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Two common ways of approaching destinations in the city

From fixed locations
e.g. homes, workplaces

G. Caillebotte - Jeune homme à la fenêtre

While moving around
e.g. on the way to transit
1. Fixed Origin Spatial Accessibility Metrics

From fixed locations
e.g. homes, workplaces

G. Caillebotte - Jeune homme à la fenêtre
Reach accessibility index
How many surrounding destinations \( j \) can be reached from building \( i \) within a given network radius?

\[
Reach[i]^r = \sum_{j \in G - \{i\}, d[i,j] \leq r} W[j]
\]

Figure 2 Positive and negative illustrations of a Reach effect, controlling for Distance, Turns, and Intersections Remoteness.
A similar conclusion emerges from the Distance Remoteness coefficients in Model 4. In order to facilitate the interpretation of these controlled coefficients, we also provide a simple illustration of their positive and negative effects in Figure 3. We again show a hypothetical building \( i \) in black at the center of the branching roads in the diagram, and illustrate different environmental configurations on the left and right producing lower and higher Remoteness measures for \( i \) accordingly. Model 4 suggests that Distance Remoteness to jobs, built volume, and subway stations is negative and highly significant, indicating that as the cumulative distance to these types of destinations in a ten-minute walking radius increases, the likelihood of observing retailers decreases. Each kilometer of distance away from the nearest subway station, for example, decreases retail probabilities by 0.0516% on average (\( p < 0.1 \)). Distance Remoteness to residents, however, is positive (\( 3.00E-08, p < 0.0001 \)), telling that retailing activities increase as we move further from locations that are closest to residents, controlling for the number of residents and other covariates.

Attraction towards subway stations stands out as the only destination type that also exhibits significant effects for Turns Remoteness. The negative coefficient of Turns suggests that retailers tend to locate in buildings that require fewer changes in direction when approaching from subway stations, controlling for distance and other covariates. Each turn away from the nearest subway station along the shortest path decreases retail probabilities by 0.082% (\( p < 0.1 \)) on average. Put alternatively, our data suggest that...
The map shows buildings that lie within a 10-minute (600m) walkshed from Darwin’s café (shaded dark). On Brattle St.
Accessibility can be specified to any type of destination

Transit

Businesses

Jobs

Residents
% population within 1KM of a retail cluster of >25 stores walking distance

- Detroit, MI: 4%
- Memphis, TN: 6%
- Fort Worth, TX: 6%
- Columbus, OH: 7%
- Oklahoma City, OK: 7%
- San Antonio, TX: 7%
- Cleveland, OH: 8%
- Tucson, AZ: 9%
- Jacksonville, FL: 9%
- Omaha, NE: 9%
- El Paso, TX: 10%
- Seattle, WA: 11%
- Tulsa, OK: 12%
- Phoenix, AZ: 13%
- Albuquerque, NM: 13%
- Fresno, CA: 13%
- Sacramento, CA: 16%
- Charlotte, NC: 16%
- Austin, TX: 16%
- Houston, TX: 20%
- Dallas, TX: 24%
- San Jose, CA: 29%
- Denver, CO: 30%
- Las Vegas, NV: 31%
- Long Beach, CA: 32%
- Minneapolis, MN: 33%
- Portland, OR: 34%
- San Diego, CA: 37%
- Philadelphia, PA: 37%
- Baltimore, MD: 39%
- Atlanta, GA: 40%
- Chicago, IL: 41%
- Oakland, CA: 51%
- Washington, DC: 54%
- Los Angeles, CA: 55%
- Honolulu, HI: 62%
- Miami, FL: 67%
- Boston, MA: 69%
- San Francisco, CA: 84%
- New York, NY: 88%
Towards Amenity Oriented Development (AOD)
Comparison of urban form and population density metrics across cities that provide a high (top) and a low (bottom) share of populations with walking access to retail clusters.

<table>
<thead>
<tr>
<th>Rank</th>
<th>City</th>
<th>Population within 1000m of a retail cluster</th>
<th>Population Land Area Residential Density FAR Built Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2010 (km²)</td>
<td>Density (km²)</td>
</tr>
<tr>
<td>1</td>
<td>New York City, NY</td>
<td>88%</td>
<td>8,175,133</td>
</tr>
<tr>
<td>2</td>
<td>San Francisco, CA</td>
<td>84%</td>
<td>805,235</td>
</tr>
<tr>
<td>3</td>
<td>Boston, MA</td>
<td>69%</td>
<td>617,594</td>
</tr>
<tr>
<td>4</td>
<td>Miami, FL</td>
<td>67%</td>
<td>399,457</td>
</tr>
<tr>
<td>5</td>
<td>Honolulu, HI</td>
<td>62%</td>
<td>337,256</td>
</tr>
<tr>
<td>6</td>
<td>Los Angeles, CA</td>
<td>55%</td>
<td>3,792,621</td>
</tr>
<tr>
<td>7</td>
<td>Washington, DC</td>
<td>54%</td>
<td>681,170</td>
</tr>
<tr>
<td>8</td>
<td>Oakland, CA</td>
<td>51%</td>
<td>390,724</td>
</tr>
<tr>
<td>9</td>
<td>Chicago, IL</td>
<td>41%</td>
<td>2,695,598</td>
</tr>
<tr>
<td>10</td>
<td>Atlanta, GA</td>
<td>40%</td>
<td>417,735</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>61%</td>
<td>1,831,252</td>
</tr>
<tr>
<td>31</td>
<td>Omaha, NE</td>
<td>9%</td>
<td>383,964</td>
</tr>
<tr>
<td>32</td>
<td>Jacksonville, FL</td>
<td>9%</td>
<td>822,050</td>
</tr>
<tr>
<td>33</td>
<td>Tucson, AZ</td>
<td>9%</td>
<td>520,116</td>
</tr>
<tr>
<td>34</td>
<td>Cleveland, OH</td>
<td>8%</td>
<td>396,815</td>
</tr>
<tr>
<td>35</td>
<td>San Antonio, TX</td>
<td>7%</td>
<td>1,469,845</td>
</tr>
<tr>
<td>36</td>
<td>Oklahoma City, OK</td>
<td>7%</td>
<td>579,999</td>
</tr>
<tr>
<td>37</td>
<td>Columbus, OH</td>
<td>7%</td>
<td>787,033</td>
</tr>
<tr>
<td>38</td>
<td>Fort Worth, TX</td>
<td>6%</td>
<td>854,113</td>
</tr>
<tr>
<td>39</td>
<td>Memphis, TN</td>
<td>6%</td>
<td>646,889</td>
</tr>
<tr>
<td>40</td>
<td>Detroit, MI</td>
<td>4%</td>
<td>713,777</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>7%</td>
<td>717,460</td>
</tr>
</tbody>
</table>
Key user inputs for Reach accessibility:

1. Origin points
2. Destination points
3. Optionally weights for destinations (e.g. jobs field for census tracts)
4. Search radius (along the network, e.g. 400m)
Gravity Index
Accessibility is proportional to the attractiveness & inversely proportional to the distance of reaching surrounding destinations $j$ (Hansen 1959)

$$Gravity[i]^r = \sum_{j \in G - \{i\}, d[i,j] \leq r} \frac{W[j]^\alpha}{e^{\beta \cdot d[i,j]}}$$
Walking distance to bus stops in different cities
% transit users

Source: TRB
Walking distance to bus stops in different cities

% transit users

\[ Gravity_{ij} \sum_{j=1}^{n} \frac{1}{e^{\beta \cdot dist[i,j]}}, \]  

\( \beta = 0.004 \)

NB! Beta depends on distance units (e.g. meters, feet)

Walking distance to Bus (metres)

Percent of Transit Users Walking > Distance

- Calgary, AB
- Washington, DC (low income)
- Edmonton, AB
- Washington, DC (high income)
- Small communities, BC
- Bay Ridges, ON
- Washington, DC (downtown)
Gravity access from buildings to public transit in Cambridge, MA

T-stops and bus stops (T = 5x bus). Search radius= 1,000m; beta= 0.002

Analysis performed with the UNA toolbox.
Gravity access from buildings to jobs in Cambridge, MA
Search radius= 1,000m; beta= 0.002
Example: Public transit accessibility in SG from each building
Gravity access

- Excellent
- Good
- Mediocre
- Poor
Key user inputs for Gravity accessibility:

1. Origin points
2. Destination points
3. Optionally weights for destination points (e.g. jobs field for census tracts)
4. Search radius (along the network, e.g. 400m)
5. Beta value for the decay effect*

i.e. use the following beta values if drawing units are:

“meters” 0.002
“feet” 0.000663
“kilometers” 2.175
“miles” 3.501.
How can accessibility be improved?

**a. Facilitate transportation to destinations**

All else being constant

- Less impedance  
  + accessibility

- More impedance  
  - accessibility
How can accessibility be improved?

**Increase the density of destinations around a location**

All else being constant

- **Denser destinations**
  - + accessibility

- **Sparser destinations**
  - - accessibility
How can accessibility be improved?

**Increase capacity (or attractiveness) of destinations**

All else being constant

Bigger destinations  
+ accessibility

Smaller destinations  
- accessibility
How can accessibility be improved?

**Improve spatial connectivity to destinations**

All else being constant

More connectivity  
+ **accessibility**

Less connectivity  
- **accessibility**
2. Mobile Origin Spatial Accessibility Estimation

While moving around e.g. on the way to transit
Distribute Origin Weights
Spatial origins and Destinations
**Shortest route**
Spacing synthetic points along the shortest route between the O and D at 10m intervals. Overall origin weight remains the same.
All plausible routes
Up to 20% longer than shortest route
Key user inputs for Distributing Weights:

1. Origin points.
2. Destination points.
3. Optionally **weights for origin points** (e.g., people in buildings).
4. Observer points, that can count passersby but do not send out or receive any trips themselves.
5. Nearest, All, Search radius (determines which destinations are used).
Example 1: Planning Commercial Centers in Singapore

Dwelling unit density
Punggol overall: 15,000 DU/km²
MRT, LRT and bus stop locations

Punggol
Betweennes: estimated distribution of walks to transit stops

Punggol

Analysis performed with the UNA toolbox.
Gravity access from homes to retail centers
Weighted by store size. Radius = 3,000m; beta = 0.001
Gravity access from metro walk routes to retail centers

Weighted by store size. Radius = 3,000m; beta = 0.001
Estimated center patronage assuming trips start from homes.

**Total visits in town** 33,211.

Analysis performed with the spatial network-based Huff model available as part of the Rhino UNA toolbox.
Estimated center patronage assuming trips start from metro walk routes.

Total visits in town 35,055.
Estimated center patronage assuming trips start from MRT walk routes.

**Total patronage in town = 35,055 households.**

Changing our assumption about where trips originate from changes accessibility results and alters how many people we expect to actually patronize urban amenities...

<table>
<thead>
<tr>
<th>Model type</th>
<th>Based on Access</th>
<th>Based on Access</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand locations</td>
<td>From homes</td>
<td>From MRT walks</td>
</tr>
<tr>
<td>Destination locations</td>
<td>Existing</td>
<td>Existing</td>
</tr>
<tr>
<td>Destination sizes</td>
<td>Existing</td>
<td>Existing</td>
</tr>
</tbody>
</table>
Estimate of retail patronage, where existing and future commercial clusters are located according to HDB’s current plans. Total quantum of commercial space is 136,500m².

**Total patronage in town: 38,243 households.**
Estimate of retail patronage, where the same number of commercial centres are located deliberately closer to MRT walk routes and their sizes reallocated so as to maximize access. Total quantum of commercial stays the same at 136,500m².

**Estimated patronage across all clusters is 41,254 households.**
Towards active street fronts
Example 2

Surabaya Tram Corridor
Context
Population density at RT level

South Surabaya

Population density is highest in kampungs, showing the importance of good kampung-to-tram connections.
Estimating foot-traffic from origins to destinations
Betweenness analysis, UNA Toolbox
Predicted footfall from homes to MRT stations
to stations up to 800m away

269 km of paths!
Prioritize paths with highest footfall >5,000p day to stations up to 800m away

17 km of paths to upgrade!
The catalogue provides a visual and numeric reference to streets around the world. It allows users to compare the accessibility and connectivity measurements of different streets with time-lapse videos and corresponding pedestrian counts of the same streets. Videos captured during different times of the day allow you to examine temporal changes in the character of a street between times of a day, days of a week, or times of the year. Read more

<table>
<thead>
<tr>
<th>Case ID</th>
<th>Country</th>
<th>City</th>
<th>Street name</th>
<th>From</th>
<th>To</th>
<th>Date &amp; Time</th>
<th>Weekday</th>
<th>Footfall per hour</th>
<th>Betweenness</th>
<th>Access to Businesses</th>
<th>Access to Transit</th>
<th>Access to Floor Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>10th Avenue</td>
<td>23:30</td>
<td></td>
<td>Sun</td>
<td>Weekday</td>
<td>1108</td>
<td>621</td>
<td>597</td>
<td>Transit</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Swanston Street</td>
<td>11:00</td>
<td></td>
<td>Mon</td>
<td>Weekday</td>
<td>2223</td>
<td>239</td>
<td>1071</td>
<td>Transit</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hudson Street</td>
<td>18:57</td>
<td></td>
<td>Sun</td>
<td>Weekday</td>
<td>680</td>
<td>1288</td>
<td>801</td>
<td>Transit</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lujiazui Pedestrian Bridge</td>
<td>12:30</td>
<td></td>
<td>Thu</td>
<td>Weekday</td>
<td>1500</td>
<td>18</td>
<td>343</td>
<td>Transit</td>
<td>13</td>
</tr>
</tbody>
</table>

http://cityform.mit.edu/street-catalogue
Brattle Street, Cambridge MA
Brattle St at Harvard Square has a number of a popular shopping destinations, street cafes and restaurant. The time-lapse is captured at about 50 meters from the nearest Harvard Square subway entrance. The space in front of the camera contains a large sidewalk with ample seating areas, which also functions as a public plaza for street musicians and people-watchers.
Upgrade important kampung lanes leading to MRT stations
Drainage, lighting, landscaping, activity generating uses, bike-lanes, furniture…
Complex built environment around the last mile
Data we have: road networks
Data we should have: pedestrian networks and building entrances
Category counts:

**391 pedestrians**
- 342 walking
- 38 standing
- 3 baby strollers
- 8 running

**7 cyclists**

**14 passenger cars**
- 1 truck
- 4 buses
Governments maintain good databases on vehicular roads
e.g. US Census TIGER roads data
E.g. US Census TIGER roads data
The lack of good data is a huge barrier to better walking infrastructure. Denver, a self-styled Vision Zero city, can't eliminate traffic deaths without a safe walking network. And the city can’t improve its walking network if it doesn’t know where the weaknesses are. And yet, no city department has an inventory of the city’s sidewalks and crosswalks.

Streets Blog Denver
Crowd-sourcing sidewalk data
e.g. Walkscope in Denver
City governments should maintain equally good databases on pedestrian networks...
OECD ITF to develop standards and recommendations for cities around the world?
Conclusions

• It is customary to measure spatial accessibility from fixed locations (e.g. homes, jobs), but people don’t necessarily start their trips from these locations.

• Changing our assumption about trip origins, changes our estimates of how frequently and by whom urban amenities can be accessed and are visited.

• When planning accessible environments, we need to not only think about motorized and mechanized transport infrastructure, but also focus on the scale of the street which everyone intuitively experiences.

• In order to describe accessibility on streets, we need data about sidewalks and pedestrian infrastructure.

• Could OECD help propose standards and urge cities to collect sidewalk data?

• In order for accessibility analytics to influence city design and planning, analytics needs to move from being retrospective and become projective, applied to synthetic and normative design solutions of the future, shaping decisions about potential built environments.
Thank you!

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Urban Network Analysis toolbox software (FREE)


Related Articles


