ROUTE OPTIMIZATION

Justin Gould (gould29@purdue.edu)

HONR 39900: Foundations of Geospatial Analytics

Fall 2021

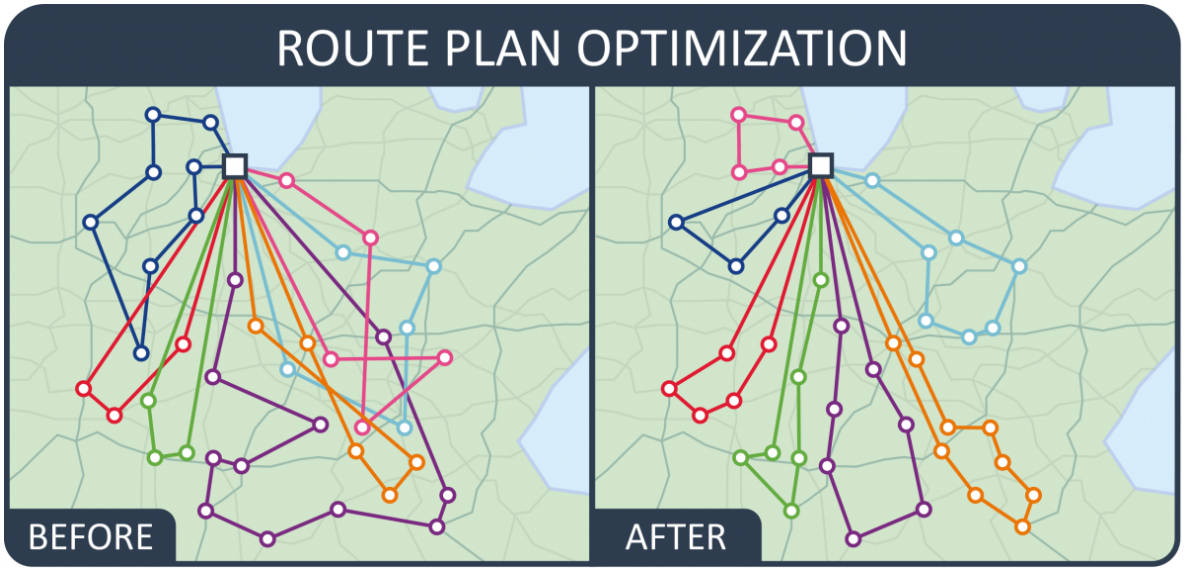
PURDUE UNIVERSITY

Topics

- Introduction to Route Optimization
  - Applications
- How to Optimize Routes
  - Single-vehicle Optimization
  - Python
- Fleet-level Optimization
  - Research Methods

Introduction to Route Optimization

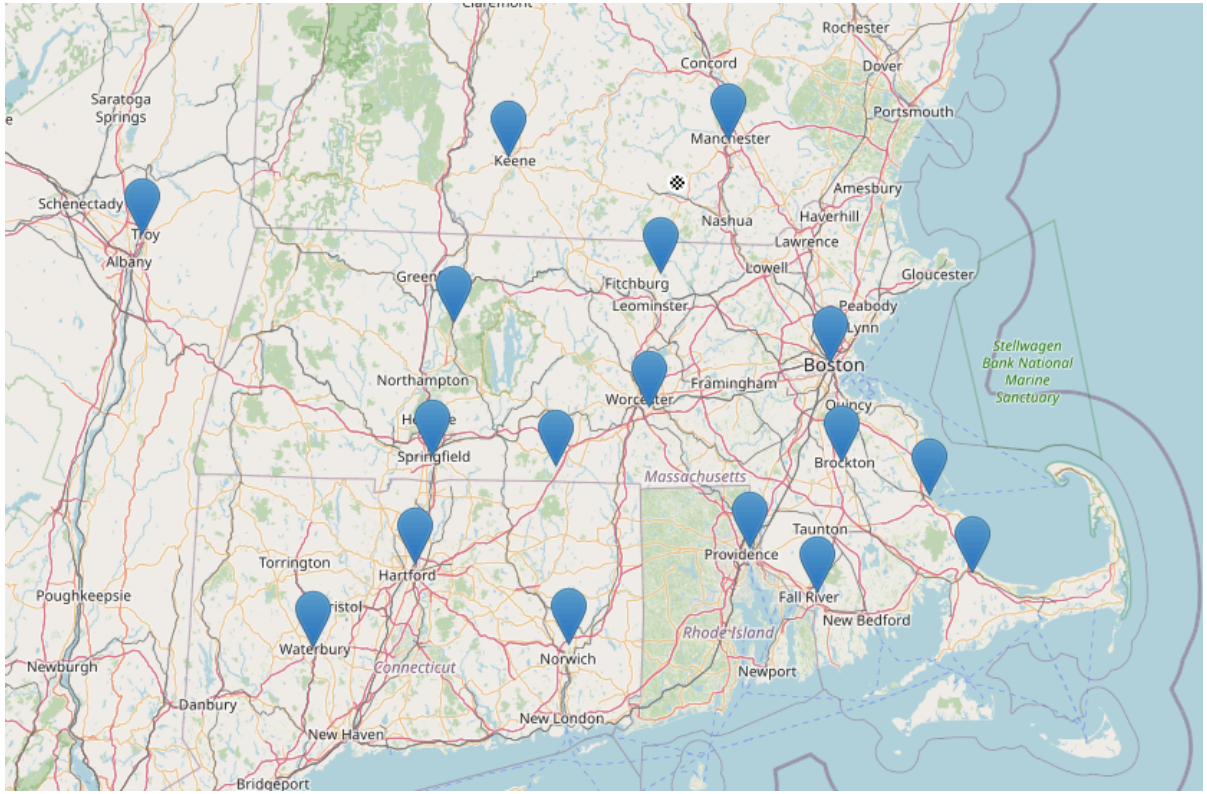
- At its most basic level:
  - Determining the most cost-efficient route, given a start and end location



https://paragonrouting-prod-site-assets.s3-eu-west-1.amazonaws.com/2020/01/Roure-Plan-Optimization-Graphic-1200x572.png

Introduction to Route Optimization

- Also known as “Traveling Salesman Problem”
  - Imagine you are a corporate sales representative for the Northeast. You need to travel to many cities to sell your company’s products, as your salary is based solely on commission. Given the vast size of your sales region, you would like to find the most optimal way to visit all your clients and prospective clients.

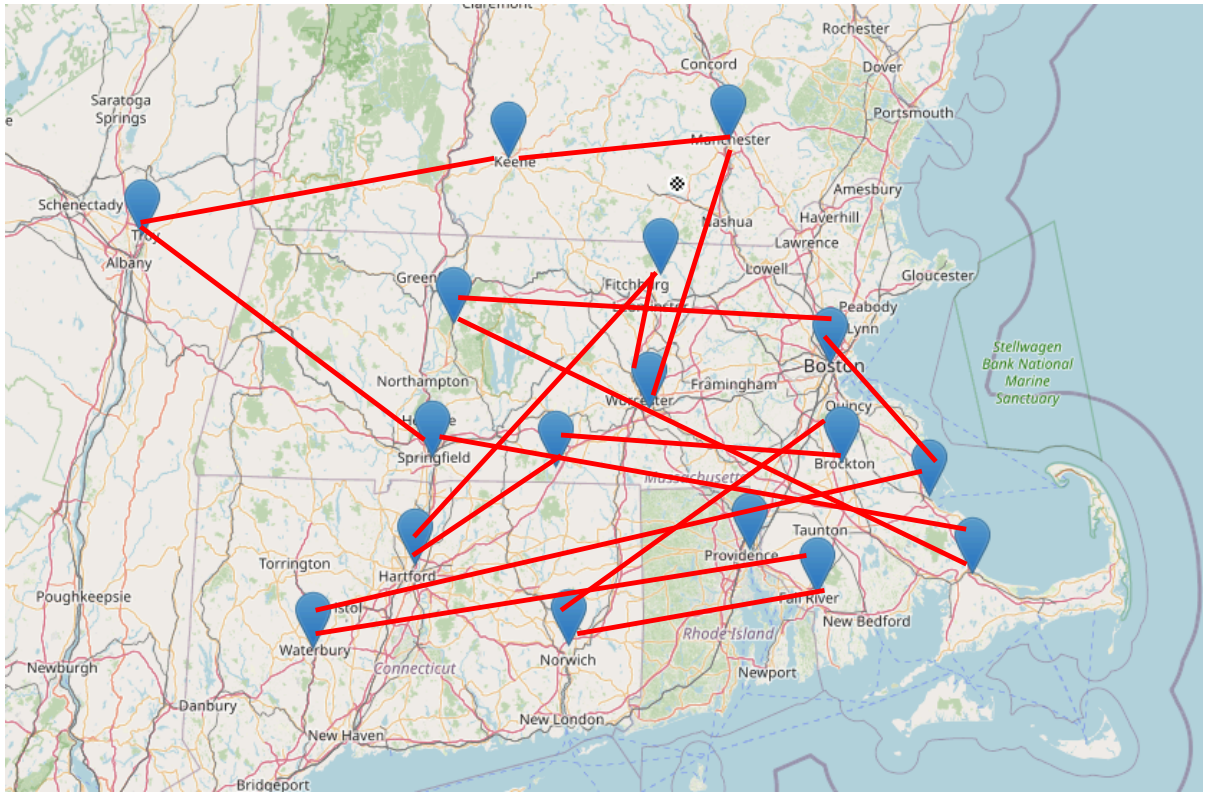


PURDUE UNIVERSITY

Introduction to Route Optimization

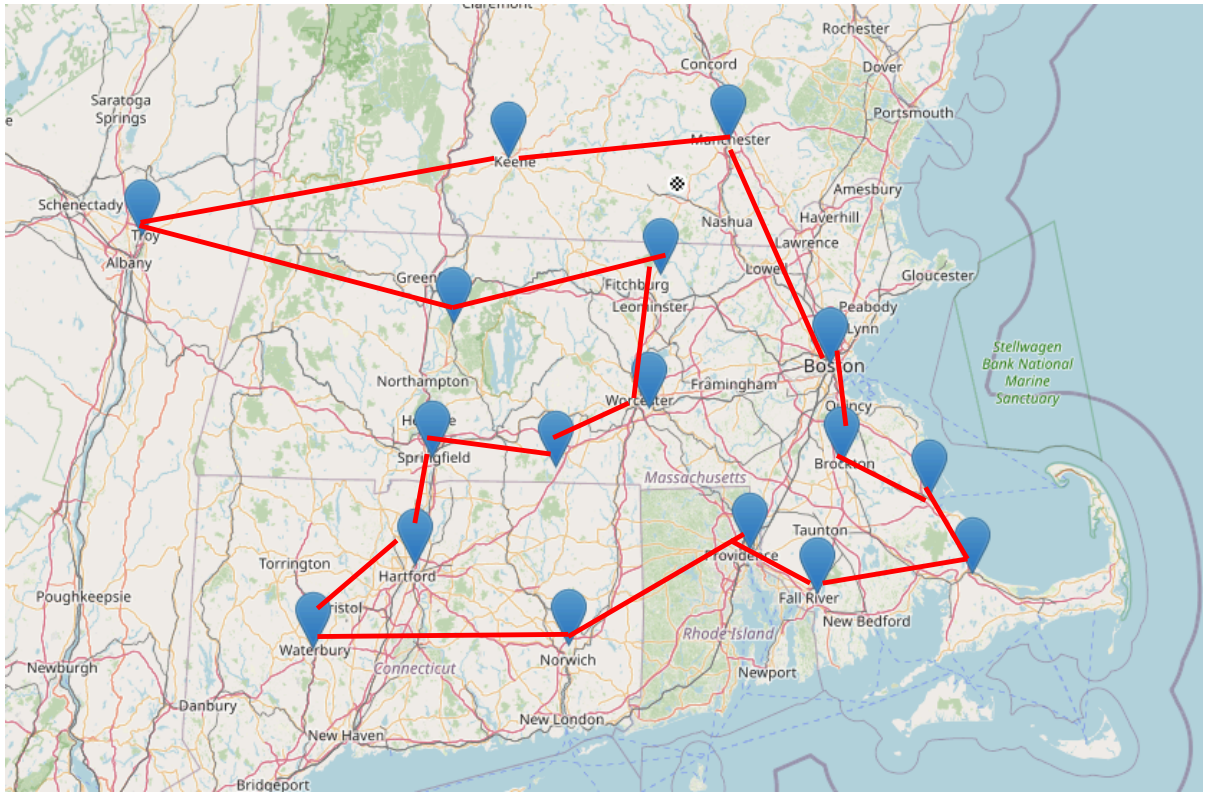
- The goal of the Traveling Salesman Problem (TSP) is to find the most economical way to tour of a select number of “cities” with the following restrictions:
  - You must visit each city once and only once
  - You must return to the original starting point

Introduction to Route Optimization



PURDUE UNIVERSITY

Introduction to Route Optimization



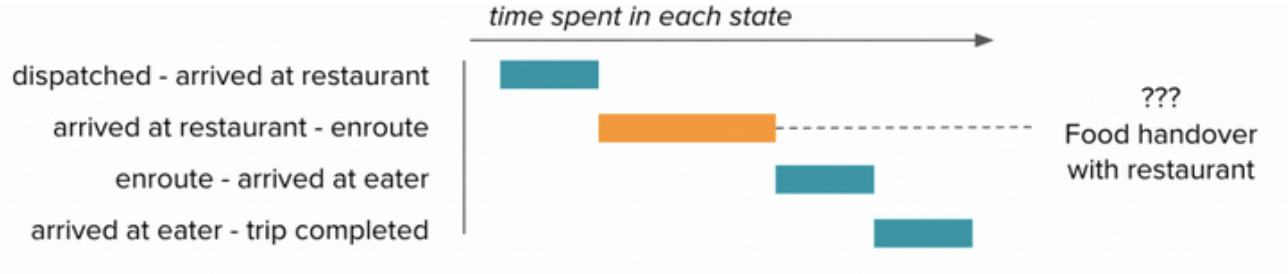
PURDUE UNIVERSITY

Applications of Route Optimization

- Ride-sharing, autonomous vehicles, traffic
- Emergency services and non-emergency medical transport
- Public transit
- Supply chain
- Field service (e.g., utilities, IT support, etc.)

Applications of Route Optimization

- **Ride-sharing, autonomous vehicles, traffic**
  - Route optimization improves time-efficiency for customers and restaurants



UBER EATS

  - Restaurants can anticipate when delivery drivers can be expected to arrive (handoff smooth (keep food warm))
  - Consumers can anticipate when the food will be delivered

- Optimization achieves all of these, while reducing the trip's time—thus improving customer experience and allowing drivers to complete more trips

Applications of Route Optimization

- **Emergency services and non-emergency medical transport**
  - Anticipating traffic congestion and distance constraints to get emergency services to patients faster
  - Once a patient is picked up, determining fastest route to a medical facility

- This is currently done via GPS and commercial routing services like Google, HERE, etc.

- Ethics Soapbox:
  - A problem with this approach is unequal access to street addresses. Something we often don't think about. As explained in Deirdre Mask's *The Address Book*, a non-insignificant share of West Virginia and some rural parts of the U.S., as well as developing nations, ***lack street addresses***. How can you route EMS/police to these locations? **If you're interested in equitable access to street addresses, talk to me after class!** I am involved with a non-profit in this space (see right).

Missing Maps

Missing Maps, a humanitarian project that preemptively maps parts of the world that are vulnerable to natural disasters, conflicts, and disease epidemics. Wikipedia

Motto: To map the most vulnerable places in the developing world.

Purpose: Humanitarian mapping.

Affiliations: OpenStreetMap Foundation

Applications of Route Optimization

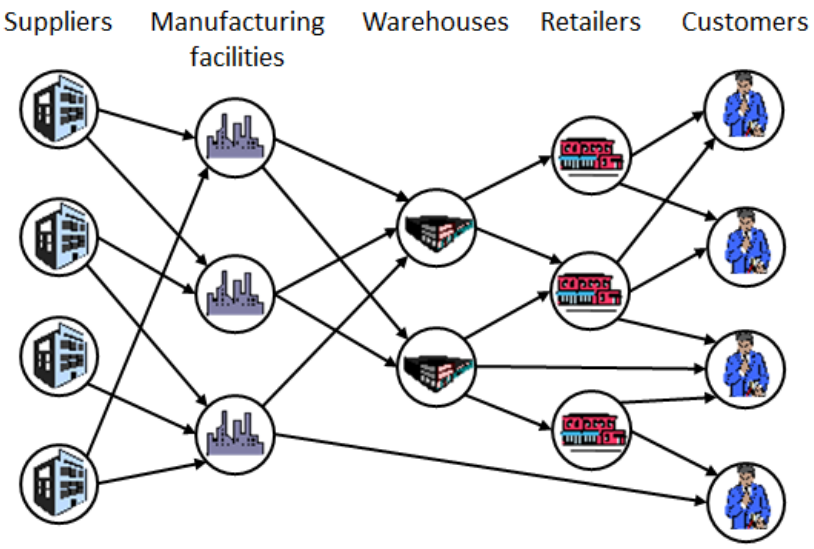
- **Public transit**

https://www.youtube.com/watch?v=I_8trRIzPlk&feature=emb_imp_woyt

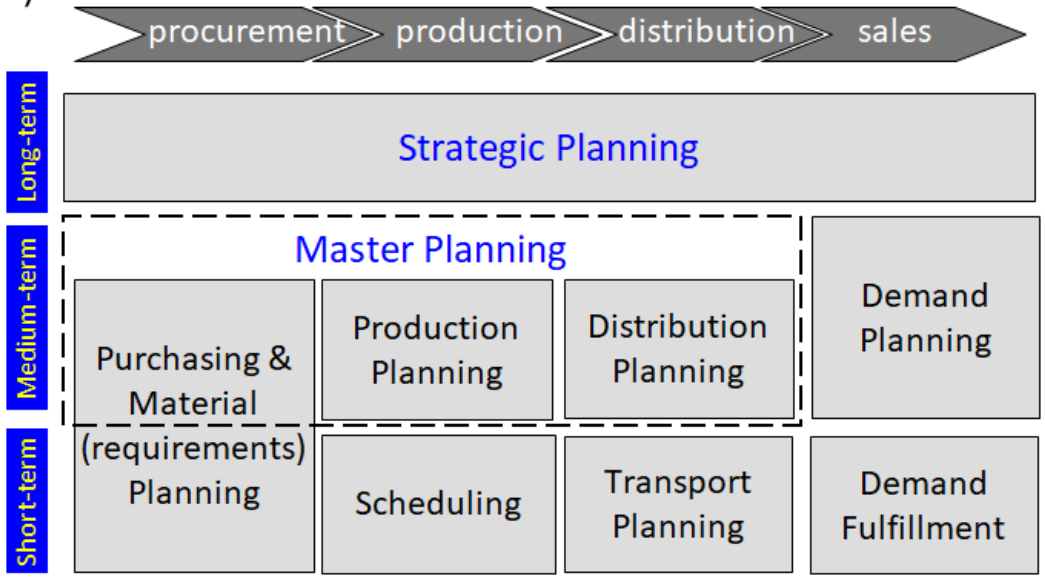
Applications of Route Optimization

- **Supply chain**

(A)



(B)



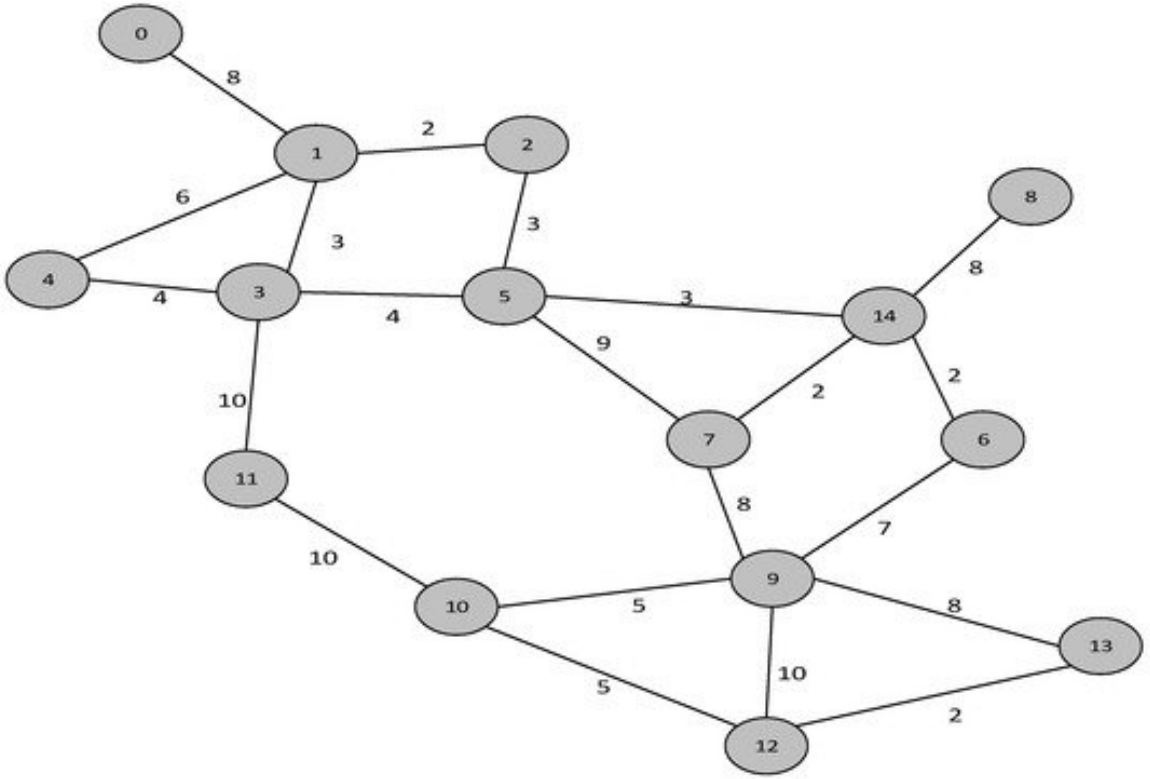
https://maravelias.princeton.edu/sites/maravelias/files/styles/panopoly_image_original/public/media/ps1_r.png?itok=Ohjrg28h

Applications of Route Optimization

- **Field service (e.g., utilities, IT support, etc.)**
  - Direct application of TSP
  - Locations of power issues (blown transformer, equipment to be upgraded, etc.)
  - Optimize route w.r.t.:
    - Lower gas costs
    - Lower time spent traveling to locations
    - Severity of problem (equipment inspection < equipment upgrade < sparking/arcing power line) as weight

Route Optimization Approaches

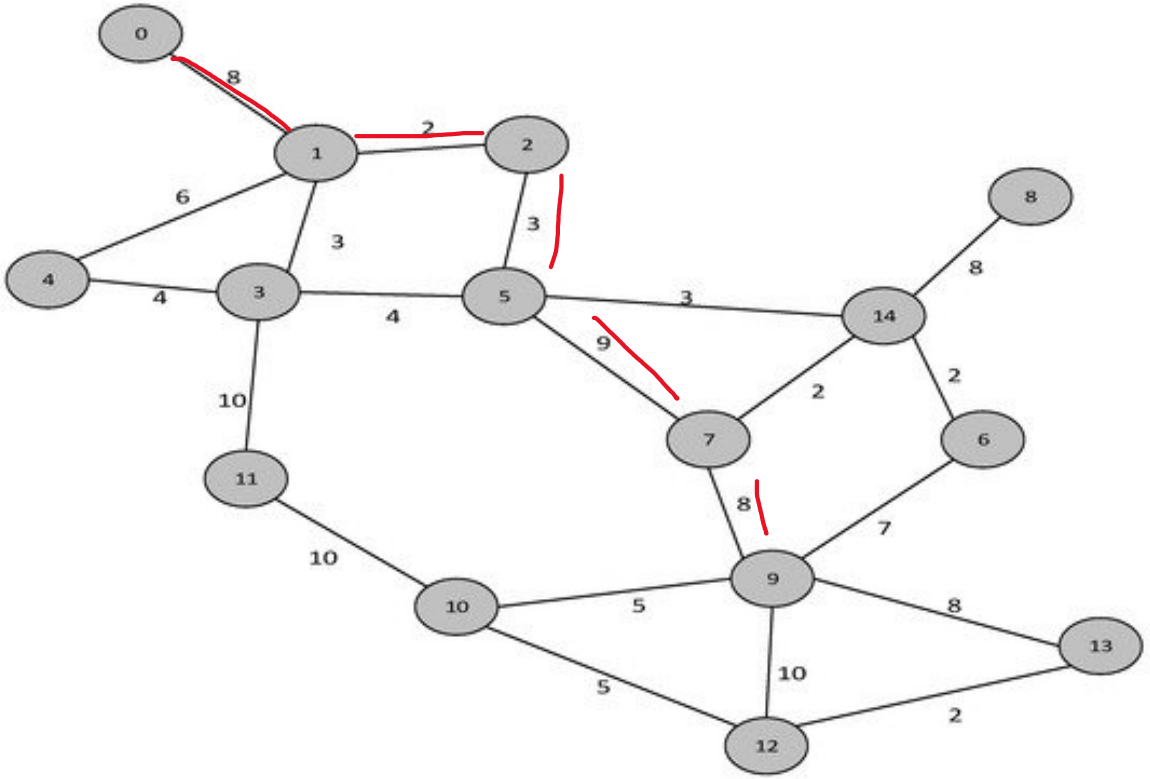
- Graph-based (shortest path)
  - Each node in the graph at the right is numbered. Think of it as the node's ID. A driver must start at 0. What is the shortest path to node ID 9?



Route Optimization Approaches

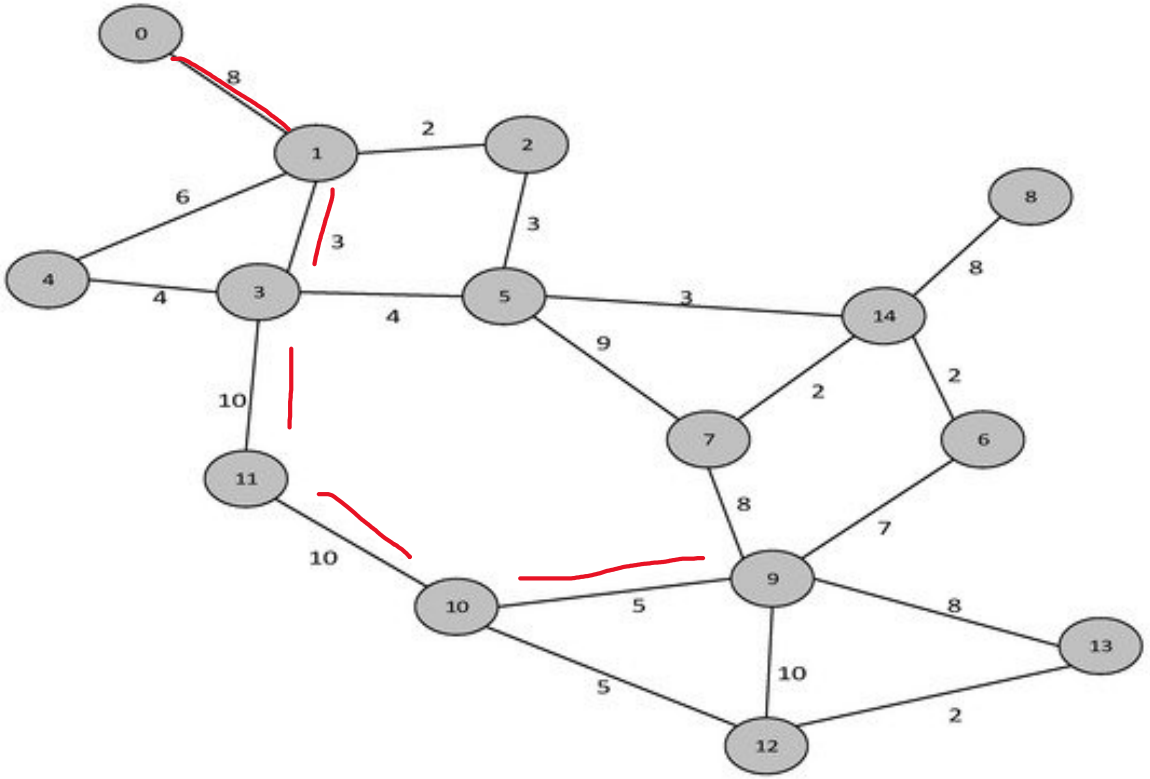
- ID 0 to ID 9:
  - 0→1: 8
  - 1→2: 2
  - 2→5: 3
  - 5→7: 9
  - 7→9: 8

  - TOTAL = 30 *distance*



Route Optimization Approaches

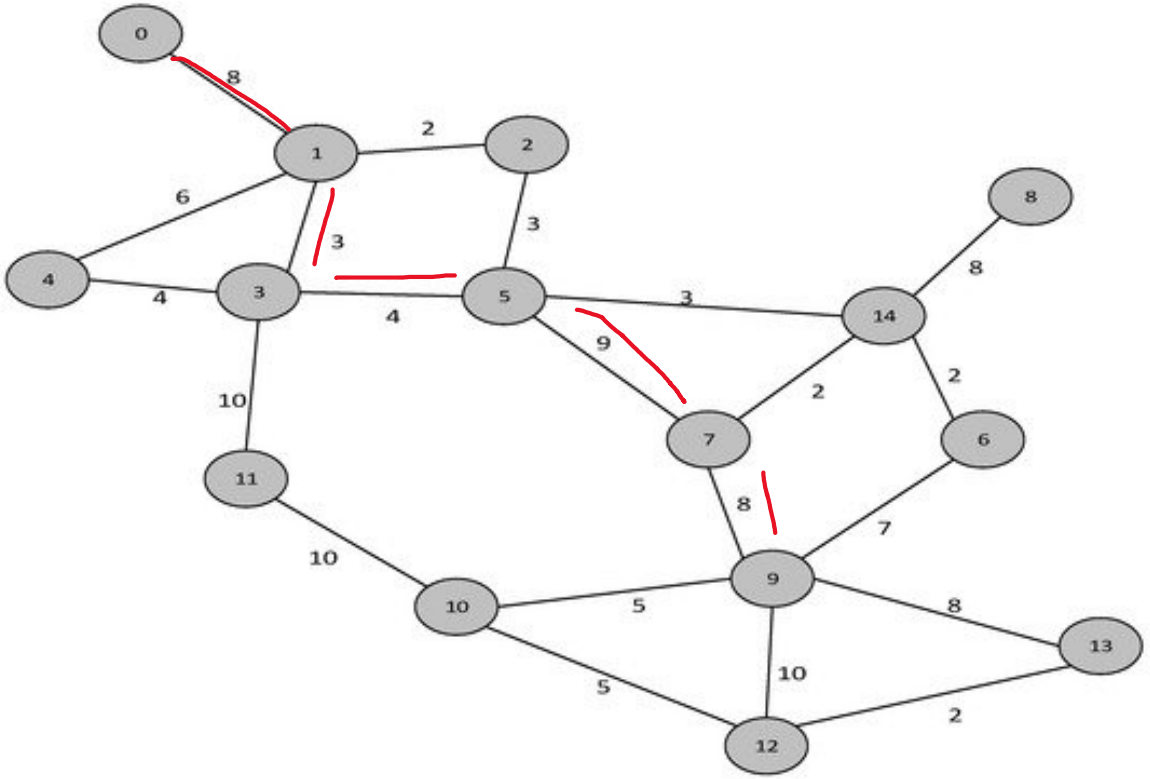
- ID 0 to ID 9:
  - 0→1: 8
  - 1→3: 3
  - 3→11: 10
  - 11→10: 10
  - 10→9: 5
  - TOTAL = 36 *distance*



Route Optimization Approaches

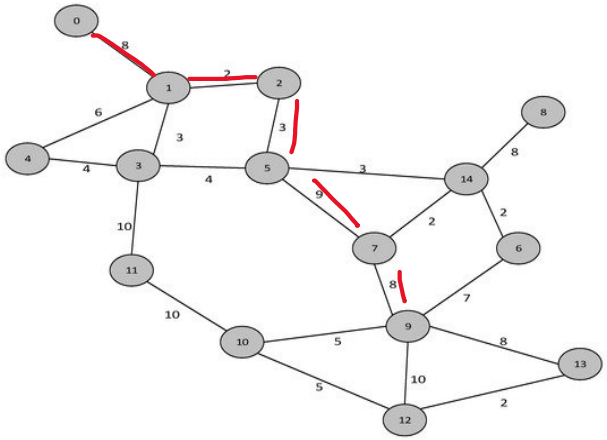
- ID 0 to ID 9:
  - 0→1: 8
  - 1→3: 3
  - 3→5: 4
  - 5→7: 9
  - 7→9: 8

  - TOTAL = 32 *distance*

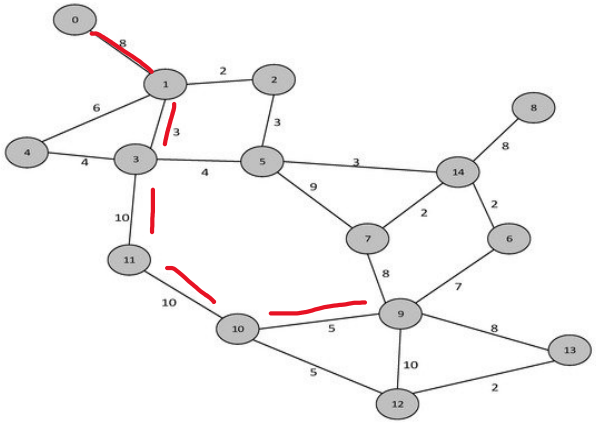


Route Optimization Approaches

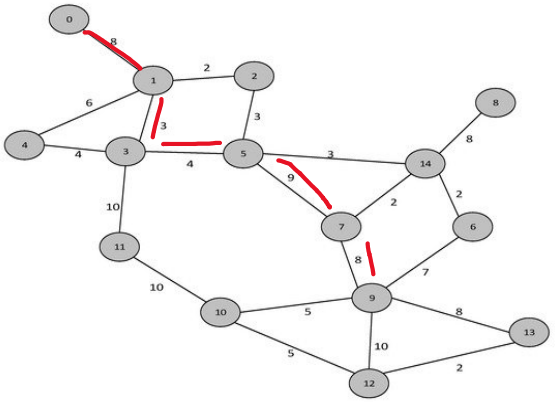
- Shortest = best



Option 1
Distance = 30



Option 2
Distance = 36



Option 3
Distance = 32

Route Optimization: Real GPS Data

- We can think of latitude and longitude points as being X/Y coordinates on a graph, where the graph is a provided road network. We cannot drive on non-roads, so sometimes the straightest physical path between two points is not the most optimal **drivable** route

(See next slides for an example)


What is the “shortest path” to grab an ice cream after work?
Henry Ford II World Center
Ford Credit Building
Ford Motor Company World Headquarters
Dairy Queen Grill & Chill
Comerica Bank
Michigan Ave
Mercury Dr
Dearborn Police Department
Henry Ford Centennial Library
Dearborn City Hall
Ghafari Associates
Michigan Ave
Michigan Ave


Using our Haversine function from HW 2: 1003.49 meters
Dairy Queen Grill & Chill
Henry Ford II World Center
Ford Credit Building
Ford Motor Company World Headquarters
Comerica Bank
Michigan Ave
Mercury Dr
Dearborn Police Department
Henry Ford Centennial Library
Dearborn City Hall
Ghafari Associates
Michigan Ave
Michigan Ave


According to Google Maps:
2253.09 meters
Henry Ford II World Center
Ford Credit Building
Ford Motor Company World Headquarters
Comerica Bank
Dairy Queen Grill & Chill
Dearborn Police Department
Henry Ford Centennial Library
Dearborn City Hall
Ghafari Associates
Michigan Ave
Michigan Ave
Mercury Dr
Greenfield Rd

In-Class Notebook

- https://github.com/gouldju1/honr39900-foundations-of-geospatial-analytics/tree/master/Lectures/Weeks%2012-13