Accessibility: introduction, perspectives and applications

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1. Different perspectives to measuring accessibility

2. A review of different approaches to measuring accessibility
   - Theoretical and practical strengths and weaknesses
   - Usability in economic and social evaluations

3. Conclusions
What is accessibility?

“Accessibility is a slippery notion... one of those common terms that everyone uses until faced with the problem of defining and measuring it” (Peter Gould, 1969)
There is more to life than simply increasing its speed.
- Mahatma Gandhi
Definition of accessibility:


- Accessibility is an indicator for the impact of land-use and transport developments and policy plans on the functioning of the society in general.

- Fundamentally, it should relate to the role of transport in society; to provide individuals the opportunity to participate in activities in different locations.

- Definition (passenger travel) “the extent to which land-use and transport systems enable (groups of) individuals to reach activities or destinations by means of a (combination of) transport mode(s) (at various times of the day)”.
Four components of accessibility

Four main perspectives on accessibility

1. **Infrastructure-based** measures (transport planner’s perspective)

2. **Location-based** measures (urban planner’s perspective)

3. **Person-based** measures (time-space geography)

4. **Utility-based** measures (economist’s perspective)
Choice and operationalisation of accessibility measures depend on:

1. **Study goal**

2. **Theoretical strengths and weaknesses**: treatment of different components and elements within these components.

3. **Practical strengths and weaknesses**
   - Applicability/operationalisation (e.g., data availability, models)
   - Interpretability /communicability (for researchers and practitioners)

4. **Usability in economic evaluations**

5. **Usability in social evaluations**
Perspective 1: infrastructure-based measures

- Describe the performance of transport networks in terms of I/C ratios, congestion, travel times, travel costs, distance to public transport, etc.

- Many different indicators, range form simple to more complex network-based analysis: centrality/connectivity indicators:
## Accessibility measures in Dutch national transport policy

<table>
<thead>
<tr>
<th>Policy document</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Transport Structure Plan ('SVV1'; 1979)</td>
<td>Level-of-service (motorways)</td>
</tr>
</tbody>
</table>
| Second Transport Structure Plan ('SVV2'; 1990) | Detour factor (motorways)  
Congestion probability (motorways)  
Distance to access road (motorways)  
Capacity (motorways)  
Relative travel time (car/public transport)  
Speed (rail)  
Number of delayed trains (rail) |
| Mobility Policy Document ('Nota Mobiliteit', 2004) | Relative travel time between peak/off peak hours (motorways) |
  | Travel time reliability (motorways)  
Vehicle-hours lost (motorways)  
Punctuality (rail) |
| National Policy Strategy for Infrastructure and Environment ('SVIR'; 2012) | Relative travel time between peak/off peak hours (motorways)  
Generalised transport cost |

New Accessibility Indicator announced in the 2012 Dutch national spatial planning/transport policy document (SVIR)

Connectivity indicator generalised travel time between OD-pairs (municipality), weighted by number of trips

All modes or by Mode (Car, PT)
Infrastructure-based measures

- Theoretical strengths/weaknesses
  - Excludes land use and individual components. A partial measure of accessibility

- Practical strengths/weaknesses:
  - Easy to understand and communicate, easy to operationalise (standard output of transport models),
  - Link to transport policy goals;
  - Standard input for economic appraisal of transport investments
Limitations to accessibility goals and measures in the Dutch transport policy and planning practice

- Limitation 1: A sectoral policy approach
- Limitation 2: A Lack of attention for interactions between transport and land use.
- Limitation 3: The treatment of the transport component
- Limitation 4: A lack of attention for measuring urban accessibility (including walking and cycling).
- Limitation 5: Lack of attention for equity/distributional and justice effects.

(There are some exceptions at the regional level)
Perspective 2: location-based accessibility measures

- Threshold-based measures (travel time isochrones, cumulative opportunities/contour measures)
- Potential accessibility
- Potential accessibility including competition effects
Threshold based accessibility measures
(Cumulative opportunities/contour measure)
Time isochrone/cumulative opportunities:
UT, car, morning peak hour, 2008
Interactive website ‘national accessibility map’ (www.bereikbaarheidskaart.nl)
Threshold-based accessibility measures

- Theoretical strengths/weaknesses
  - Land use component included in aggregate way
  - Arbitrary choice of maximum travel time
  - Assumes all activities are equally important -> weak link with travel behaviour
  - Standard measure does not include mismatch between demand and supply of opportunities

- Practical strengths/weaknesses:
  - Easy to compute (e.g. using GIS), does not require transport models (thus popular among urban planners/geographers)
  - Easy to communicate (absolute values)
Potential accessibility measure

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

Accessibility, Social justice and TRansport emission Impacts of TOD strategies

This project seeks to investigate the causal mechanisms underlying disparity and social injustice in job accessibility and air quality in metropolitan areas, and the potential of transit-oriented development to promote social justice.

Research Focus Themes

MORE INFO: HTTPS://WWW.ASTRIDPROJECT.COM/

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DATA DESCRIPTION

• Growing abundance of detailed spatial data and real-time transport datasets provides many opportunities for improved accessibility modelling

• TOMTOM™ Speed Profile Data (2014)

• General Transit Feed Specification data (GTFS)

• Door-to-Door Approach
POTENTIAL JOB ACCESSIBILITY 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**: Navigation data, GTFS data

- **Individual component**:
  - Job matching by job skills and sector (in NL), based on micro data
  - Detailed survey conducted in NL (Randstad), London, Sao Paulo on perceptions/barriers to accessibility, housing market, pollution

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JOB ACCESSIBILITY BY CAR
CITY COMPARISON OF DAILY CAR ACCESSIBILITY FLUCTUATIONS
JOB ACCESSIBILITY BY PT
CITY COMPARISON OF PT ACCESSIBILITY FLUCTUATIONS
JOB ACCESSIBILITY – WALK AND RIDE
ZUID HOLLAND (PC5) – PT ACCESSIBILITY VARIABILITY ACROSS THE DAY

night
(2-3 am)

morning peak
(7-8 am)

peak-off
(10-11 am)

afternoon peak
(5-6 pm)

evening
(10-11 pm)

Job accessibility by public transport (Walk & Ride model)

Job data: LISA (2014)
GTFS data: 9292.nl for 01.03.2016 (accessed 28.02.2016)
PT network created by AddGTSScenario Tool
Travel time calculations: ArcGIS Network Analyst

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JOB ACCESSIBILITY – BIKE AND RIDE
ZUID HOLLAND (PC5) – PT ACCESSIBILITY VARIABILITY ACROSS THE DAY

night (2-3 am)

morning peak (7-8 am)

peak-off (10-11 am)

afternoon peak (5-6 pm)

evening (10-11 pm)

Job accessibility by public transport (Bike & Ride model)
Advanced location-based measures: potential accessibility with competition.


\[ A_i = \sum_{j=1}^{n} \left[ \frac{GP_j}{\sum_{k=1}^{m} P_k F(d_{jk})} \right] F(d_{ij}) \]
Inverse balancing factors of the doubly constrained spatial interaction model

\[ T_{ij} = a_i b_j F(c_{ij}) \]

\[ a_i = \sum_{j=1}^{n} \frac{1}{b_j} D_j e^{-\beta c_{ij}} \]


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Location-based measures – Potential Accessibility

- Theoretical strengths/weaknesses
  - Rooted in Spatial Interaction Modelling; entropy-maximizing SIM and MN logit model are compatible
  - Includes land-use component; applicable in transport, land-use and integrated land-use/transport policy appraisal
  - Individual component: lacks heterogeneity in needs, preferences
  - Standard PA does not include competition effects

- Practical strengths/weaknesses:
  - Easy to measure (e.g. GIS; SIM (thus popular among urban planners and geographers)
  - Standard PA easy to interpret; PA with competition less easy
  - Measure itself has no meaning in terms of costs or benefits or activity values
Perspective 3: “Person-based” measures

- Analysis of accessibility at the individual level
- Time-Space Geography
- Accessibility strongly depends on individual constraints (activity scheduling), temporal constraints (opening hours of shops), spatial constraints (travel budget)
- Space-time prisms (STP) and Daily Potential Path Area (DPPA):

Person-based accessibility measures

Theoretical strengths/weaknesses

- Comprehensive measure of accessibility,
- Addresses all components of accessibility (transport typically in simplified way)
- Capture interpersonal differences
- Hybrid utility-/person-based measures applied in the literature
- Does not include competition effects

Practical strengths/weaknesses

- Data need
- Complexity; difficult to operationalise and aggregate
- Difficult to visualise and communicate
Perspective 4: Utility-based measures

- Benefits that people derive from access to spatially distributed activities

- Accessibility benefit measures based on doubly constrained spatial interaction model (Martinez, 1995; Martinez and Araya, 2000)

- Logsum accessibility benefit measures based on MNL model (Ben-Akiva and Lerman, 1985)
Logsum measure of accessibility benefits

- The log of the denominator of the multinomial logit model
- Logsum considers the expected utilities of all alternatives in the choice set of each traveller
- Exact measure of user benefits. Calculated in money terms, multiplying the logsum by the inverse of the marginal utility of income (time or cost variable in utility function)).

MN logit model:

\[ P_{nj} = \frac{e^{V_{nj}}}{\sum_j e^{V_{nj}}} \]

\[ E(CS_n) = \frac{1}{\alpha_n} \ln \left( \sum_{j=1}^{J} e^{V_{nj}} \right) + C \]
Example: using the logsum in an economic appraisal of a new railway link between Amsterdam and Almere, using a LUTI model

- Redistribution of opportunities can result in substantial accessibility benefits
- Spatial planning affects efficiency of rail infrastructure projects
- Logsum measure of accessibility benefits gives substantially higher benefits than conventional rule-of-half (includes destination utility). Important even with small distributional effects

Logsum – theoretical strengths and weaknesses

- Closed form expression founded in discrete choice theory
- Flexible; variety of attributes of the alternatives that it can encapsulated within a single term (incl. latent variables)
- MNL properties: no natural constraints to the choice set; does not account for unobserved taste variations
- Only utility of the choices made is counted. Stochastic element represents uncertainty due to imperfect knowledge of the analyst, not the traveler.
  - Option value literature suggest that people might value options that they have available (in this case: options to reach destinations, use modes or maybe even routes)
- Expected utility may differ from experienced utility
Logsum – practical strengths and weaknesses

More difficult to operationalise - > discrete choice model is needed (but simple if present)
Method is relatively difficult to communicate to non-experts
Useful to analyse changes in utility/monetary, does not represent absolute levels of accessibility
Visualisation is more difficult; logsums per transport mode or zone cannot easily be calculated, since modes and zones are endogenous choice variables (can be estimated by proxy)
Outputs in monetary terms are easily communicated
Comparative studies

- Different location-based accessibility metrics often work together to explain trip making at the aggregate or disaggregate level.

- Location-based and person-based measures are distinctive accessibility measures which reflect different dimensions of accessibility, i.e. space-time measures are more capable of capturing interpersonal differences (Kwan, 1998).

- Substantial differences are found within the group of person-based measures (Neutens et al.).
Usability in economic evaluations

Logsum!
Usability in social evaluations
(e.g., Van Wee and Geurs (2011); Lucas et al., 2016).

- **Distributional analysis** goes back to 1970s: examine spatio-temporal inequalities in accessibility; input for e.g. Gini-index
- **Equity-based** accessibility analysis: what is ‘fair’ or ‘unfair’
  - **Utilitarian** approach; choices of travellers are based on willingness to pay (WPT) for travel options; not appropriate when there is specific aim to achieve greater equity from an investment.
  - **Egalitarianism**: all people should be treated equally (Sen, 1992). Egalitarian theories focus on relative differences in levels of well-being
  - **Sufficientarianism**: everybody should be well off up to a certain threshold -> a ‘sufficient’ level of accessibility. Focus is on an absolute level of well-being.
Equity-based accessibility analysis (1)

- A growing field of research, but needs more work!

- A balanced treatment of the four components of accessibility is important: infrastructure-based measures are not appropriate

- Treatment of competition effects needs more attention in analysing equity-based accessibility (health access, education, etc.): a ‘sufficient’ level of access depends on competitors.

- Monetising accessibility is problematic. WTP of low income people for (additional) travel is inherently low, which makes the valuation of the accessibility increases low.
Equity-based accessibility analysis (2)

- Person-based and utility-based measures focus on interpersonal differences which is problematic from the ethical perspectives of egalitarianism and sufficientarianism.

- Standard and adapted location-based measures are more appropriate than logsum and arguably time-space measures.

- A main challenge to set threshold values for a sufficientarianism index – what are ‘sufficient’ for accessibility levels to guarantee continued wellbeing. There is very little literature on this and this is an area which needs more research.
  - Life satisfaction decreases with commuting distance, and increase when the commute is by bike or foot (Lancée et al, 2017)
Conclusions:

- There is a trade off between theoretical and practical strengths and weaknesses

- The definition and operationalisation (choice of perspective and treatment of the 4 components) strongly affects the conclusions

- Choice of accessibility measure depends on study aim, trade-off between theoretical and practical strengths/weaknesses

- The Dutch practice focuses on infrastructure-based accessibility analysis, limiting accessibility to a sectoral approach
Conclusions:

- Typically a combination accessibility measures works better, reflecting different dimensions of accessibility.

- Location-based measures are more appropriate as egalitarianism and sufficientarianism indexes than logsum and arguably also time-space measures.

- There is very little literature on operationalizing accessibility-based sufficientarianism indices.