Transportation Networks & Land Use:

GGR424 - Transportation Geography & Planning

Jeff Allen

University of Toronto

February 7, 2022

Land Use
Urban Form
Built Environment
Urban Spatial Structure

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

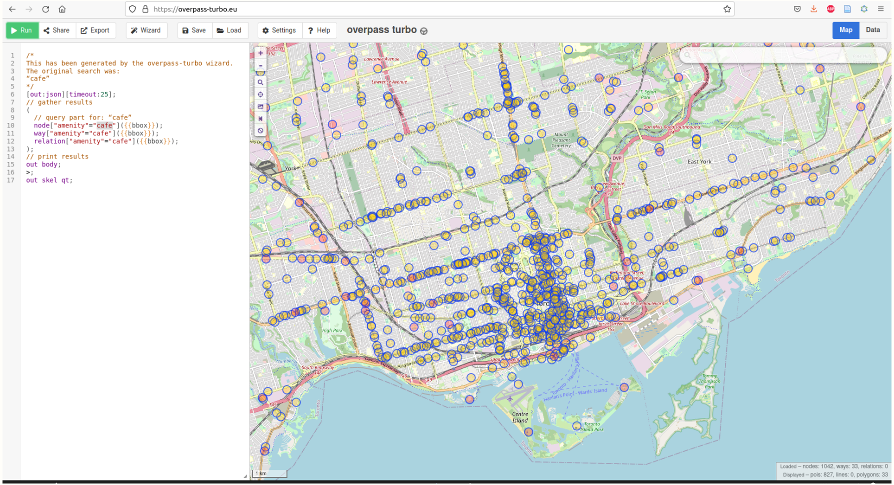
- The spatial patterns of transportation networks
- Usually **Lines** (and nodes/intersections)

Travel Data (more on this next week)

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

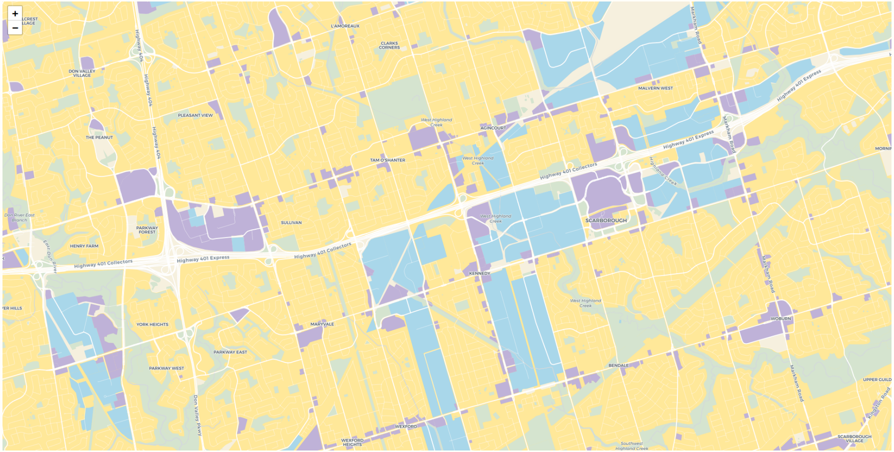
Land Use Data

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



Land Use Data - e.g. polygon data

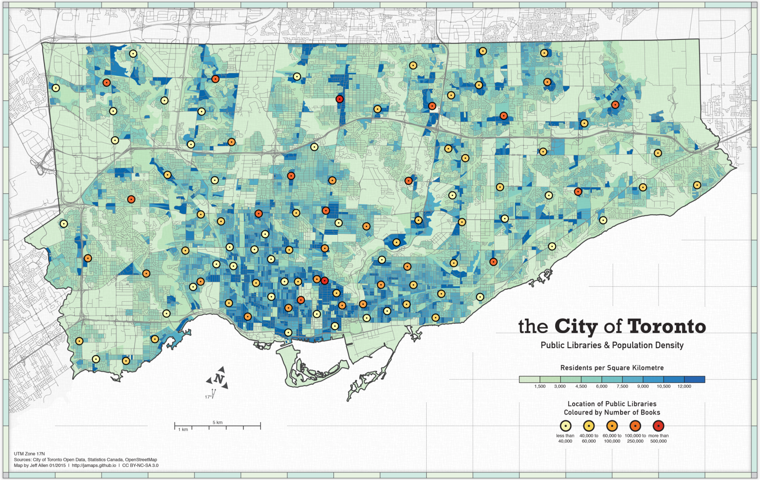
yellow = residential, purple = retail/commercial, blue = industrial, etc.



Land Use Data

e.g. polygon data - census data, who lives and works where

e.g. point data - libraries in Toronto



https://en.wikipedia.org/wiki/Toronto_Public_Library

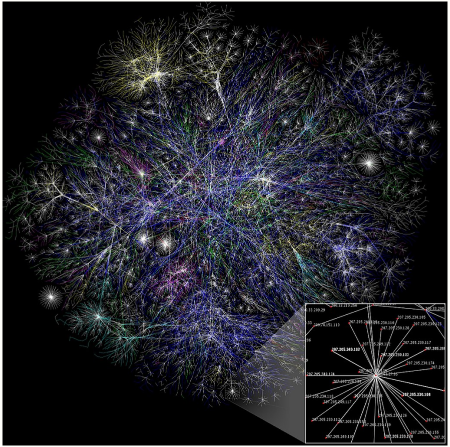
Network Data:

Network - an interconnected group or system

Examples

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

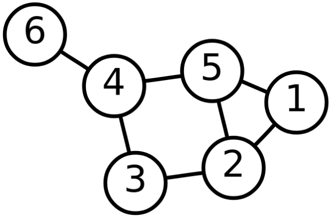
Often represented using **graphs**



Source: https://en.wikipedia.org/wiki/Network_science

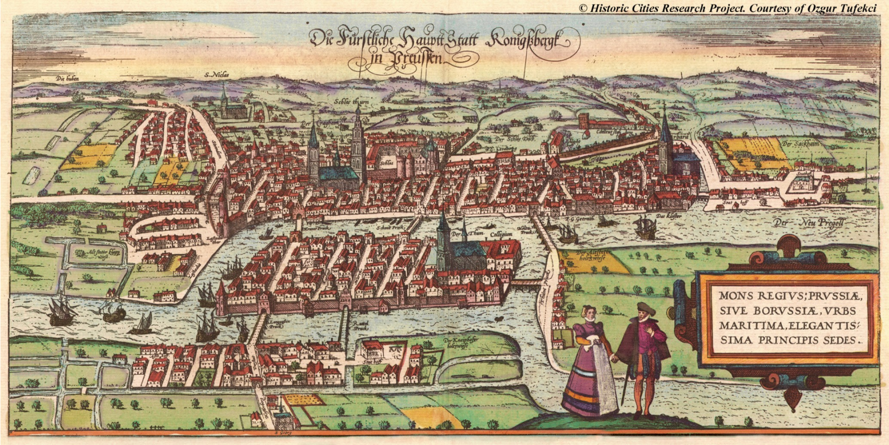
Graph

- 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)

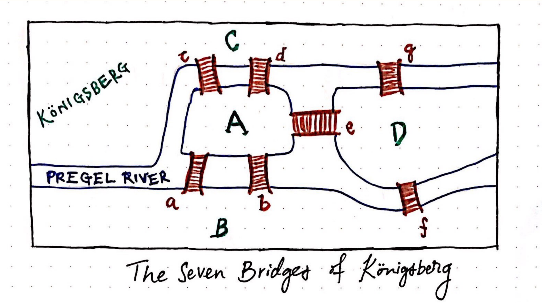
Can you walk across all of the seven bridges in Königsberg, without ever repeating a single bridge in the course of one's walk? (Leonhard Euler, 1736)

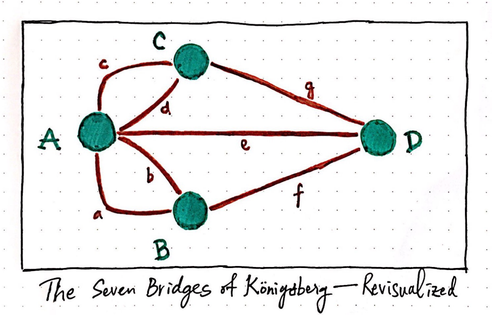


Source: https://medium.com/basecs/konigsberg-seven-small-bridges-one-giant-graph-problem-2275d1670a12

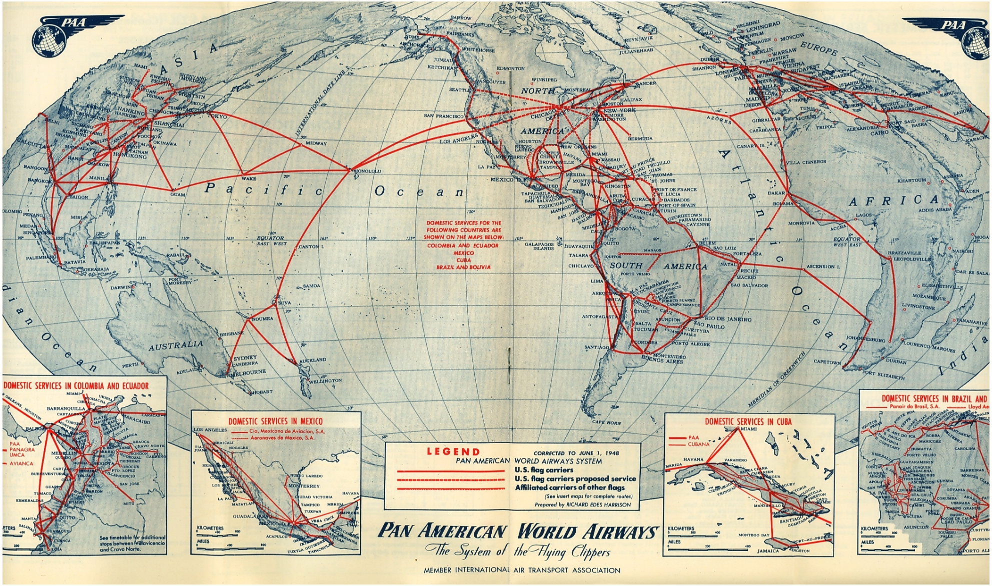
Can you walk across all of the seven bridges in Königsberg, without ever repeating a single bridge in the course of one's walk? (Leonhard Euler, 1736)

Representing Königsberg as a graph





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

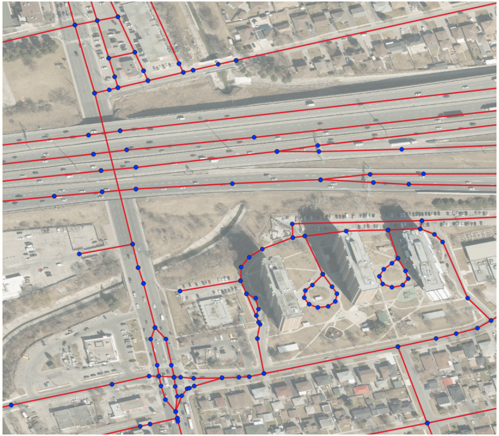


PAA
ASIA
EUROPE
AFRICA
AUSTRALIA
NORTH AMERICA
SOUTH AMERICA
Pacific Ocean
Atlantic Ocean
Indian Ocean
INTERNATIONAL DATE LINE
MERIDIAN OF GREENWICH
EQUATOR
DOMESTIC SERVICES FOR THE FOLLOWING COUNTRIES ARE SHOWN ON THE MAPS BELOW:
COLOMBIA AND ECUADOR
MEXICO
CUBA
BRAZIL AND BOLIVIA
DOMESTIC SERVICES IN COLOMBIA AND ECUADOR
PAA
PANAGRA
UMCA
AVIANCA
See timetable for additional stops between Villavicencio and Cravo Norte.
DOMESTIC SERVICES IN MEXICO
Cia. Mexicana de Aviacion, S.A.
Aeronaves de Mexico, S.A.
KILOMETERS
MILES
LEGEND
CORRECTED TO JUNE 1, 1948
PAN AMERICAN WORLD AIRWAYS SYSTEM
U.S. flag carriers
U.S. flag carriers proposed service
Affiliated carriers of other flags
(See insert maps for complete routes)
Prepared by RICHARD EDES HARRISON
DOMESTIC SERVICES IN CUBA
PAA
CUBANA
DOMESTIC SERVICES IN BRAZIL AND
Panair do Brasil, S.A.
Lloyd Ae
PAN AMERICAN WORLD AIRWAYS
The System of the Flying Clippers
MEMBER INTERNATIONAL AIR TRANSPORT ASSOCIATION

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

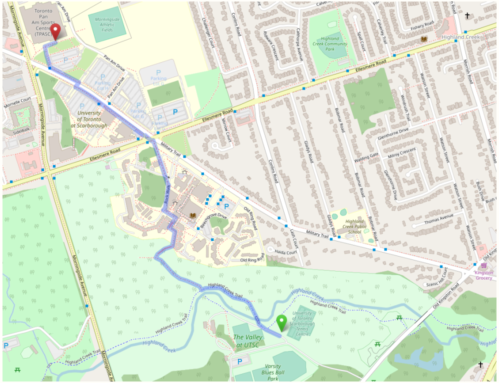
- GTFS (General Transit Feed Specification)

Network Distance

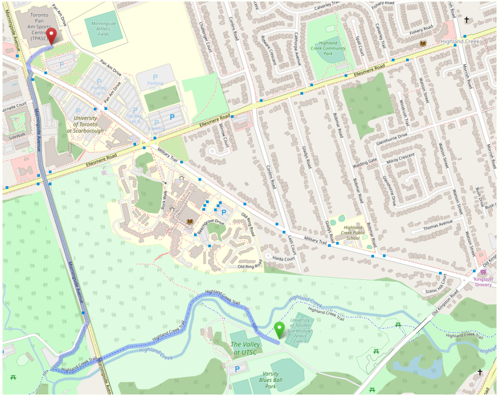
- The distance or travel time between two points, based on the *shortest-path* in a network graph.
- Included in many mapping applications and software (e.g. Google Maps, Uber, etc.)
- Different than straight-line (e.g. Euclidean) distance

Source: `https://www.openstreetmap.org`

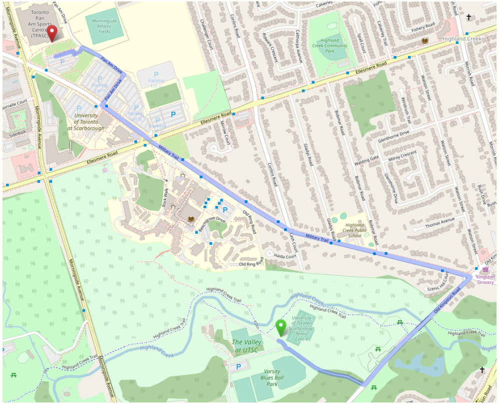
shortest-path by walking (22 min, 1.8 km)



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

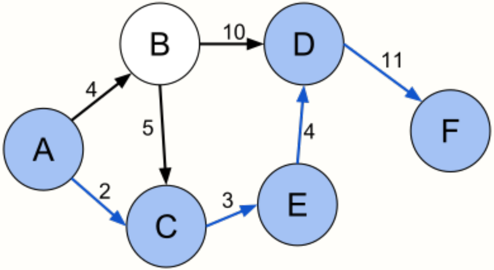


shortest-path by car (8 min, 3.0 km)

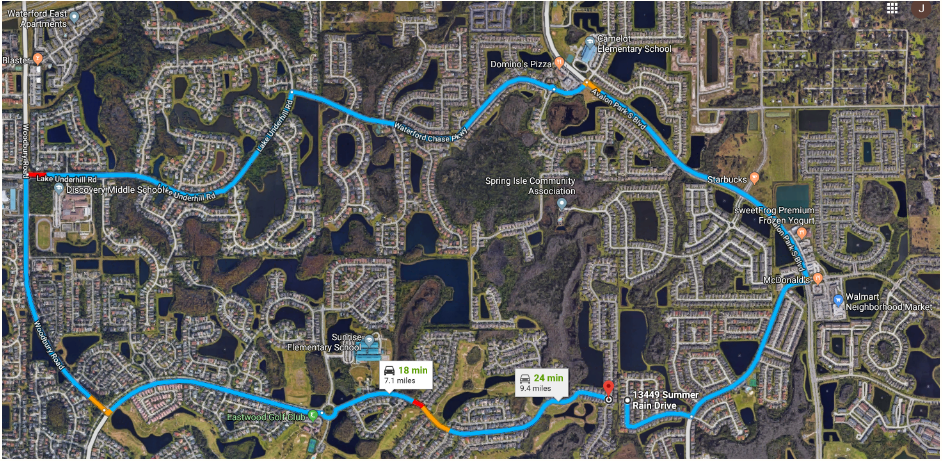


Shortest Path Analysis

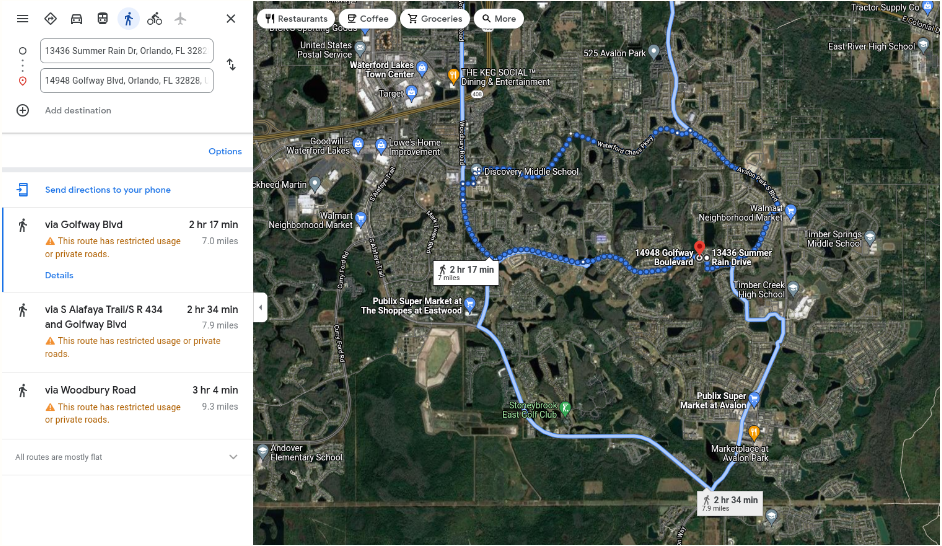
- Finding the "shortest" path between A and B
- "shortest" can be in distance, time, other costs, or combination of costs
- Several different algorithms (e.g. Dijkstra)



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



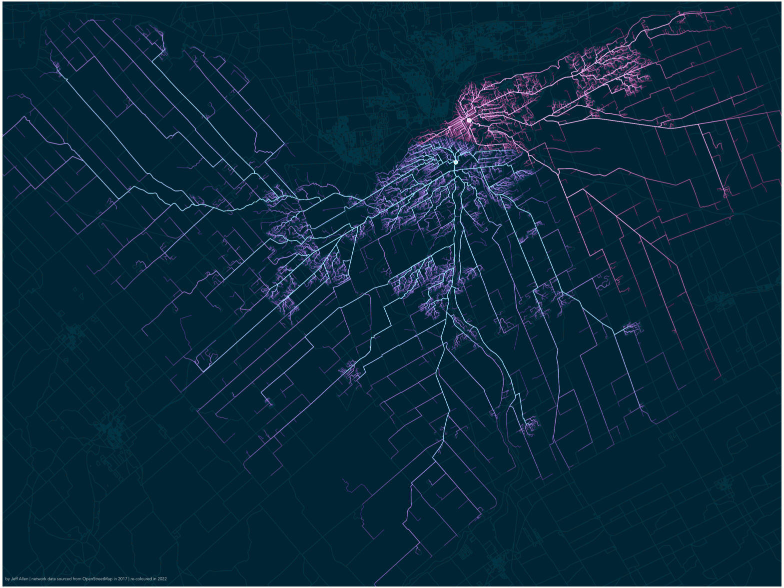
https://www.google.ca/maps/dir/28.5327099,-81.1608841/28.5326847,-81.1618508/@28.5363151,-81.1840563,6816m/data=!3m1!1e3!4m3!4m2!3e0!5i1

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?



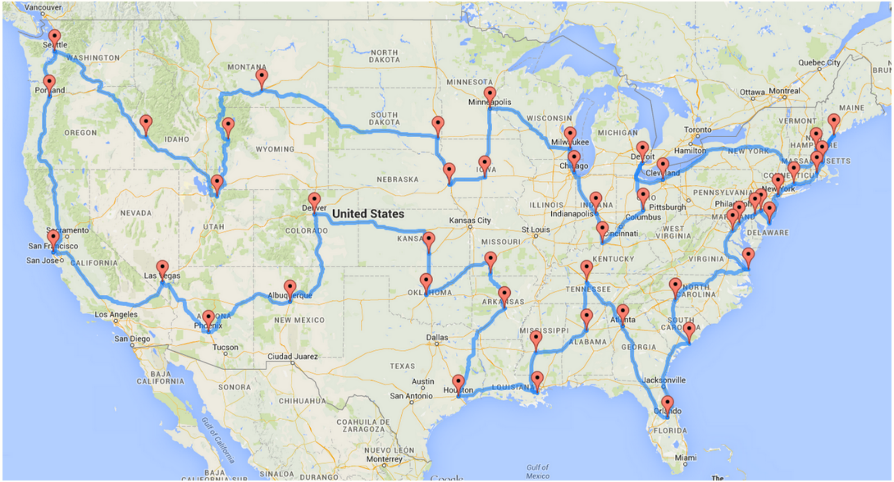
Location Allocation

- 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)

Travelling Salesman

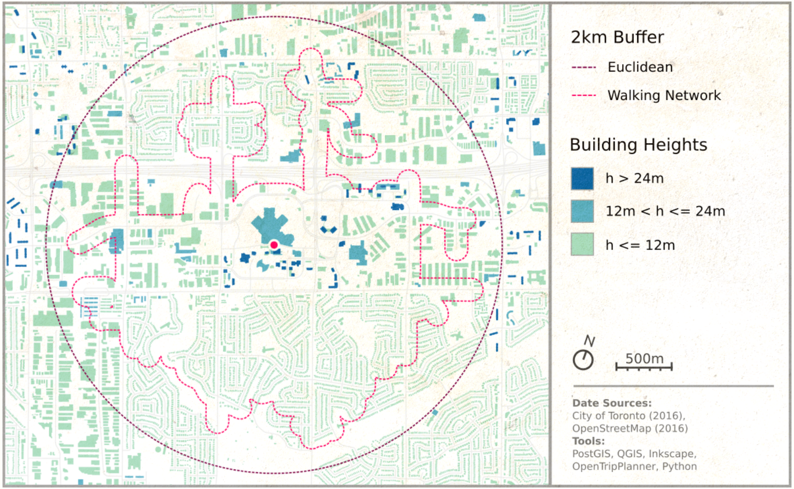
- Given a list of locations, and the (network) distances between each pair of locations, what is the shortest possible route that visits each location and returns to the origin point?
- e.g. what is the optimal route a salesman can take to visit potential clients in a region
- other applications include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

The optimal road trip visiting 50 cities in the USA

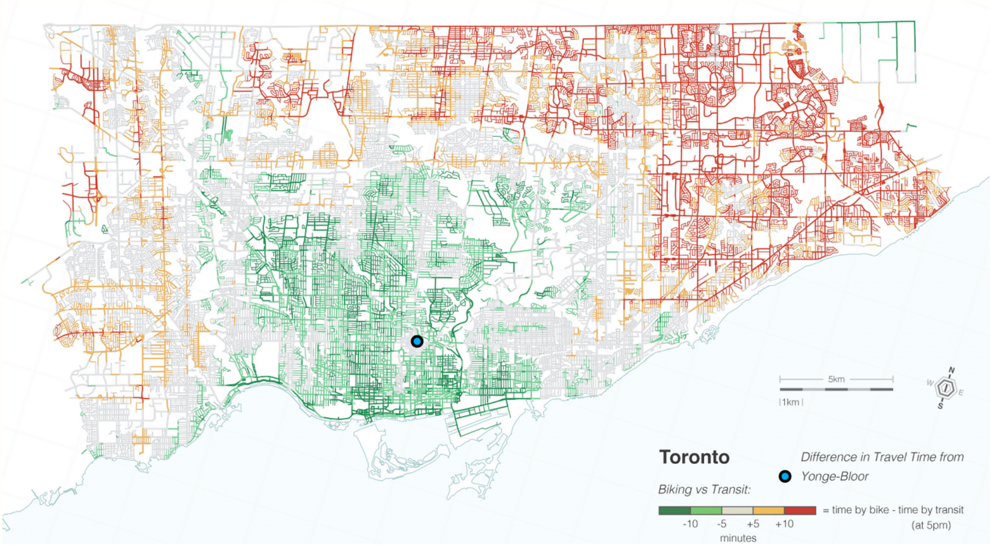


Source: Randy Olson (2015) http://www.randalolson.com/2015/03/08/computing-the-optimal-road-trip-across-the-u-s/

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



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

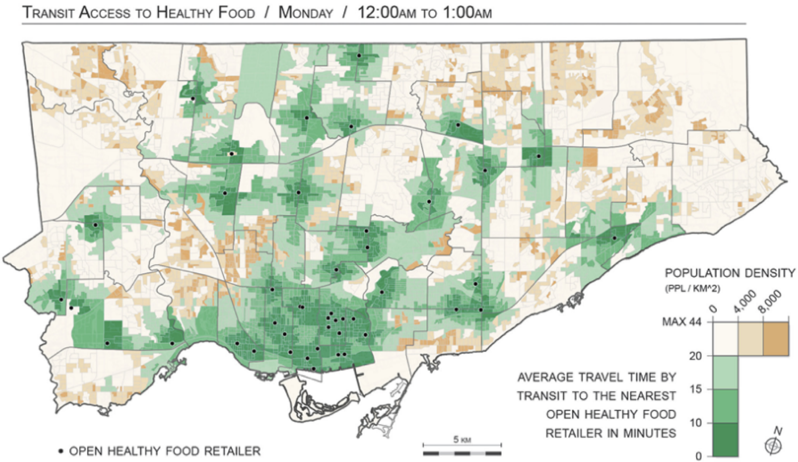
- Common output of network distances/times from a set of origins to a set of destinations
- Also called travel time or distance matrices
- e.g. an isochrone can be a one-to-many OD matrix, capped at a certain threshold (e.g. 30 minutes)

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)



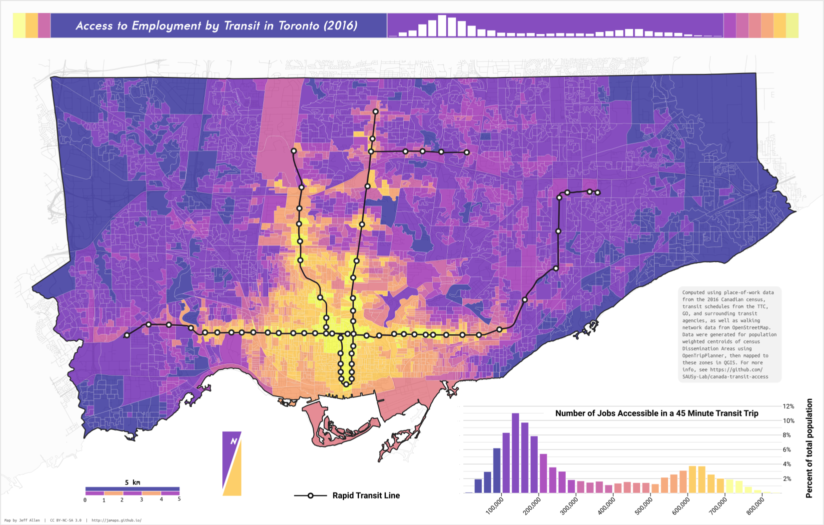
Source: Widener et al (2017) How do changes in the daily food and transportation environments affect grocery store accessibility?
https://doi.org/10.1016/j.apgeog.2017.03.018

Measuring accessibility - minimum travel time to reach X

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

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



https://en.wikipedia.org/wiki/Accessibility_(transport)

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)

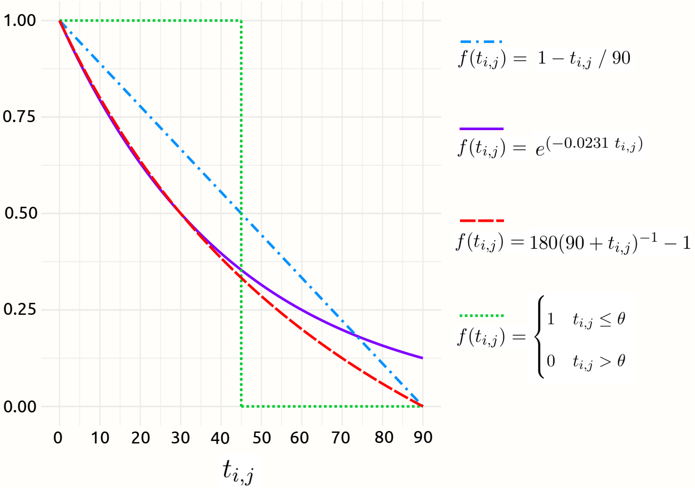
$t_{i,j}$ = travel cost from i to j (usually by computing an OD matrix)

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

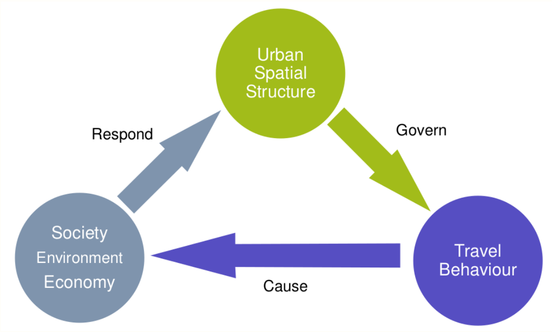
θ = travel cost threshold (e.g. 45 minutes)

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

Walkability

15-minute cities

Over time historically - re commuting

Over time - Ontario Line - planning example