

Transportation Networks & Land Use:

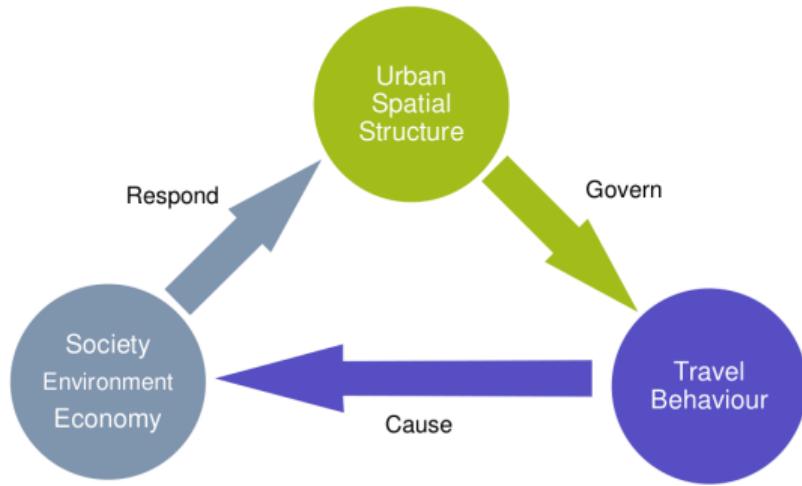
GGR424 - Transportation Geography & Planning

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February 7, 2022

Today: How do we measure and analyze (*Urban*) Spatial Structure?



(Urban) Spatial Structure is a combination of

- ▶ Land Use
- ▶ Transportation Networks

Data & GIS

In transportation geography and planning, we are usually working with **vector** data (rather than raster data)

Land Use Data

- ▶ What is located where
- ▶ Usually **Points or Polygons**

Network Data

- ▶ The spatial patterns of transportation networks
- ▶ Usually **Lines** (and nodes/intersections)

Travel Behaviour Data (more on this next week)

- ▶ Travel Surveys (usually tables, linked to locations)
- ▶ GPS/Sensor Mobility Data (usually big N point data)

Land Use Data

- ▶ What is located where
- ▶ Usually Points or Polygons
- ▶ Many data sources, e.g. OpenStreetMap

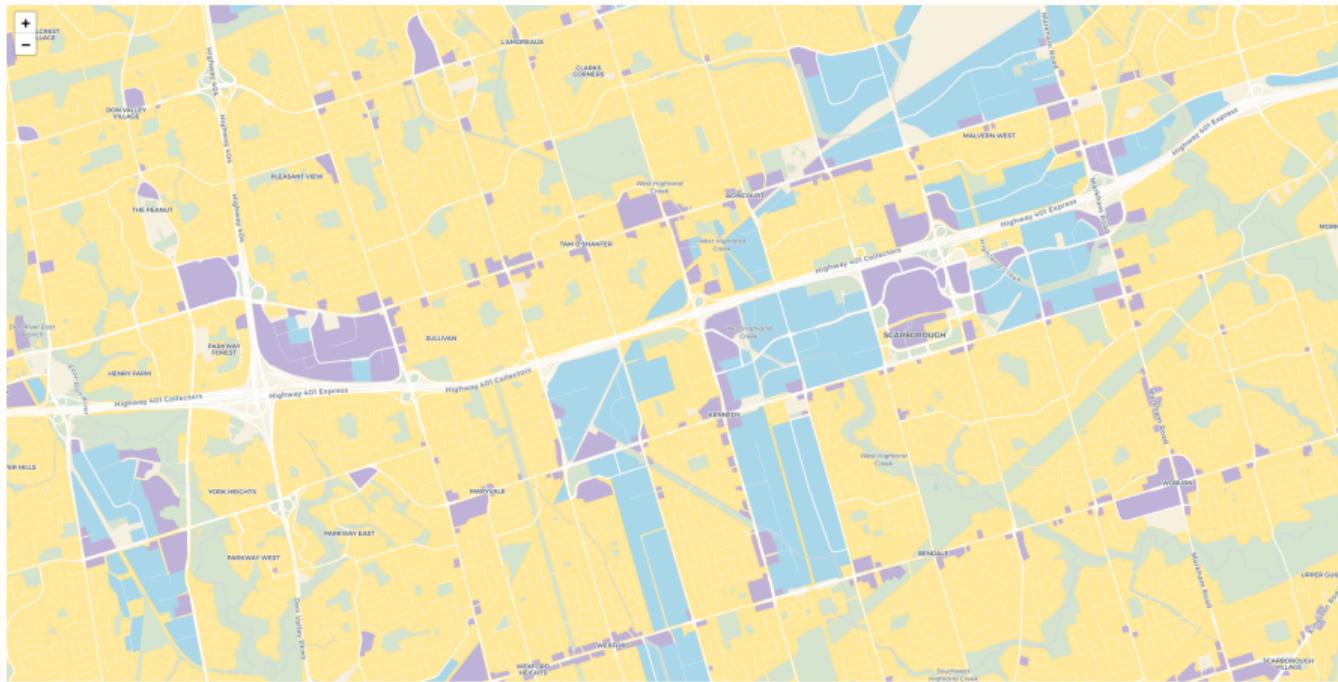
The screenshot shows a web-based map editor called Overpass Turbo. The map displays the city of Toronto, Canada, with a grid of streets and various geographical features like water bodies and parks. Numerous yellow circular markers are scattered across the map, primarily concentrated in the downtown area and along major thoroughfares, representing the locations of cafes. The Overpass Turbo interface includes a top navigation bar with links for Run, Share, Export, Wizard, Save, Load, Settings, Help, and a search bar labeled "overpass turbo". On the left side, there is a code editor window containing an Overpass query. The query is as follows:

```
1 /*  
2 This has been generated by the overpass-turbo wizard.  
3 The original search was:  
4 "cafe"  
5 */  
6 [out:json][timeout:25];  
7 // gather results  
8 !  
9 // query part for: "cafe"  
10 node["amenity"]="cafe"!{{bbox}};  
11 way["amenity"]="cafe"!{{bbox}};  
12 relation["amenity"]="cafe"!{{bbox}};  
13 !  
14 // print results  
15 out body;  
16 >;  
17 out skel qt;
```

In the bottom right corner of the map, there is a status bar with the text "Located - nodes: 1042, ways: 33, relations: 0" and "Displayed - points: 827, lines: 0, polygons: 33".

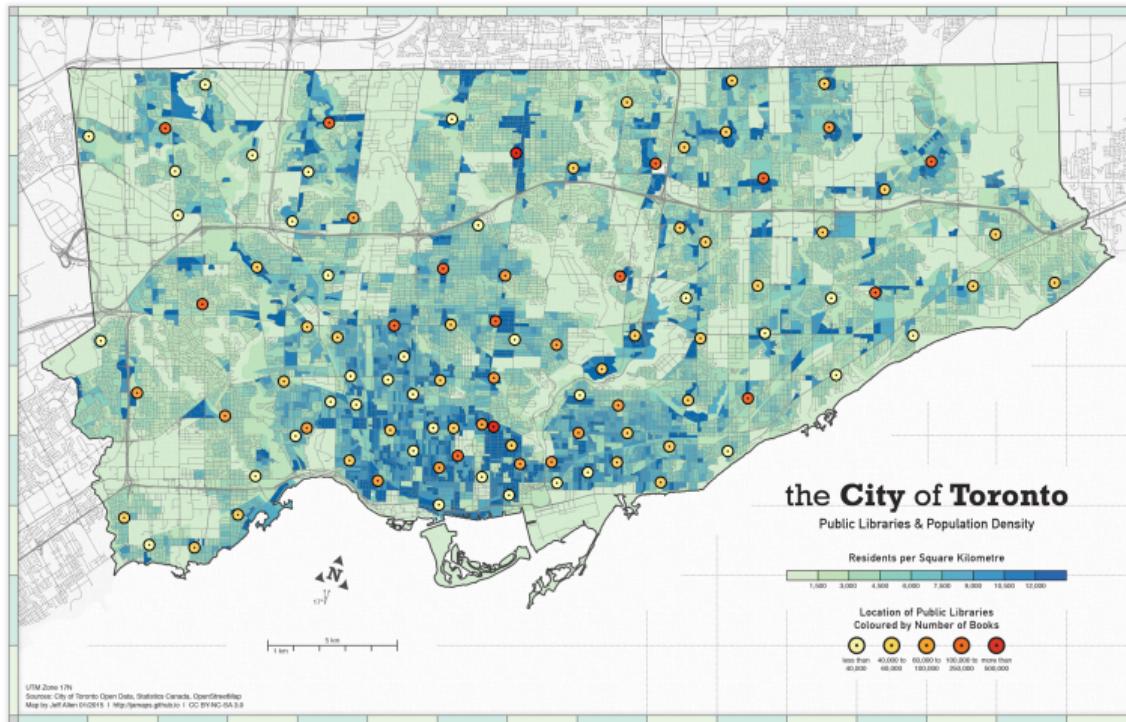
Land Use Data - e.g. polygon data

yellow = residential, purple = retail/commercial, blue = industrial, etc.



Land Use Data

e.g. polygon data - census data, who lives and works where
e.g. point data - libraries in Toronto



Network Data:

Network - an interconnected group or system

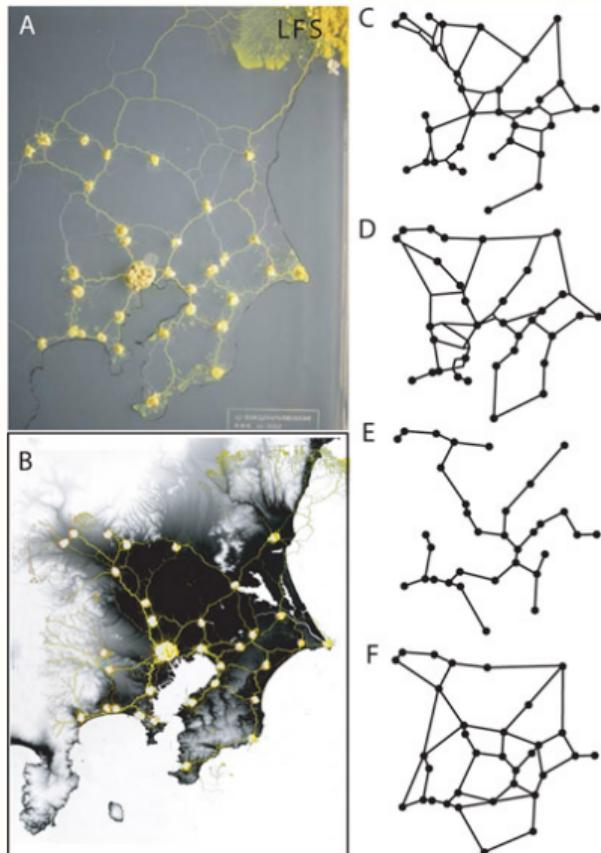
Examples

- ▶ Computer network
- ▶ Social network
- ▶ Transportation network
- ▶ Biological network

Often represented using **graphs**

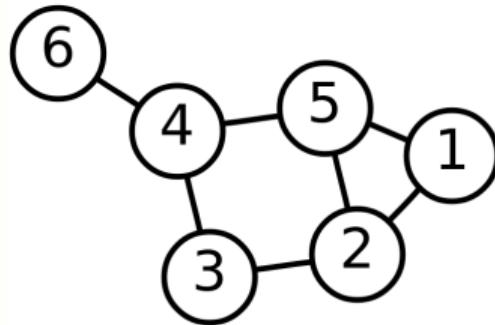
e.g. https://en.wikipedia.org/wiki/Physarum_polycephalum

<https://www.wired.com/2010/01/slime-mold-grows-network-just-like-tokyo-rail-system/>



Graph

- ▶ Set of *nodes* (also called points or vertices) and *edges* (also called lines or arcs)
- ▶ $G = (V, E)$
- ▶ If two nodes have a relationship, then there is an edge linking them
- ▶ Edges can have weights (e.g. travel time or speed, surface quality, elevation, etc.)
- ▶ Graphs can be directed or un-directed (e.g. can have one-way relationship)



Source: [https://en.wikipedia.org/wiki/Graph_\(discrete_mathematics\)](https://en.wikipedia.org/wiki/Graph_(discrete_mathematics))

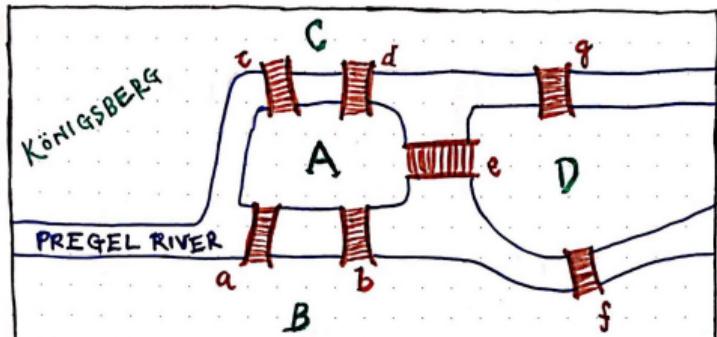
Can you walk across all of the seven bridges in Königsberg, without ever repeating a single bridge in the course of one's walk? (Leonhard Euler, 1736)



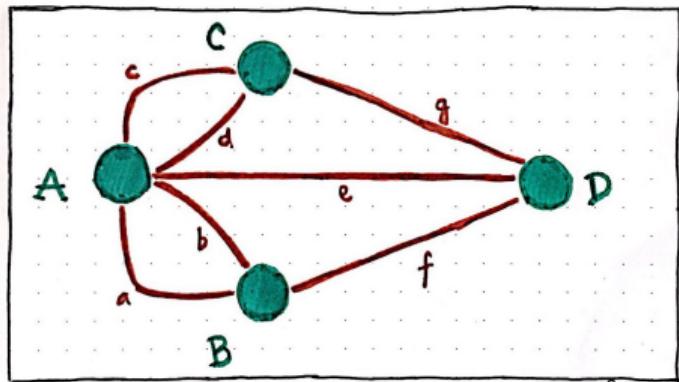
Source: <https://medium.com/basecs/konigsberg-seven-small-bridges-one-giant-graph-problem-2275d1670a12>

Can you walk across all of the seven bridges in Königsberg, without ever repeating a single bridge in the course of one's walk? (Leonhard Euler, 1736)

Representing Königsberg as a graph

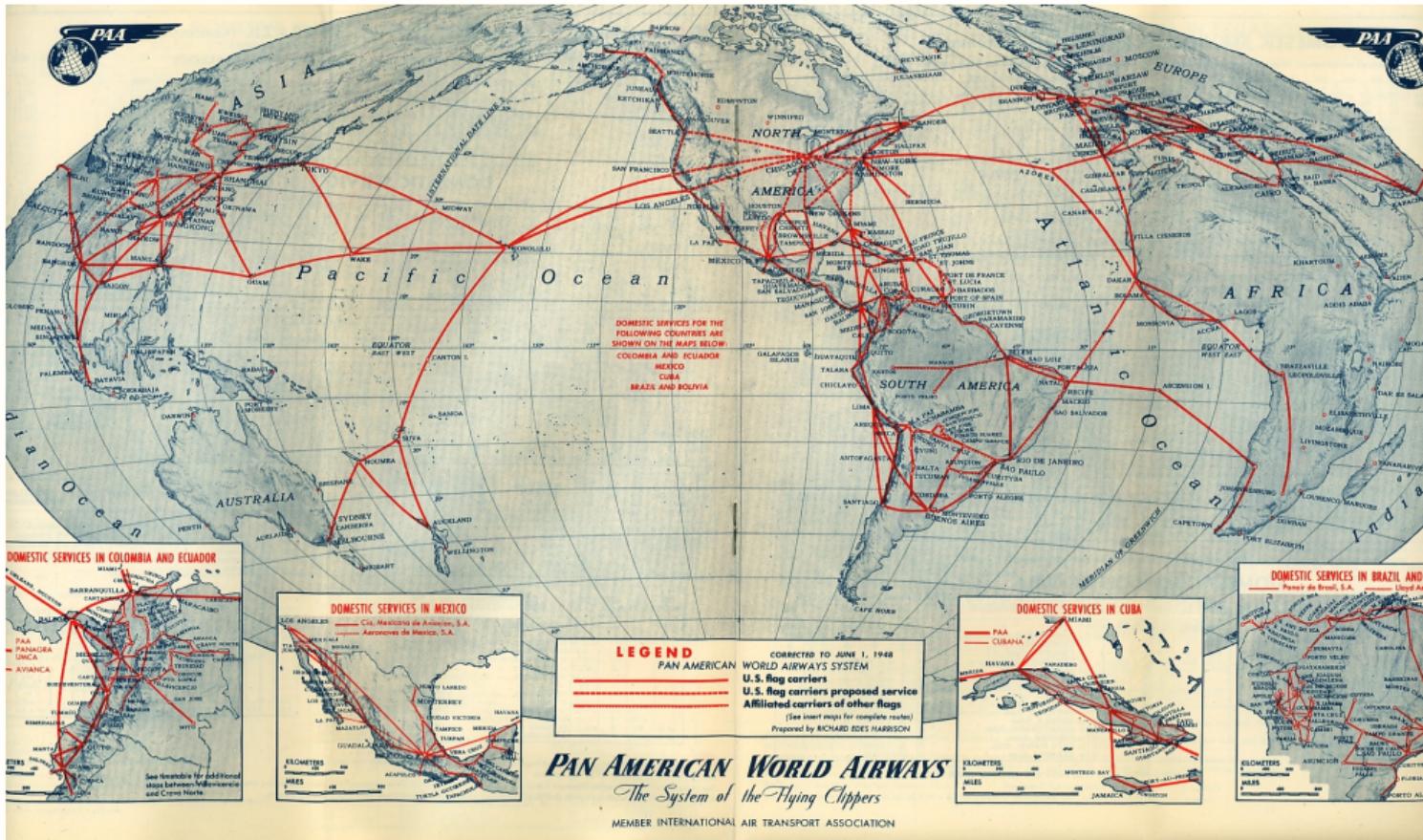


The Seven Bridges of Königsberg



The Seven Bridges of Königsberg—Revisualized

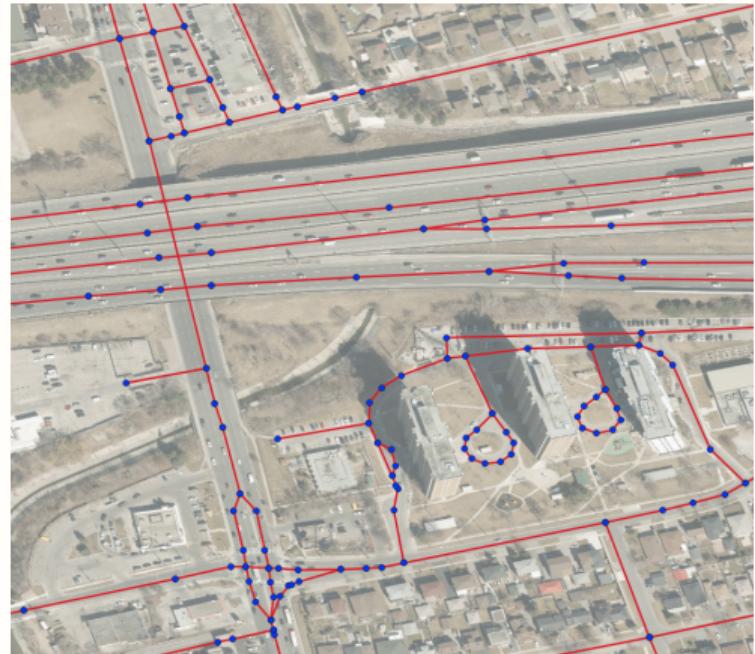
Source: <https://medium.com/basecs/konigsberg-seven-small-bridges-one-giant-graph-problem-2275d1670a12>



In transportation geography and planning, network data are used for measuring distances and travel times over *network* space.

These distances/times can be used for a range of analyses

Source: <https://www.openstreetmap.org>



Transportation network data sources:

Driving

- ▶ OpenStreetMap (free and detailed, depending on crowdsourced activity)
- ▶ Government sources (e.g. City of Toronto Centreline, Federal Road Network Files)
- ▶ Proprietary Networks (e.g. HERE, DMTI, Google Maps, etc.). Often used if needing travel times with congestion

Walking & Cycling

- ▶ OpenStreetMap (free and detailed, depending on crowdsourced activity)
- ▶ Various municipal gov't data sources

Transit

- ▶ GTFS (General Transit Feed Specification)

Transportation network analysis tools:

Walking, biking, driving (single mode-specific network)

- ▶ QGIS (free, but not too many options)
- ▶ ArcGIS network analysis (paid, good tools, but really slow)
- ▶ PGRouting (extension to PostGIS, need to know SQL)
- ▶ OSRM (very customizable and quite fast, bigger learning curve though)
- ▶ OSMNX (Python package using OSM data)

Public Transit (combine walking network with GTFS data)

- ▶ OpenTripPlanner
- ▶ R5
- ▶ Add GTFS to ArcGIS Network Analyst

Online APIs

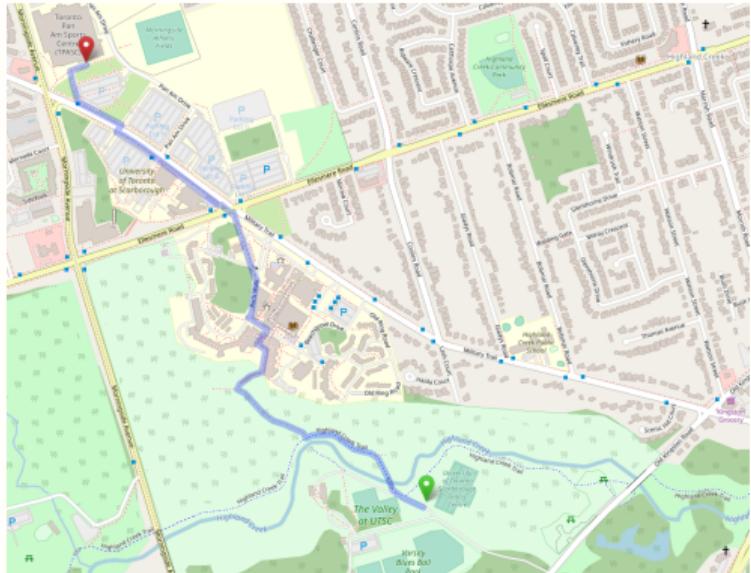
- ▶ Google Maps, Apple Maps, etc.
- ▶ No need to build network, but usually quite expensive for large analyses

Network Distance

- ▶ The distance or travel time between two points, based on the *shortest-path* in a network graph.
- ▶ Included in many mapping applications and software (e.g. Google Maps, Uber, etc.)
- ▶ Different than straight-line (e.g. Euclidean) distance

Source: <https://www.openstreetmap.org>

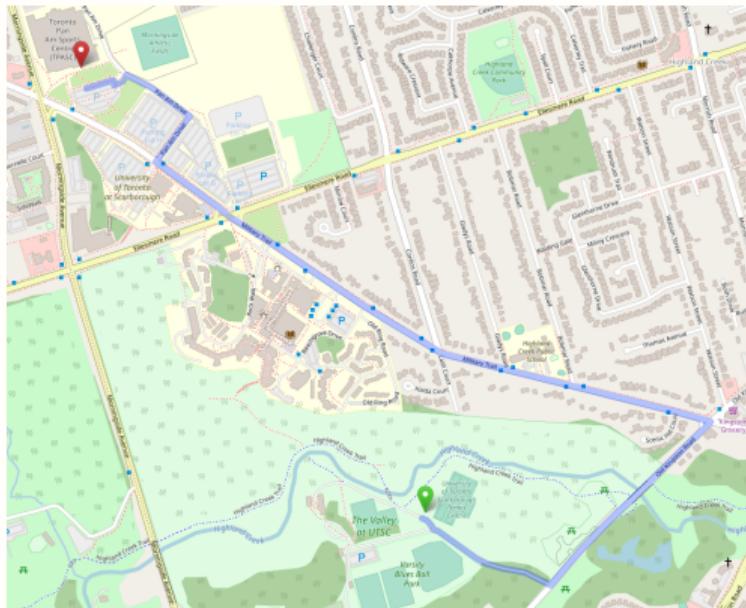
shortest-path by walking (22 min, 1.8 km)



shortest-path by bicycle (12 min, 2.5 km)

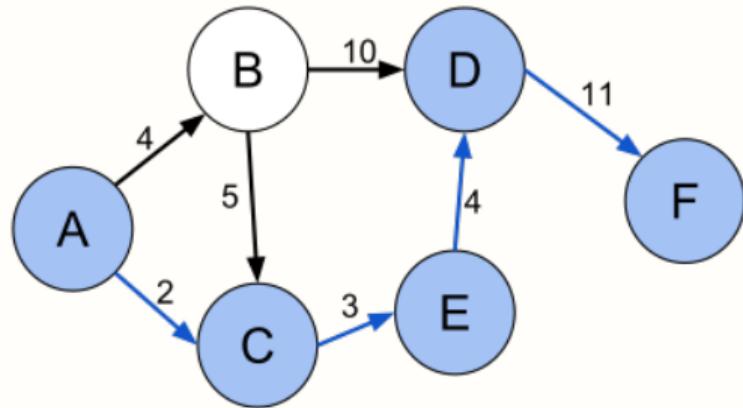


shortest-path by car (8 min, 3.0 km)

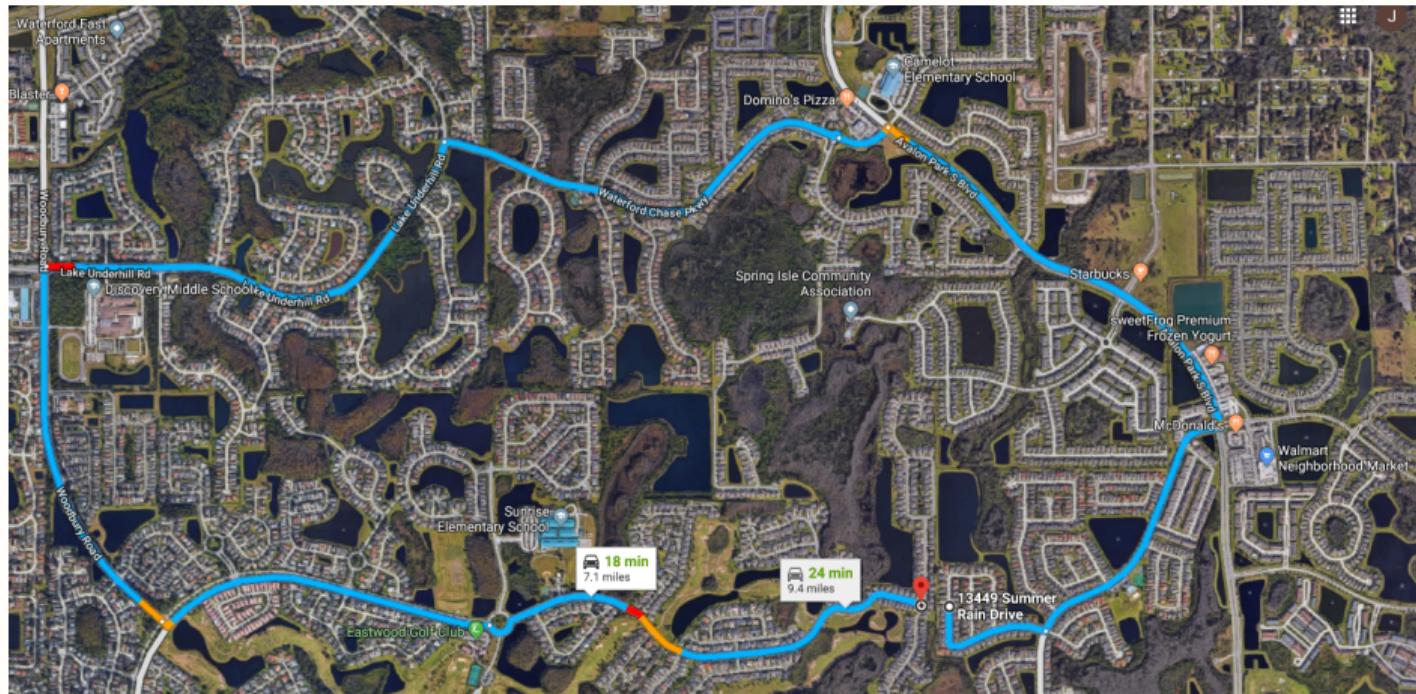


Shortest Path Analysis

- ▶ Finding the "shortest" path between A and B
- ▶ "shortest" can be in distance, time, other costs, or combination of costs
- ▶ Several different algorithms (e.g. Dijkstra)



https://en.wikipedia.org/wiki/Dijkstras_algorithm
https://en.wikipedia.org/wiki/Shortest_path_problem



<https://www.google.ca/maps/dir/28.5327099,-81.1608841/28.5326847,-81.1618508/@28.5363151,-81.1840563,6816m/data=!3m1!1e3!4m3!4m2!3e0!5i1>

☰ ⚡ 🚗 🚲 🚶 ✈ X

13436 Summer Rain Dr, Orlando, FL 32824
14948 Golfway Blvd, Orlando, FL 32828, FL

Add destination

Options

Send directions to your phone

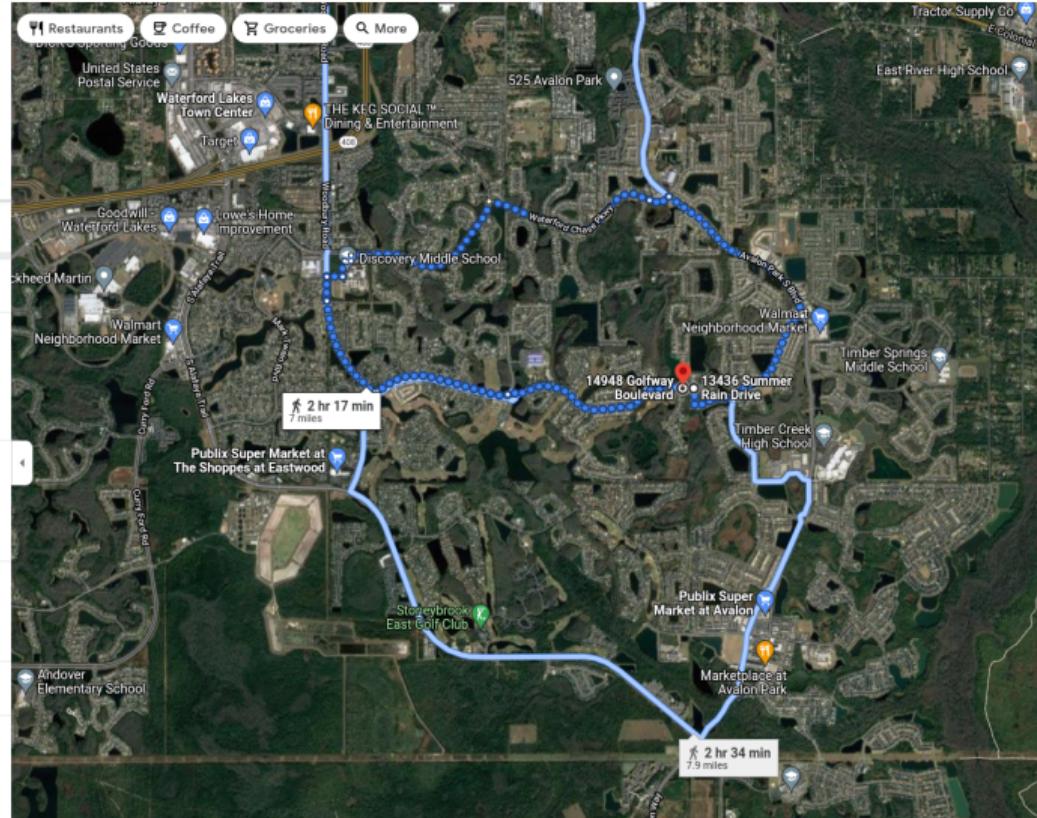
via Golfway Blvd 2 hr 17 min
⚠ This route has restricted usage or private roads.
7.0 miles

Details

via S Alafaya Trail/S R 434 and Golfway Blvd 2 hr 34 min
⚠ This route has restricted usage or private roads.
7.9 miles

via Woodbury Road 3 hr 4 min
⚠ This route has restricted usage or private roads.
9.3 miles

All routes are mostly flat



<https://www.google.ca/maps/dir/28.5327099,-81.1608841/28.5326847,-81.1618508/@28.5363151,-81.1840563,6816m/data=!3m1!1e3!4m3!4m2!3e0!5i1>

Travelling Salesman

- ▶ Given a list of locations, and the (network) distances between each pair of locations, what is the shortest possible route that visits each location and returns to the origin point?
- ▶ e.g. what is the optimal route a salesman can take to visit potential clients in a region
- ▶ other applications include planning delivery routes or road trips

The optimal road trip visiting 50 cities in the USA



Source: Randy Olson (2015) <http://www.randalolson.com/2015/03/08/computing-the-optimal-road-trip-across-the-u-s/>

Closest Facility Analysis - finding the nearest location(s) from a set of locations distributed over space

Often used in medical and emergency services.

- ▶ e.g. which fire station is closest to a fire
- ▶ e.g. what is the nearest emergency room

e.g. in Ottawa, is UofO or Carleton closer to where you live?

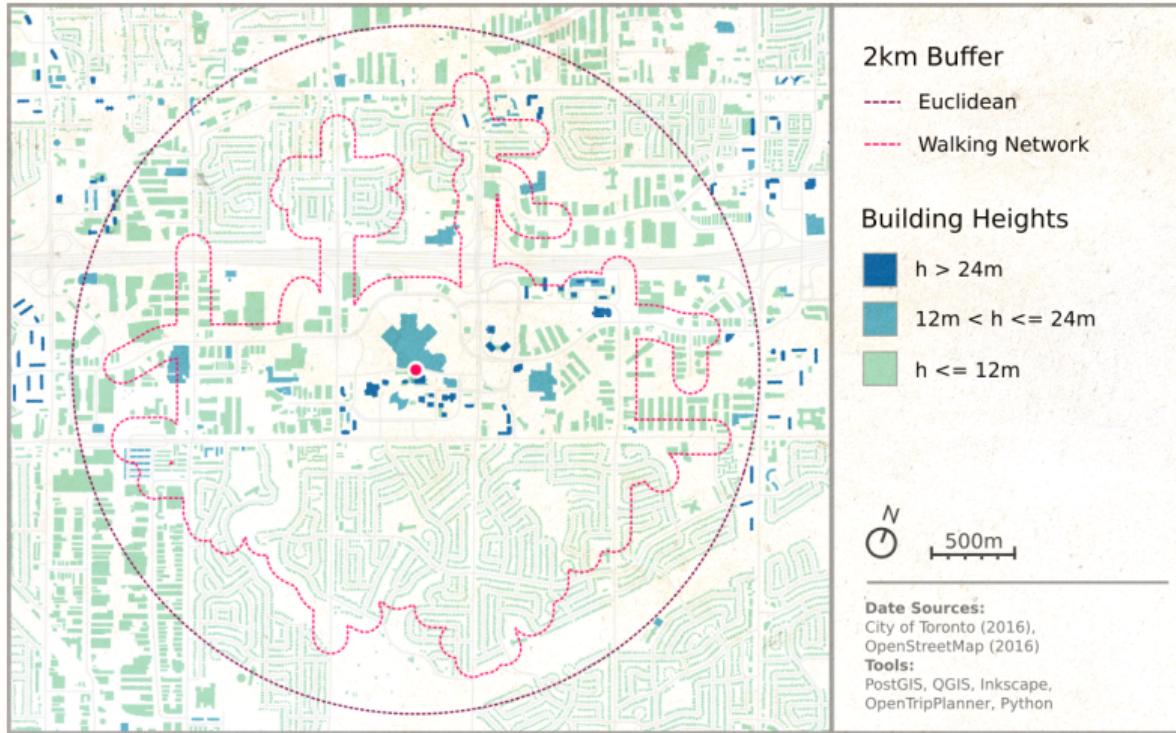


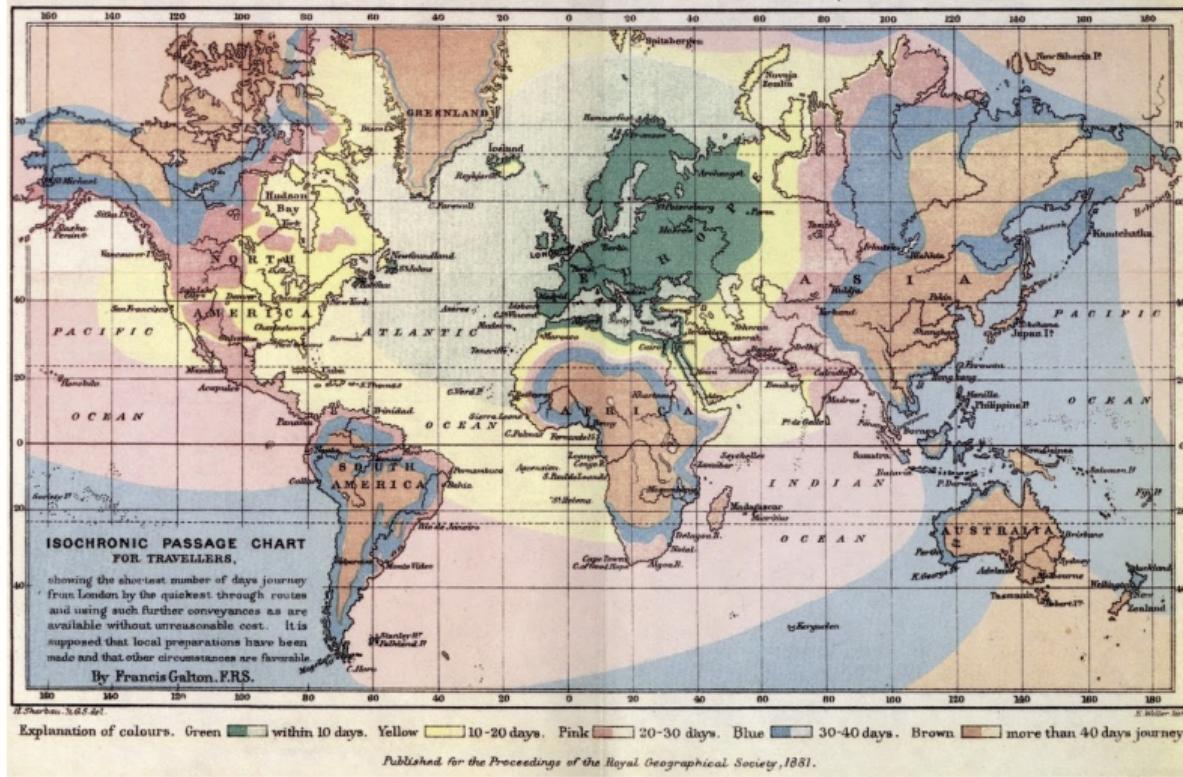
by Jeff Atton | network data sourced from OpenStreetMap in 2017 | re-coloured in 2022

Location Allocation

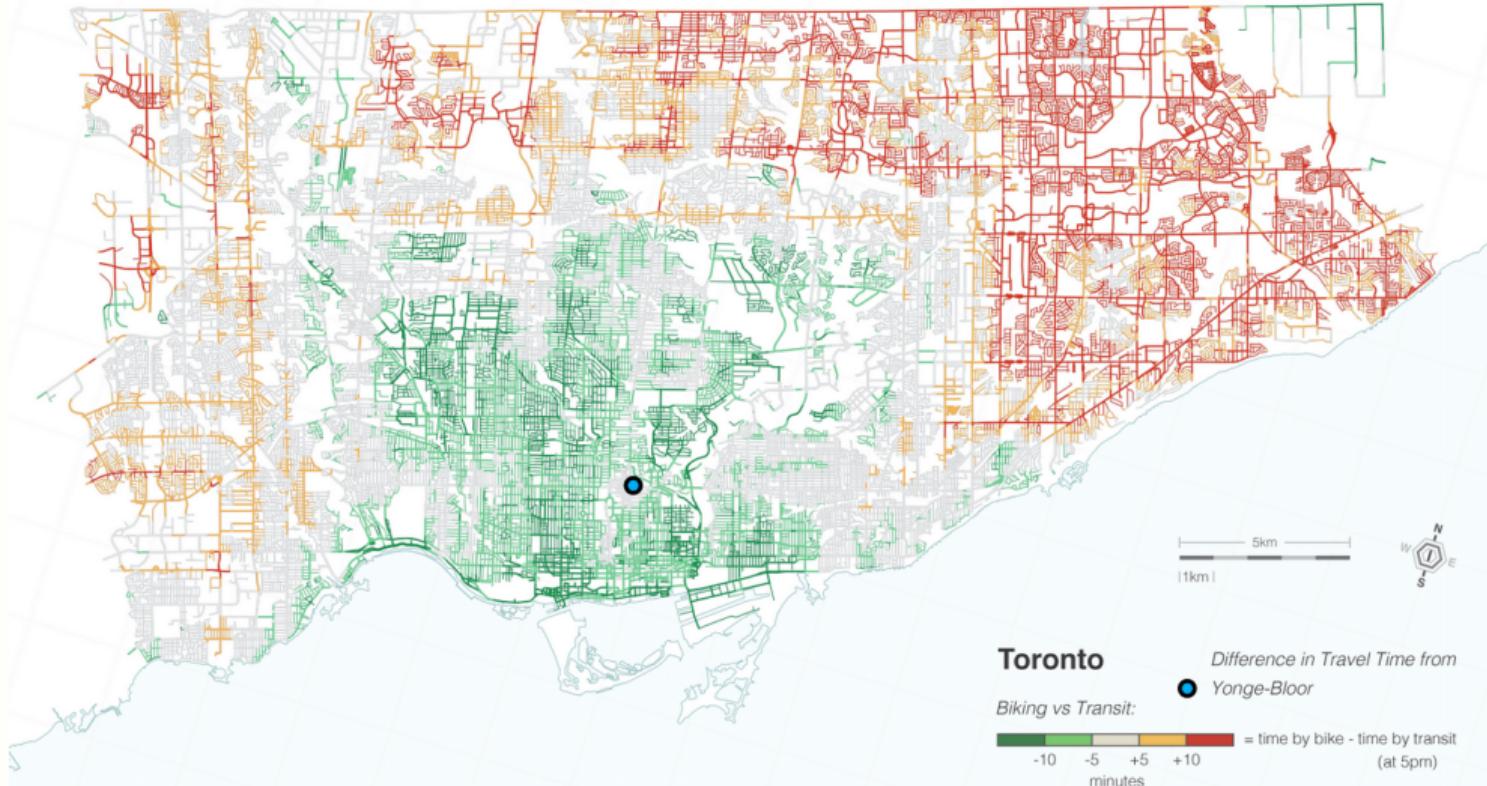
- ▶ Procedures for determining the optimal location for one or more facilities that will service demand from a given set of points across space
- ▶ Often used in planning new locations of retail, public facilities, distribution centres, etc.
- ▶ Often use network distances + other data (e.g distributions of population)

Isochrones (iso = equal, chrone = time) - A buffer based on *network* distances or travel times (sometimes called "service areas")





Source: Galton, Francis. 1881. "On the Construction of Isochronic Passage-Charts." *Proceedings of the Royal Geographical Society and Monthly Record of Geography* 3: 657-658



Source: Allen, J. - *Using network segments in the visualization of urban isochrones* - Cartographica -
http://jamaps.github.io/docs/allen_2018_isochrones.pdf

Origin-Destination (OD) Matrices

- ▶ Common output of network distances/times from a set of origins to a set of destinations
- ▶ Also called travel time or distance matrices
- ▶ e.g. an isochrone can be a one-to-many OD matrix, capped at a certain threshold (e.g. 30 minutes)

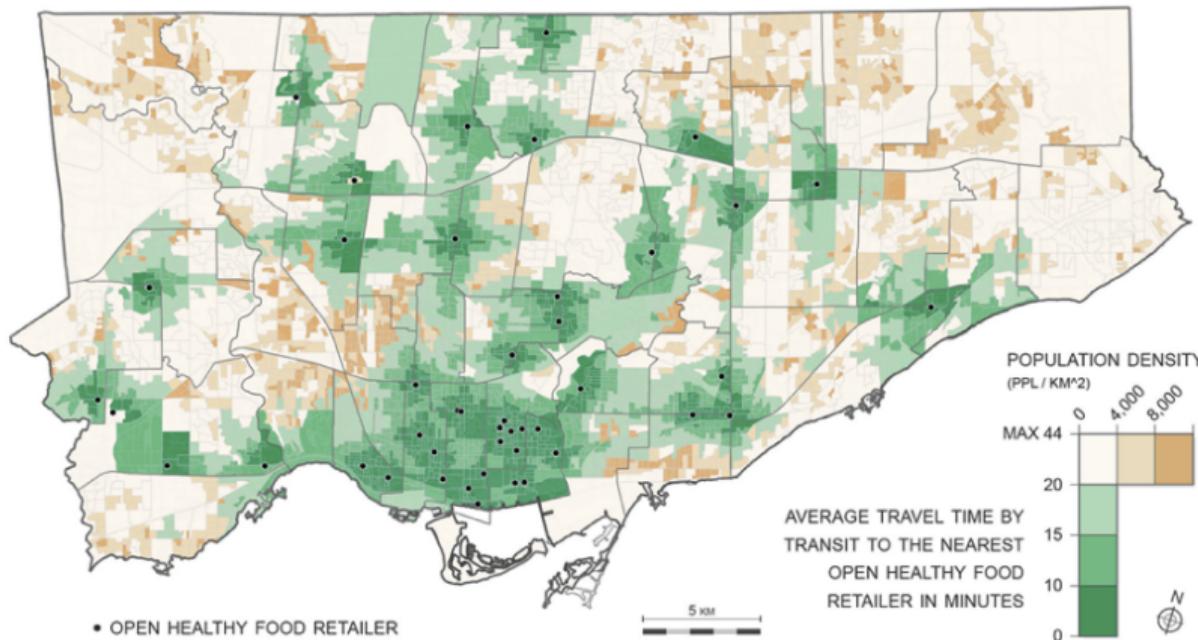
Zones O\D	1	2	3	4	5	6	7	8
1		23	35.73	41.52	37.68	25.24	20.5	22
2	23		28.91	34.06	43.79	22.06	37.27	32.24
3	22.67	27.14		21.09	24.05	27.82	38.04	33.79
4	40.08	30.74	22.41		14.36	43.79	48.22	43.38
5	38.1	43.74	34.68	14.36		32.74	35.44	30.61
6	28.48	21.98	31.04	43.79	32.51		26.13	48.16
7	20.51	37.56	39.14	48.87	35.61	26.29		23.82
8	21.9	39.95	36.06	44.13	30.88	38.3	23.91	

Accessibility

- ▶ *The ease of reaching destinations*
- ▶ Depends on mobility (ease of travelling), but also land-use (i.e. the proximity of destinations)
- ▶ Can be measured and mapped for specific places by combining transportation network and land-use data
- ▶ Two common measurements:
 1. minimum travel time to reach X (usually for *local* analysis)
 2. how many Y can you reach in Z minutes (usually for *regional* analysis)
- ▶ Increasingly used to evaluate transportation networks and urban livability

Measuring accessibility - minimum travel time to reach X (e.g. a healthy food retailer)

TRANSIT ACCESS TO HEALTHY FOOD / MONDAY / 12:00AM TO 1:00AM



Source: Widener et al (2017) How do changes in the daily food and transportation environments affect grocery store accessibility?
<https://doi.org/10.1016/j.apgeog.2017.03.018>

Measuring accessibility - minimum travel time to reach X

$$A_i = \min_j(t_{i,j})$$

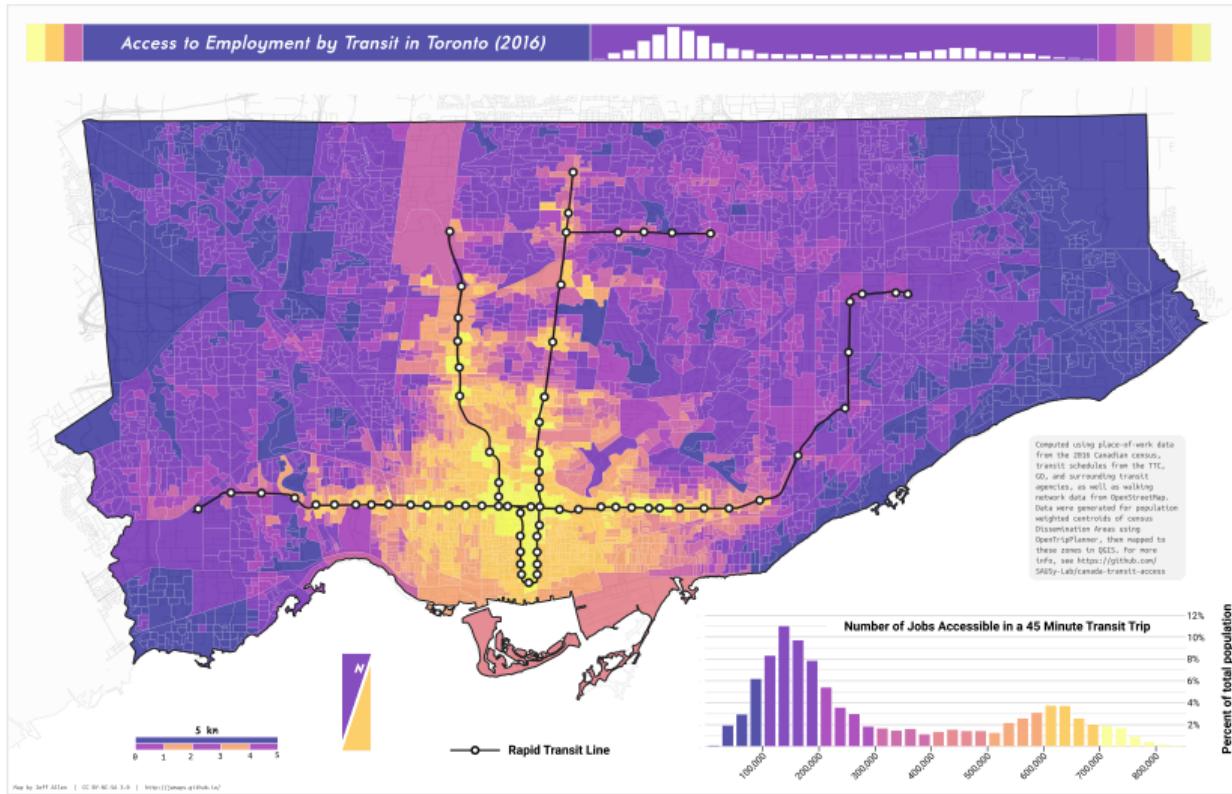
A_i = accessibility measure for location i

i = locations in space (e.g. grid cells, census polygons)

j = location of activities (e.g. grocery store)

$t_{i,j}$ = travel cost from i to j (usually by computing an OD matrix)

Measuring accessibility - how many Y can you reach in Z minutes



Measuring accessibility - how many Y can you reach in Z minutes

$$A_i = \sum_j f(t_{i,j}) Y_j$$

$$f(t_{i,j}) = \begin{cases} 1 & t_{i,j} \leq \theta \\ 0 & t_{i,j} > \theta \end{cases}$$

A_i = accessibility measure for location i

i = locations in space (e.g. grid cells, census polygons)

j = location of activities (e.g. zones with employment counts)

Y_j = number of opportunities at location j (e.g. number of jobs)

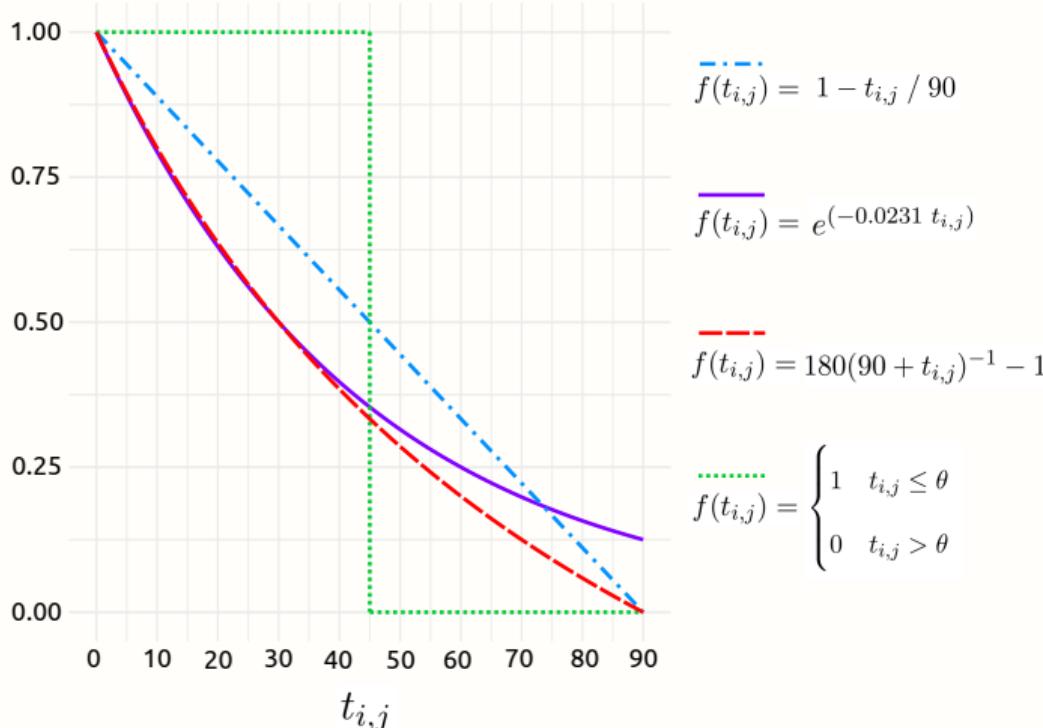
$t_{i,j}$ = travel cost from i to j (usually by computing an OD matrix)

$f(t_{i,j})$ = *impedance* function

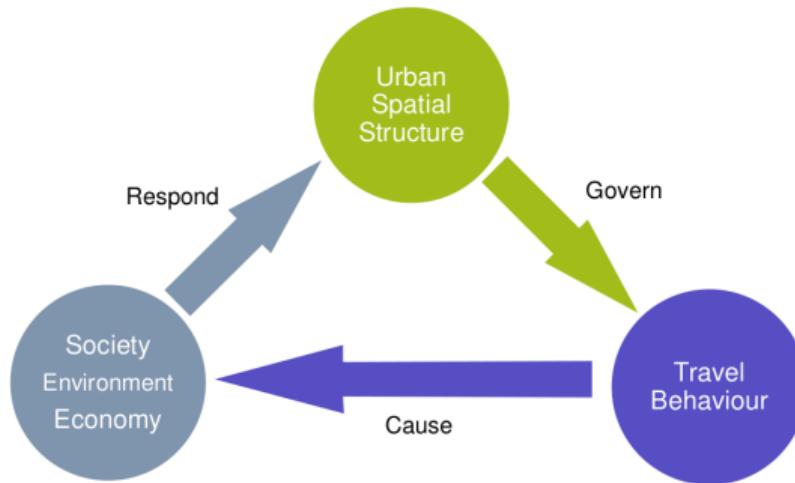
θ = travel cost threshold (e.g. 45 minutes)

Measuring accessibility - how many Y can you reach in Z minutes

Other common *impedance* functions (to try to weight nearby destinations more than those further away)



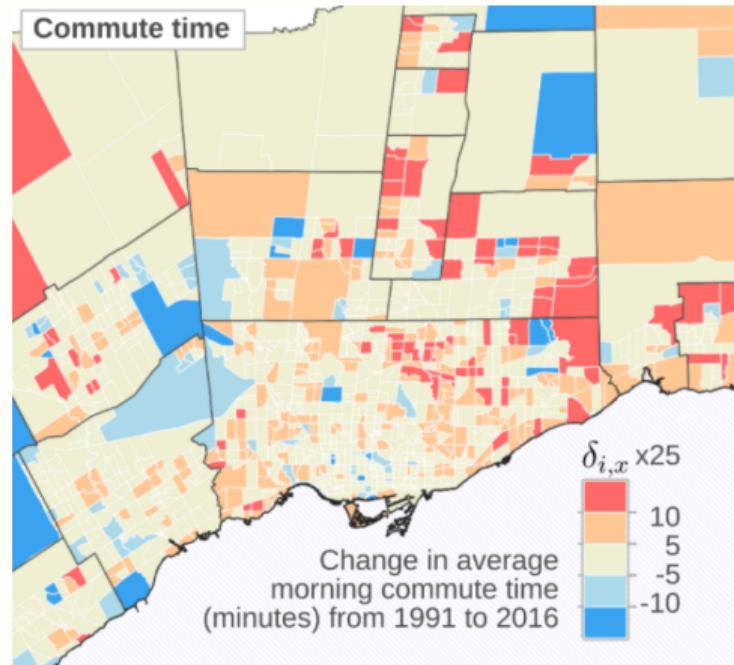
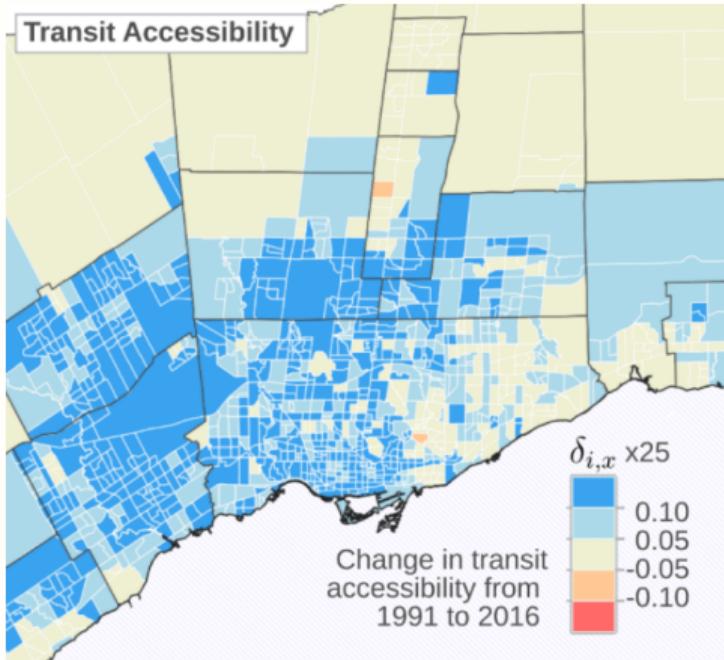
Accessibility & Travel Behaviour



Accessibility is correlated with ..

- ▶ Travel times
- ▶ Travel distances (e.g. Vehicle Kilometres Travelled)
- ▶ Mode share
- ▶ Activity participation rates
- ▶ Unemployment rates

e.g. changes in transit accessibility compared to changes in commute time



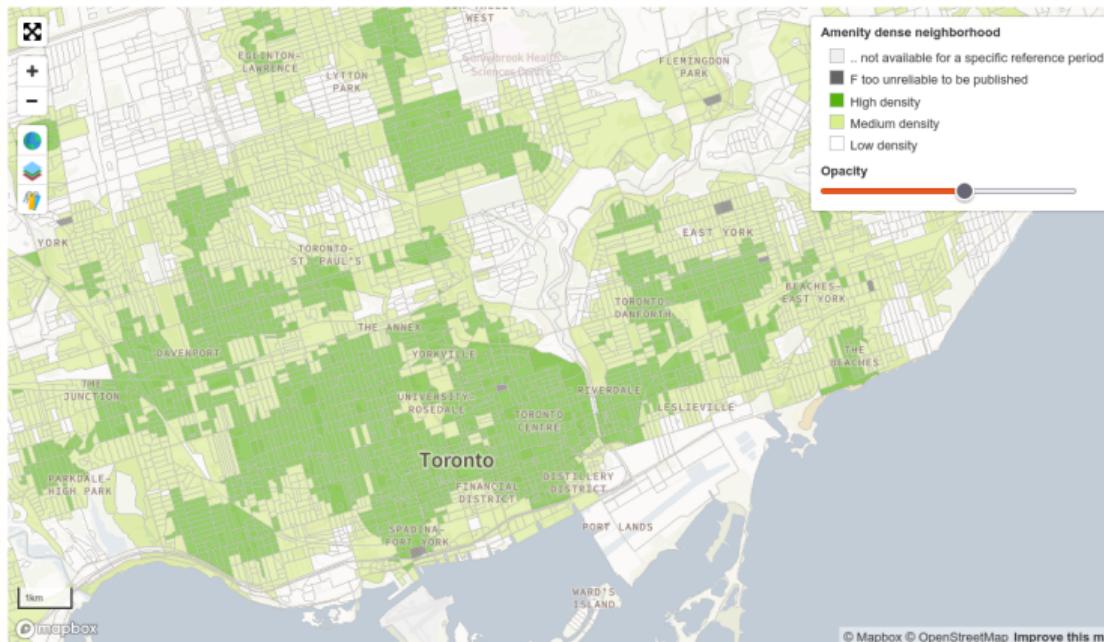
15-minute cities

- ▶ Urban planning/design strategy for most daily necessities can be reached within 15 minutes walking or cycling
- ▶ i.e. a measure of accessibility by active travel modes



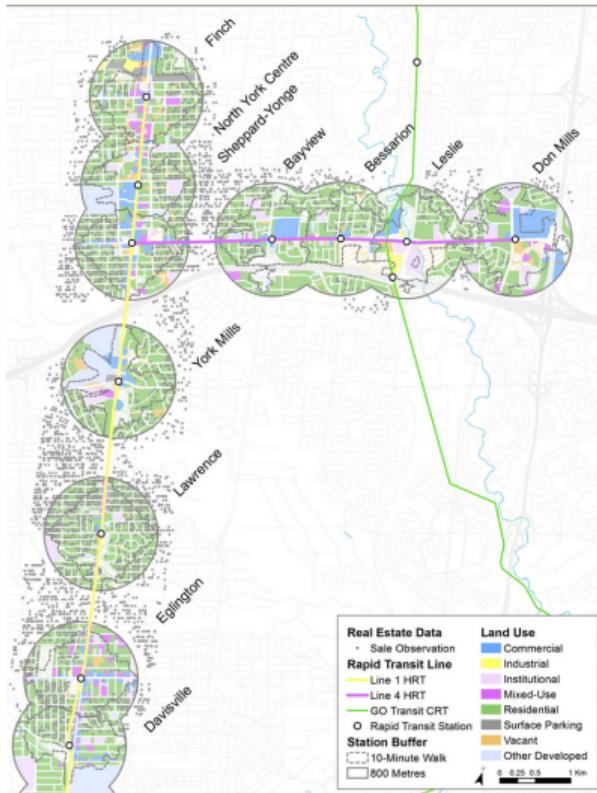
Walkability

- ▶ How friendly a neighbourhood is for walking
- ▶ Can be thought of as the quality of pedestrian accessibility
- ▶ e.g. Statistics Canada has proximity measures database



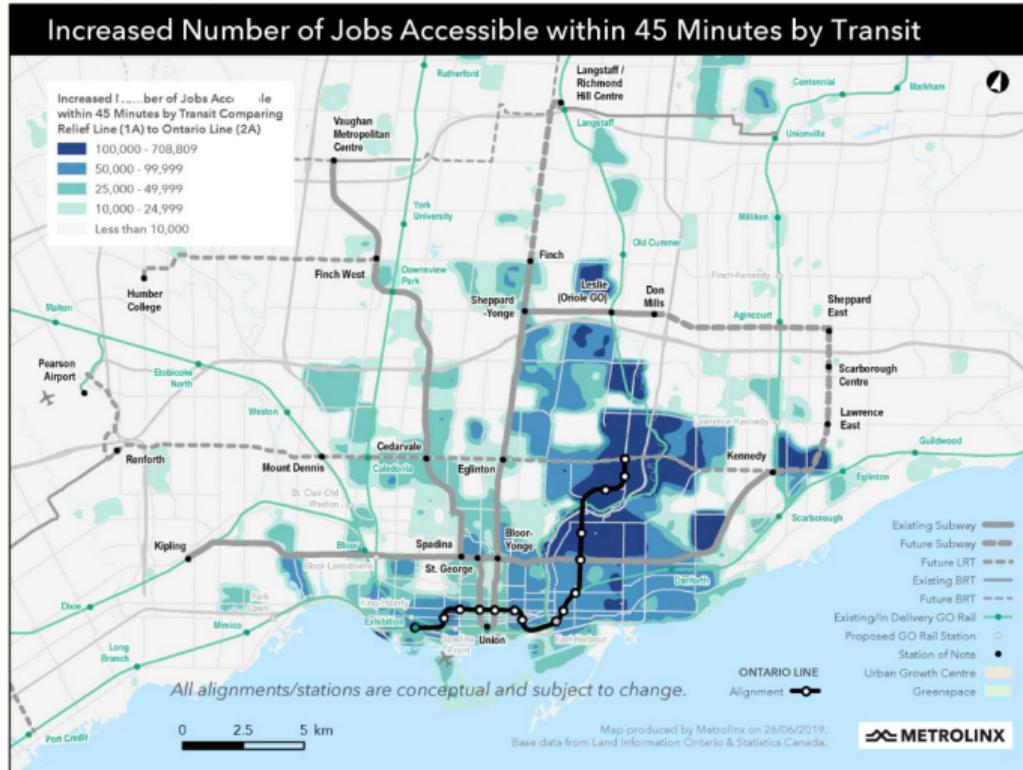
Accessibility & Housing

- ▶ Increased demand and costs of housing in more accessible neighbourhoods (all else being equal)
- ▶ Can be a catalyst for further Transit Oriented Development
- ▶ But can also be unaffordable low-income residents (e.g. concerns over "Transit Oriented Displacement")



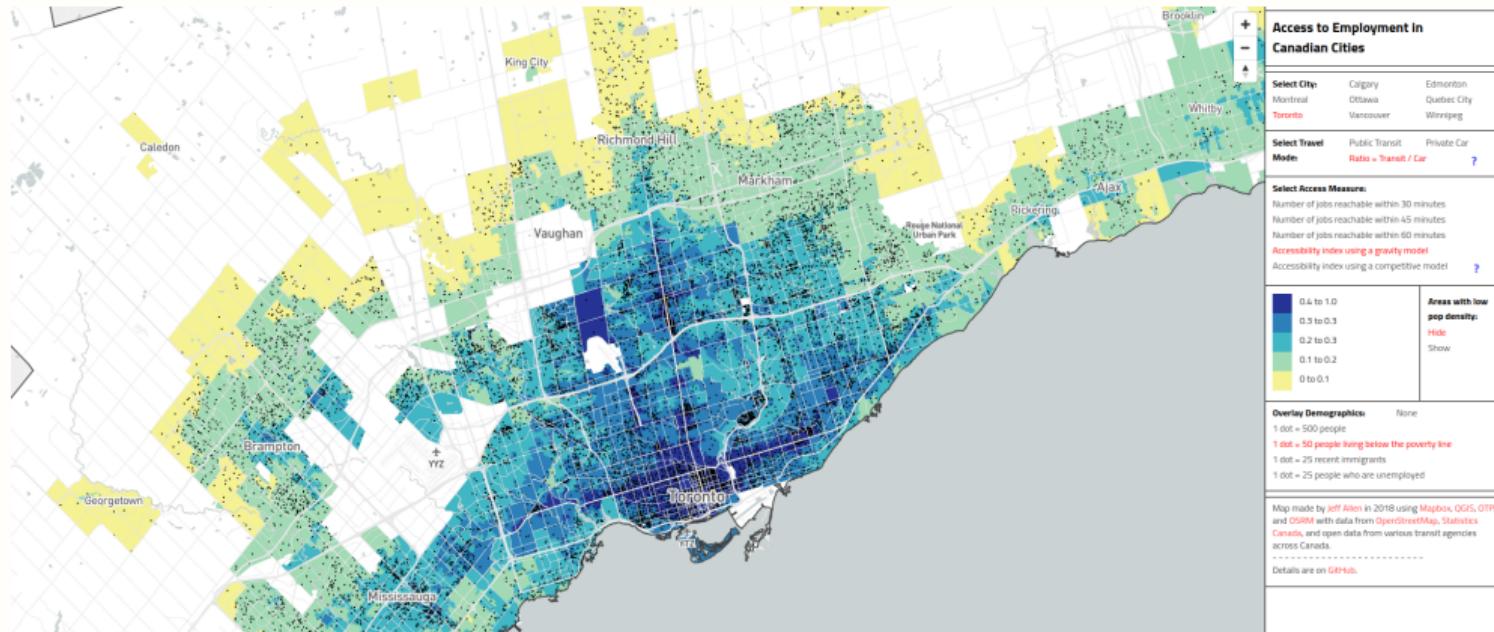
e.g. see work by Chris Higgins <https://higgicd.github.io/>

Transport planning is increasingly using accessibility to evaluate projects - e.g. this map and analysis was part of the initial business case for the Ontario Line



Mapping accessibility can be used to highlight under-served areas.

Can also be used to compare between modes:



<https://sausy-lab.github.io/canada-transit-access/map.html>

Next week (Feb 14)

- ▶ Travel behaviour data (e.g. travel surveys and GPS data)
- ▶ Maps for navigation / wayfinding
- ▶ Demoing a few things in GIS / chat about the next assignment