIBILITY TO JOBS (BIKE AND RIDE)

Based on reported ideal commuting time



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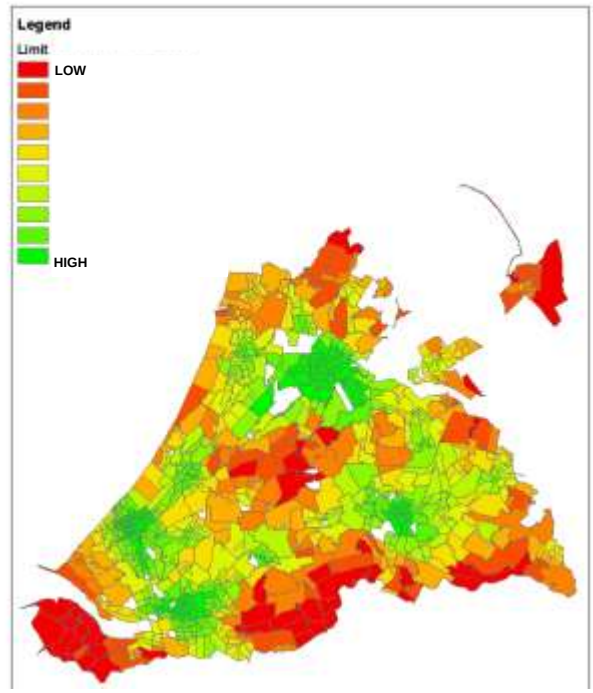
POTENTIAL ACCESSIBILITY TO JOBS (BIKE AND RIDE)

Based on the reported limit on commuting



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Implications

- If workers would follow their commuting preferences, they would substantially reduce their job accessibility and chances to find suitable work
- In the Randstad area, job/worker ratio is better by car (not by PT) than London and Sao Paulo. The gap between actual and ideal commutes is much smaller than in London and in Sao Paulo
  - > result of the polynuclear spatial structure with the quality of transport connections
- For monocentric cities such as London and Sao Paulo -> longer commutes, less ‘happy’ workers

Interested in more details?

- Pritchard, J. P., Stępniak, M., & Geurs, K. T. (2019). Equity analysis of dynamic bike-and-ride accessibility in the Netherlands (Chapter 4). In K. Lucas, K. Martens, F. D. Ciommo, & A. D. Kieffer (Eds.), *Measuring Transport Equity: Elsevier.*
- Pritchard, J. P., Tomasiello, D. B., Giannotti, M., & Geurs, K. (2019). Potential impacts of bike-and-ride on job accessibility and spatial equity in São Paulo, Brazil. *Transportation Research Part A: Policy and Practice, 121, 386-400. doi:https://doi.org/10.1016/j.tra.2019.01.022*
- Pritchard, J. P., Tomasiello, D., Gianotti, M., & Geurs, K. T. (2019). An international comparison of temporal and spatial inequalities in job accessibility – London, Sao Paulo and the Netherlands Randstad Area *Transport Findings. doi:10.32866/7412*

Conclusions -1

- The measurement of accessibility has a strong impacts on the results of equity and economic impact evaluations
- An integrated accessibility planning approach is needed to promote regional growth -> relative small changes in land use can have significant impacts on the accessibility benefits of infrastructure projects
- Transport investment may increase job competition and reduce job/worker ratio; thus it is important include competition effects

Conclusions -2

- Different statistical equity indicators and their operationalisation result in different conclusions – combine Gini index with de Palma ratio
- The land-use/transport system heavily impacts the degree to which workers can achieve their preferred commuting times
- Not dealt with in transport appraisal yet, but could have implications: transport investments are more likely to be efficient in Sao Paulo and London (higher time savings)