Transportation network modelling

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Agenda

- What is a transportation network?
- Network algorithms
  - Shortest path and
  - Travelling Salesman's Problem
- Location - Allocation
- Service area
- Availability/Accessibility
- Network datamodel
- Network features
- Exercises

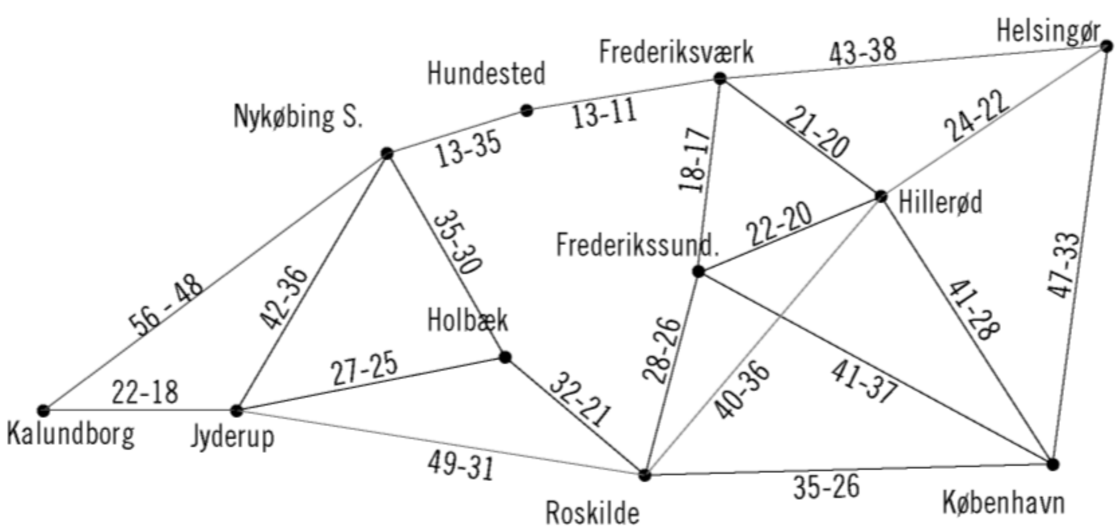
Transportation network

A transportation network is used to optimize searches relative to distances and travel time.

The network is based on graph theory and built from **edges** and **junctions**. The transportation network may include directions, and travel costs based on impedances can be time enabled.

Travelling Salesman's Problem

Challenge: Visit a set of destinations once and return home having minimized the distance travelled.



First number = distance in km
Last number = travel time in minutes

Dijkstra's algorithm:

Start point = 0

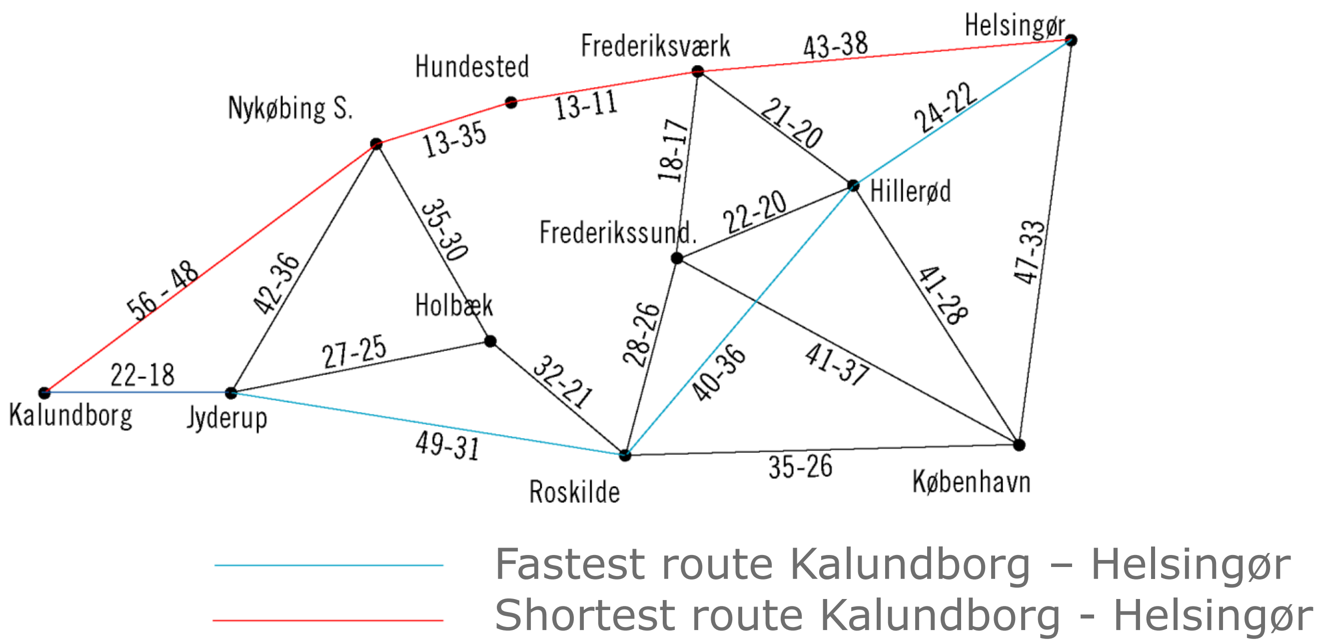
All other points = ∞

Start at 0 and determine distance to neighbors.

Sort the distances and select the point with the shortest distance to the lowest value and determine distance to neighbors from there.

Update accum. distances, select point with lowest value and continue.

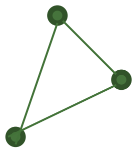
Shortest / fastest route



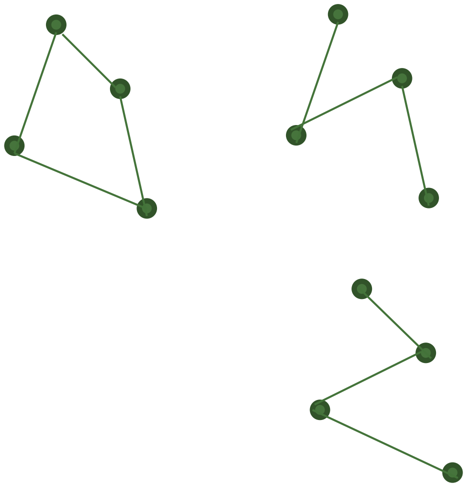
First number = distance in km
Last number = travel time in minutes

Travelling Salesman's Problem

How many various combinations of path finding in between 3 cities: 1



How many various path finding combinations in between 4 cities: 3



Thus, the number of combinations of path finding is (n-1)! / 2

n = 3 -> (3-1) ! / 2 -> 1

n = 4 -> (4-1) ! / 2 -> 3

Travelling Salesman's Problem

How many various combinations of path finding in between 20 cities:

$19\,!\,/\,2 = 6{,}08 * 10^{16}$

A fast home computer today can handle 10 Tflops (= 10^{12} floating point operations per second), the calculation will take

$1{,}9 * 10^{9}$ years

Instead several heuristics are available:

1) random, 2) greedy, 3) 2-opt, 4) simulated annealing

[TSP video]

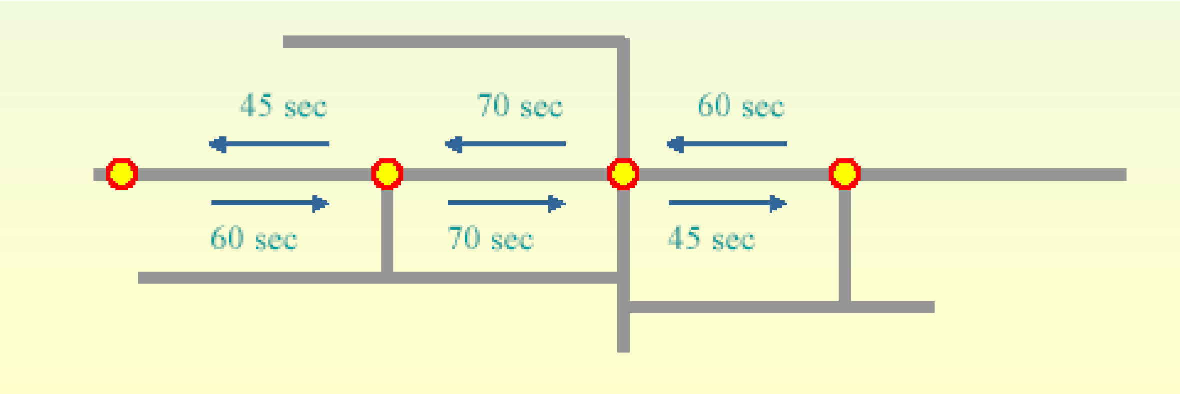
[Explanation: Simulated Annealing- The Travelling Salesman Problem (fourmilab.ch)]

Network Dataset Features

- Cost attributes (distance vs. time costs)
- Historical traffic information
- Turn delays (turns that take a long time)
- Restriction attributes (one-way streets)
- Turn restrictions
- ‘Global’ turn delays (company prefers avoiding left turns)
- Directions (prohibiting)
- U-turns (prohibiting)
- Curb approach
- Barriers (construction, accidents)

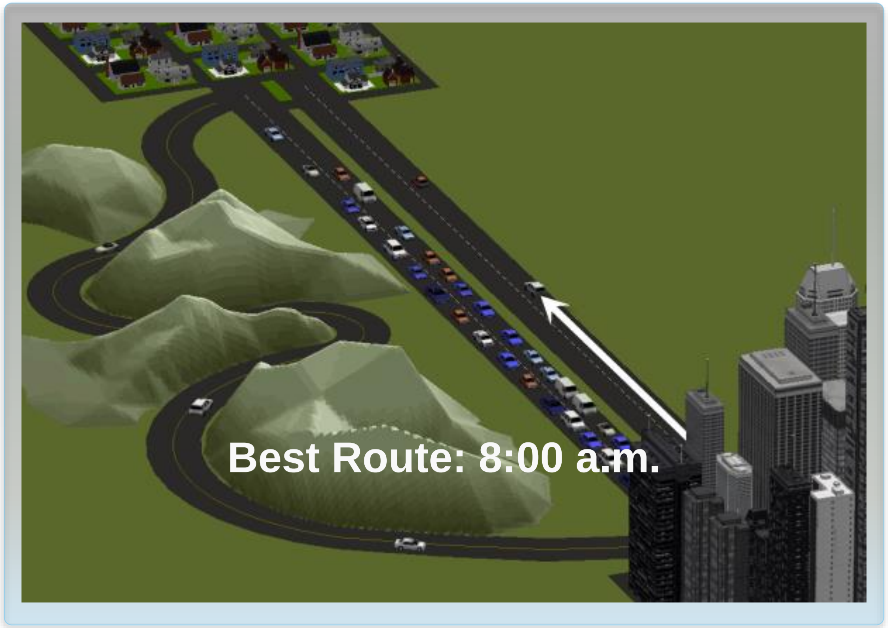
Cost of travel

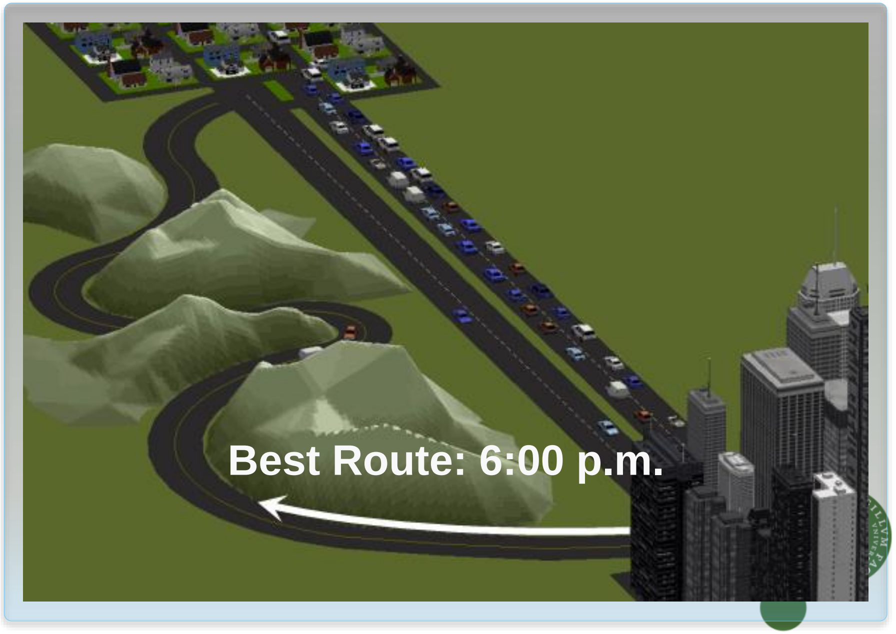
- Properties
  - One-way street
  - Number of lanes in each direction
- Impedance
  - The costs by travelling through a network is usually expressed by travel distance or travel time
- The impedance is dependent on the direction of the travel



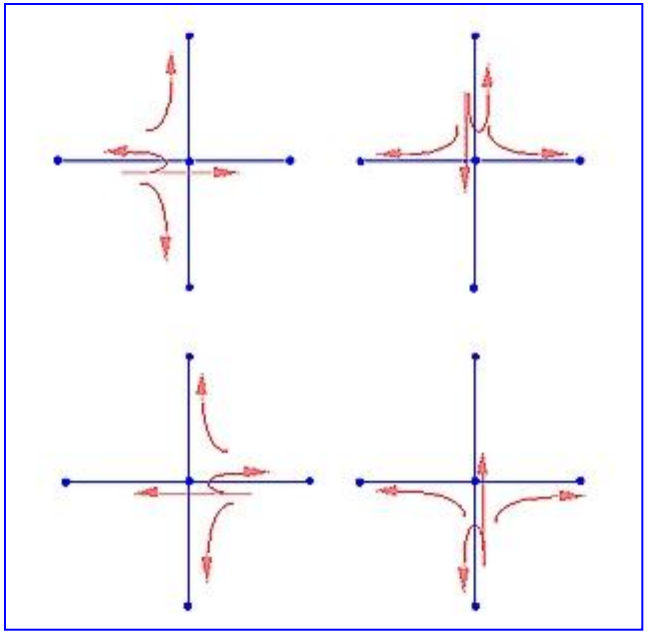
Cost Attributes

- Historical traffic
  - Find the best routes given expected traffic delays.
  - Get more accurate arrival times.





Turns



There exists 3 types of turns:
- Right turn
- Left turn
- U-turn

- Represent relationships for network connections
- Can influence the transport through a network (e.g. a right turn with oncoming traffic takes longer time than just driving straight ahead)
- Global Turn Delays
  - Global turns add a cost to every turn in the network.
  - Reduces the number of turn features you need to digitize.

Restriction attributes

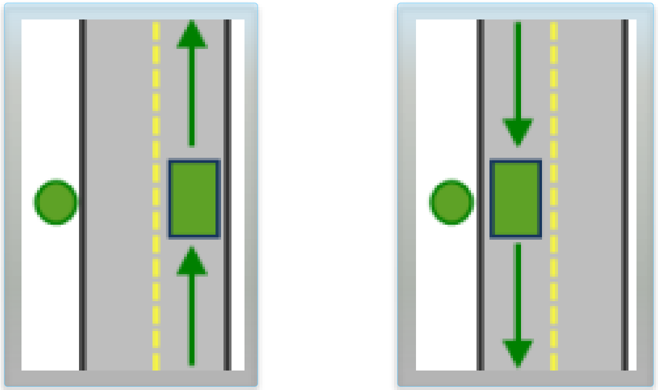
- Specify which edges, junctions, and turns that can’t be traversed
  - One ways
  - Prohibited turns (no left turns, no U-turns)

Restriction and Descriptor Attributes

- Restriction attributes can be derived from descriptor attributes and vehicle characteristics
  - Model height, weight, width limits

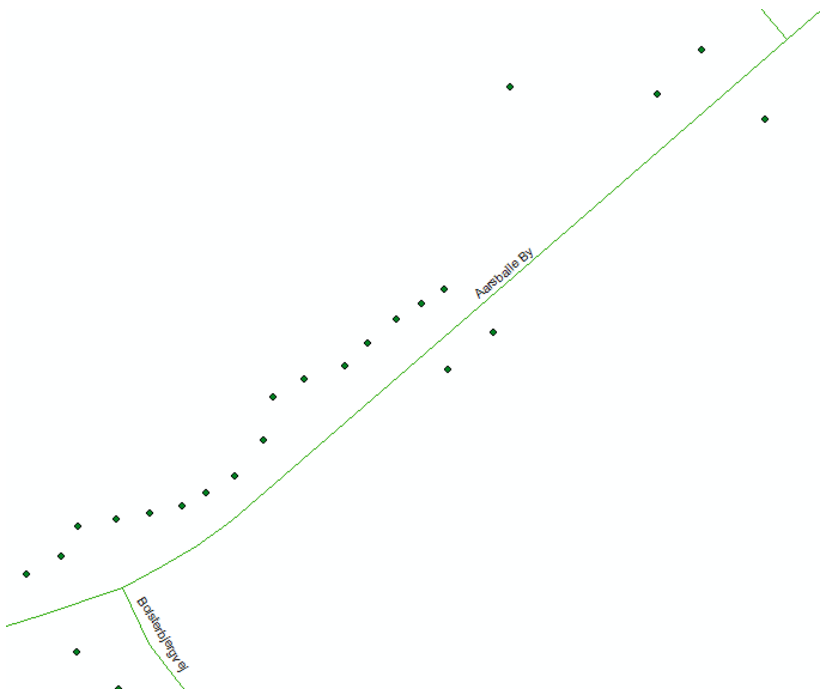
Curb Approach

- Curb approach ensures the vehicle arrives on and departs from a specific side of the road

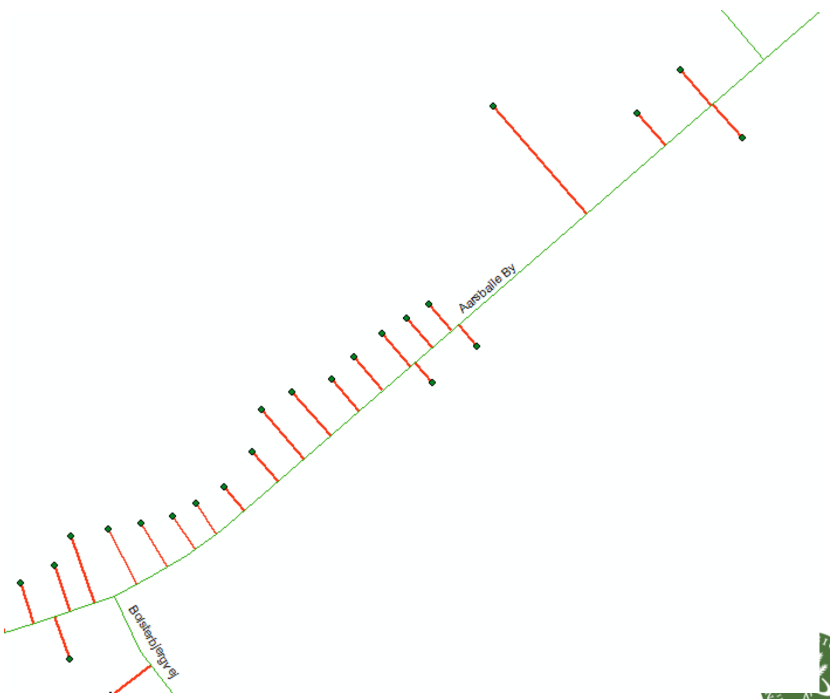


Connect address points to network

Addresses not connected to the network



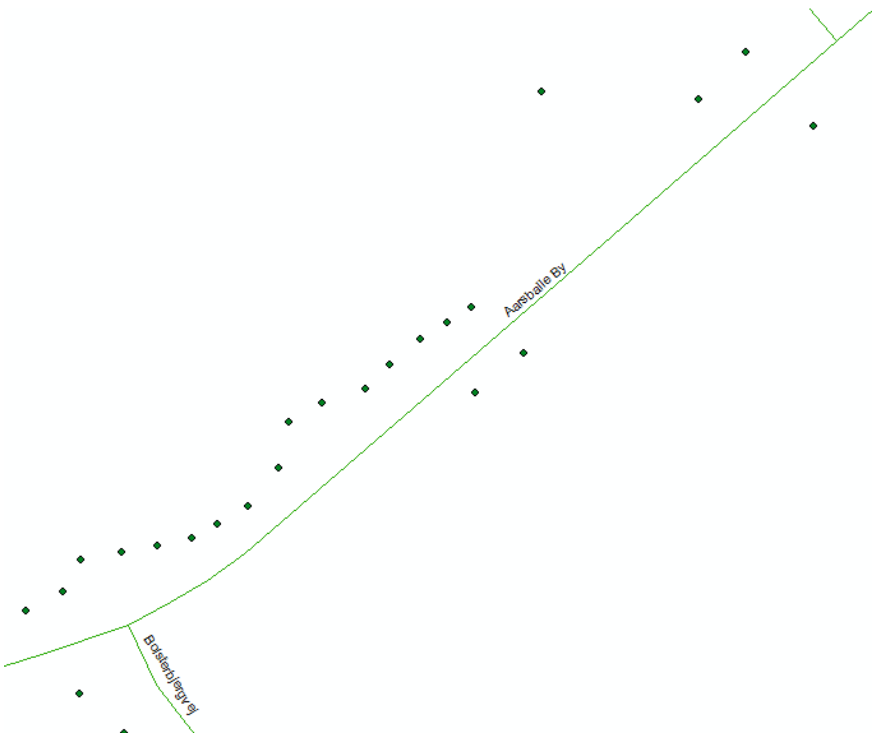
Addresses connected to the network by identyfing the shortest distance from points to roads

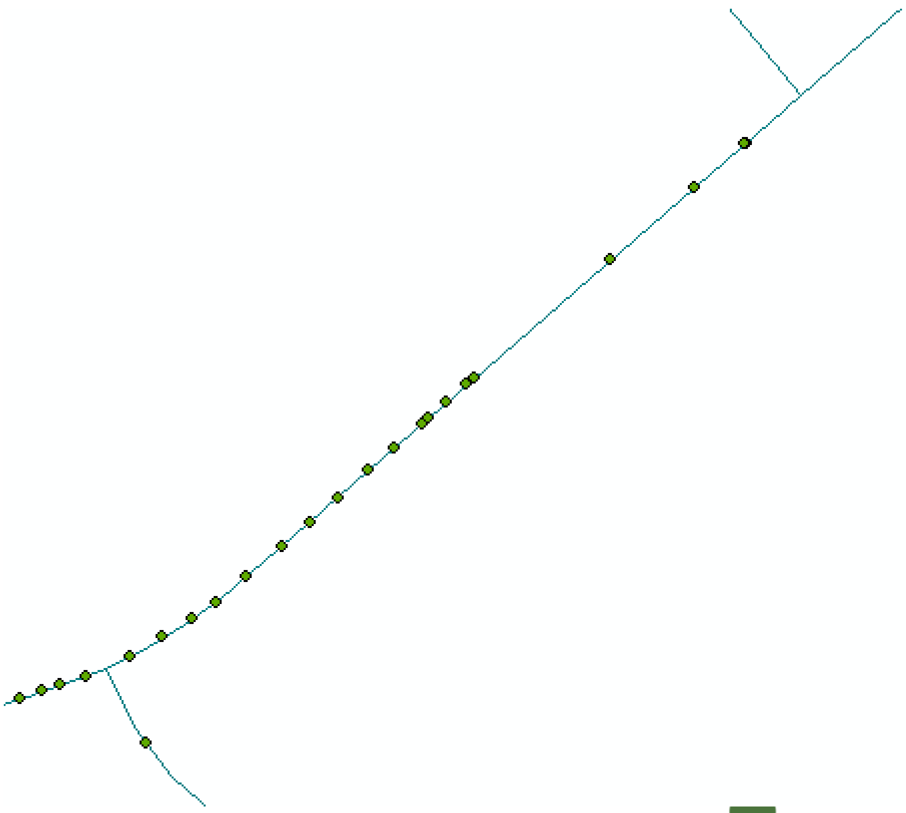


Connect address points to network

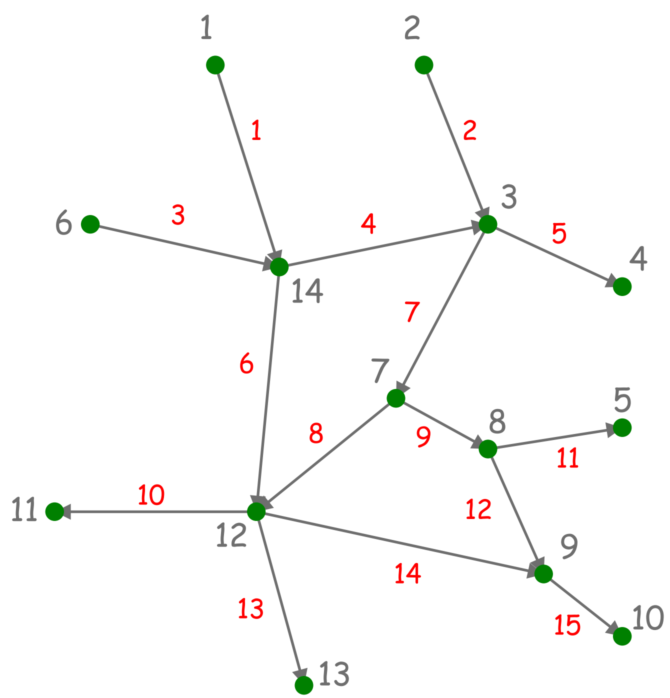
Alternatively snap the address' locations to nearest road edges

-> Use ArcGIS Snap tool





Network - datamodel



Network attribute table

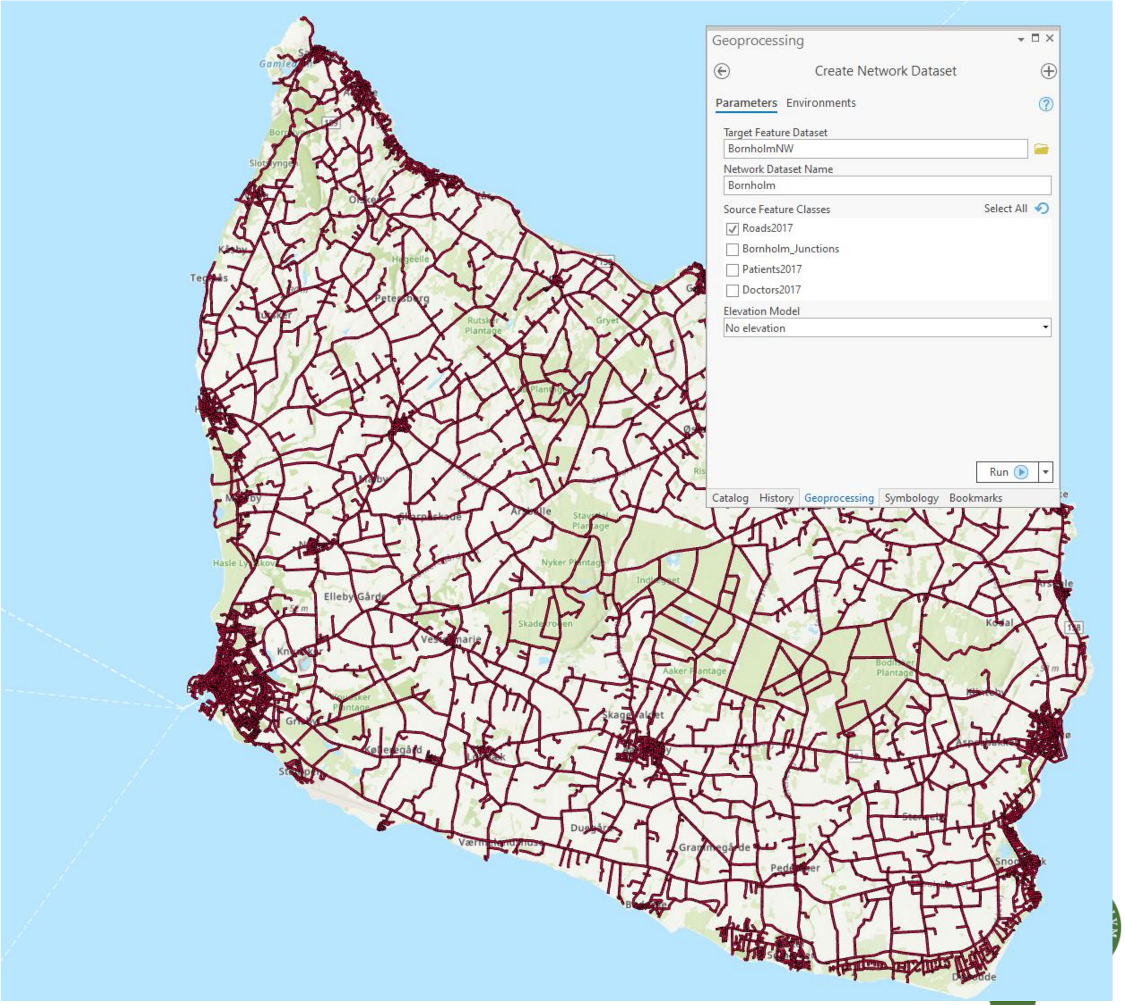
LineID	FNODE	TNODE	Cost	ONE-WAY
1	1	14	90	B
2	2	3	85	B
3	6	14	110	B
4	14	3	75	FT

Turn table

Node	Arc1	Arc2	Cost
14	1	4	-1
7	7	8	23
9	14	15	34

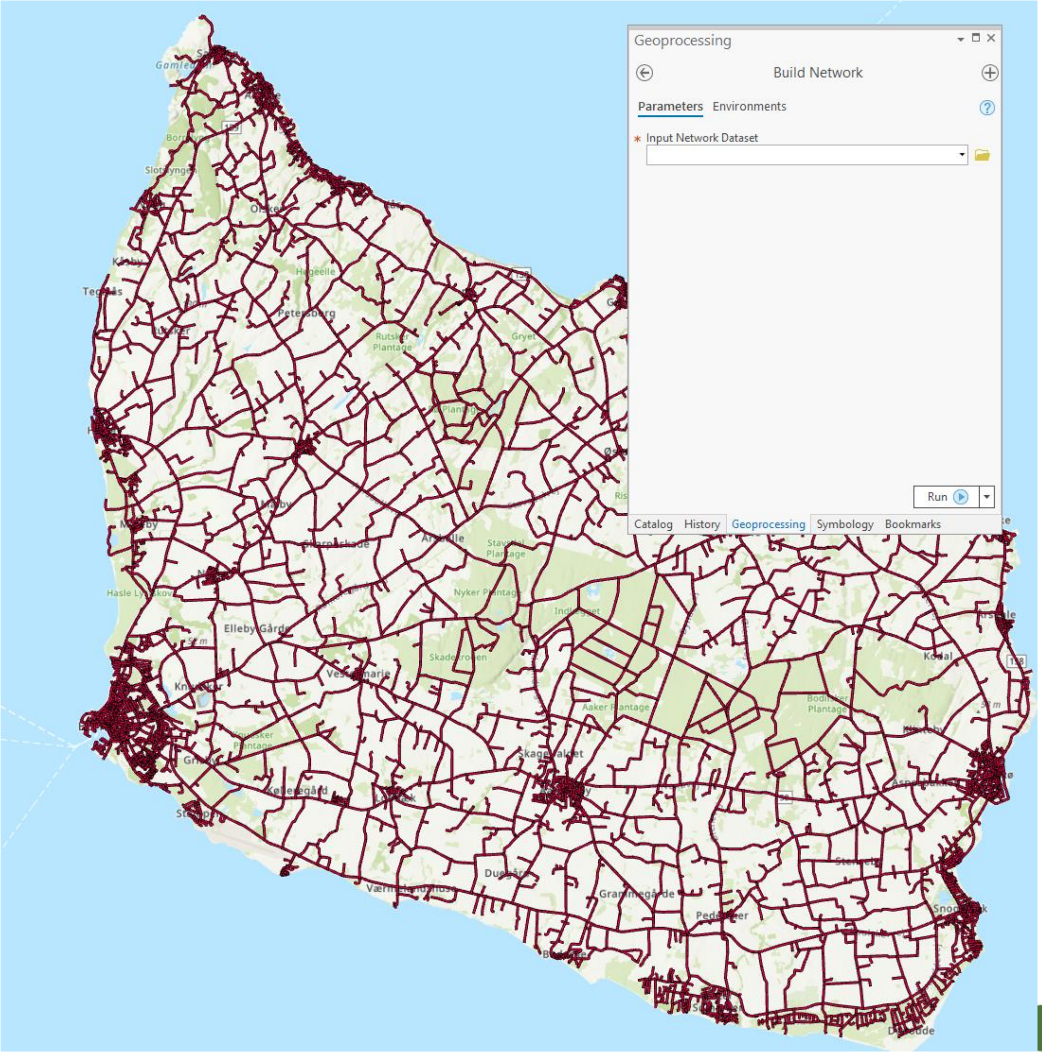
ArcGIS procedure: Create Network Dataset

Prepare the network's components and store them in a feature dataset

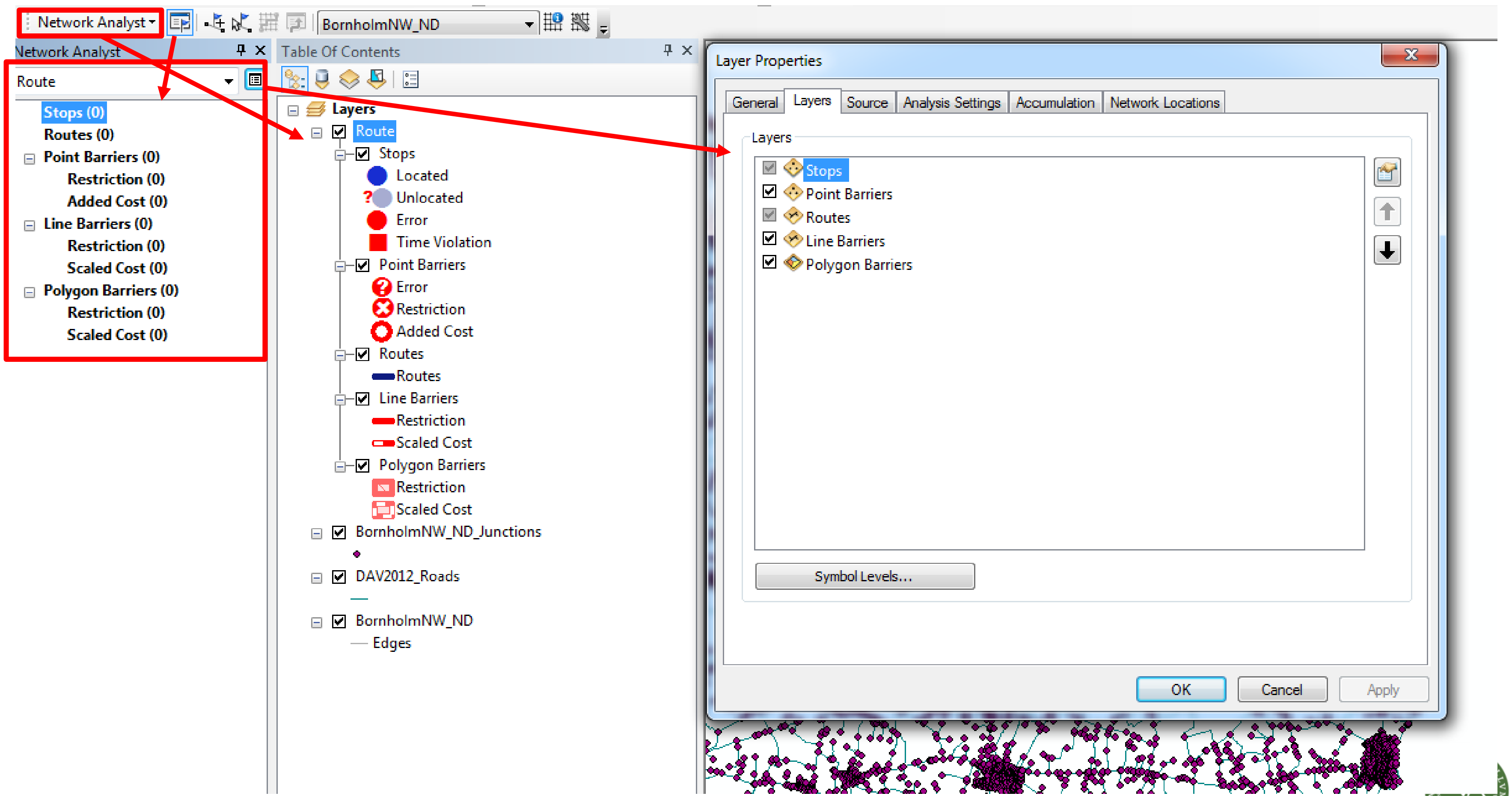


ArcGIS procedure: Build network

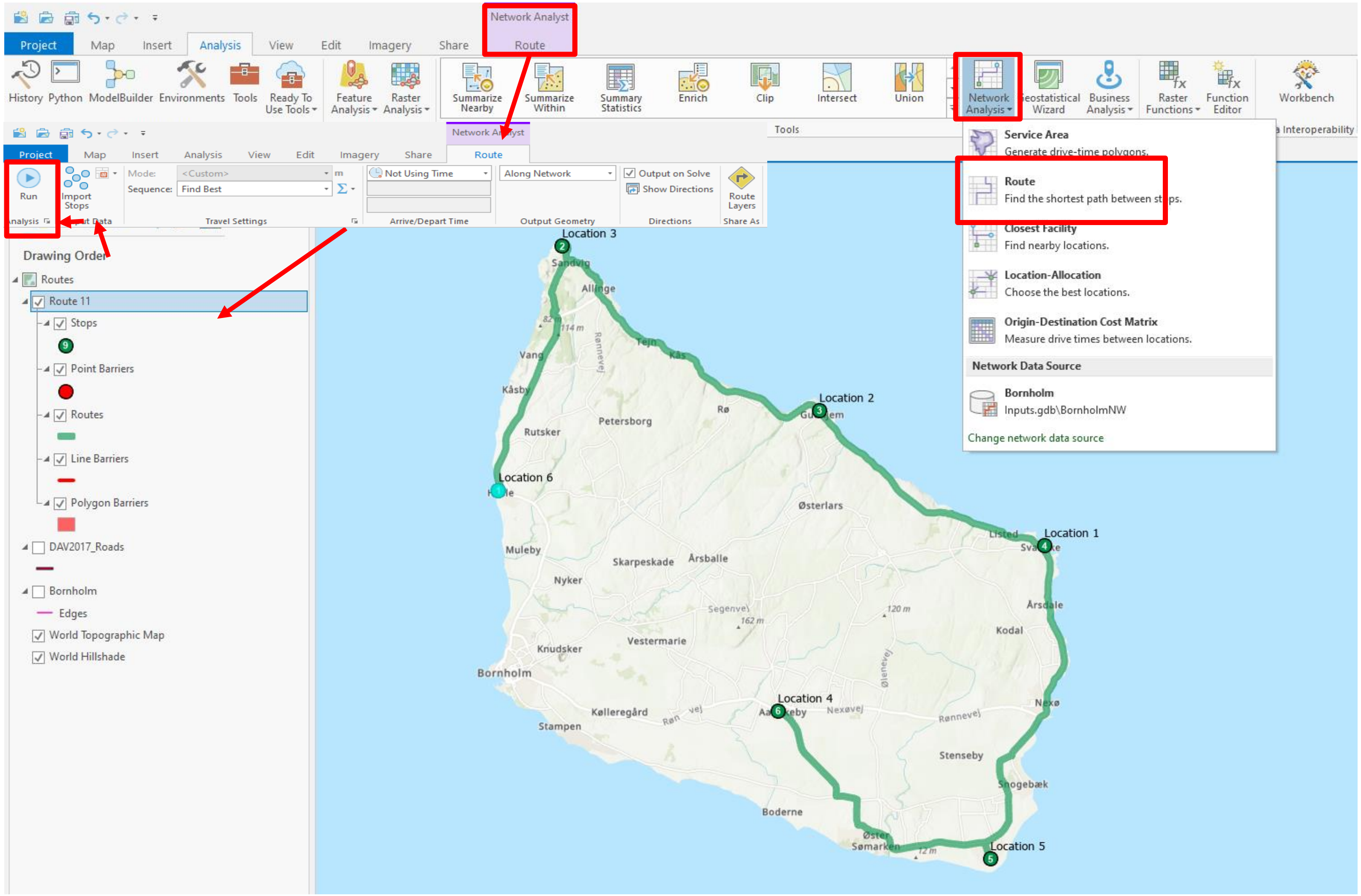
Build the network from the feature dataset's components



ArcGIS procedure: Load stops

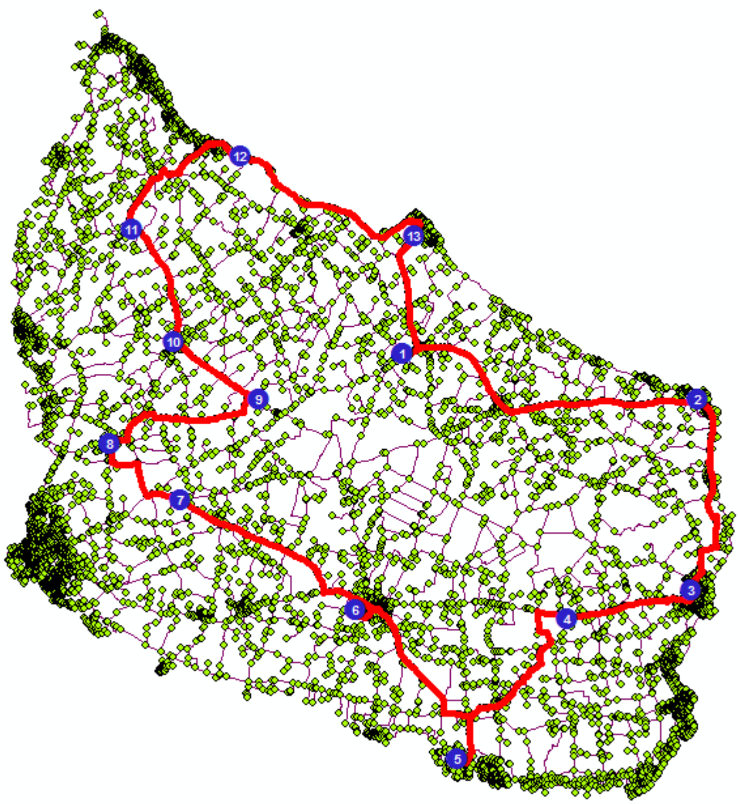


ArcGIS procedure: Line up the problem



Travelling Salesman's Problem

Driving directions

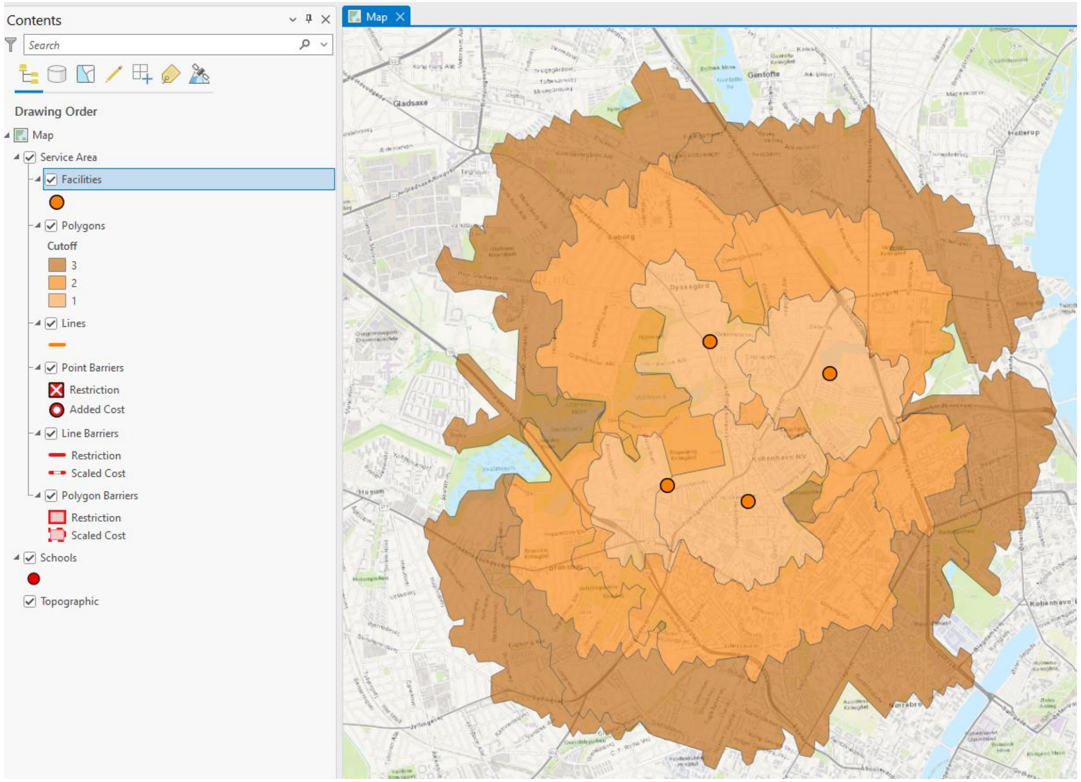


Directions (Route)

[-]	**Route: Graphic Pick 13 - Graphic Pick 13**	105 km	Map
1:	Start at Graphic Pick 13		Map
2:	Go southeast on Brommevej toward Skolevej	221 m	Map
3:	Turn left on Stavsdalvej	468 m	Map
4:	Continue on Nybrovej	3,2 km	Map
5:	Continue on Godthåbsvej	1,7 km	Map
6:	Continue on Svanekevej	5,3 km	Map
7:	Continue on Østermarievej	2,4 km	Map
8:	Continue on Storegade	385 m	Map
9:	Bear right on Otto Holst Bakke	29 m	Map
10:	Arrive at Graphic Pick 11, on the right		Map
11:	Depart Graphic Pick 11		
12:	Continue east on Otto Holst Bakke	56 m	Map
13:	Bear right on Borgergade	41 m	Map
14:	Turn right on Madvigsgade	40 m	Map
15:	Continue on Svaneke Torv	58 m	Map
16:	Continue on Postgade	51 m	Map
17:	Turn right on Kirkebakken	113 m	Map
18:	Turn left on Kirkepladsen	38 m	Map
19:	Turn left to stay on Kirkepladsen	34 m	Map
20:	Turn right on Sander Dichsgade and immediately turn left on Lille Plads	83 m	Map
21:	Turn right on Lille Plads and immediately turn left on Hullebakke	71 m	Map
22:	Continue on Søndergade	915 m	Map
23:	Continue on Aarsdalevej	1,5 km	Map
24:	Turn left on Strandvejen	596 m	Map
25:	Continue on Gaden	547 m	Map
26:	Turn left on Aarsdalevej	86 m	Map
27:	Turn right on Sdr Aarsdalevej	2,6 km	Map

Options... | Print Preview... | Save As... | Print | Close

Service areas – school districts by travel time



Service areas:

Shows the areas within specific distances from one or more facilities.

Example: The service areas covered by 4 schools

Location - Allocation

Which centres service a network?

Two criteria is applied in the allocation process:

Supply: The number of available resources in a centre.
Demand: The number of resources demanded in the nearby nodes.

Allocate works by allocating demand – usually to the nearest centre - until the demand corresponds to the supply of resources in the centre

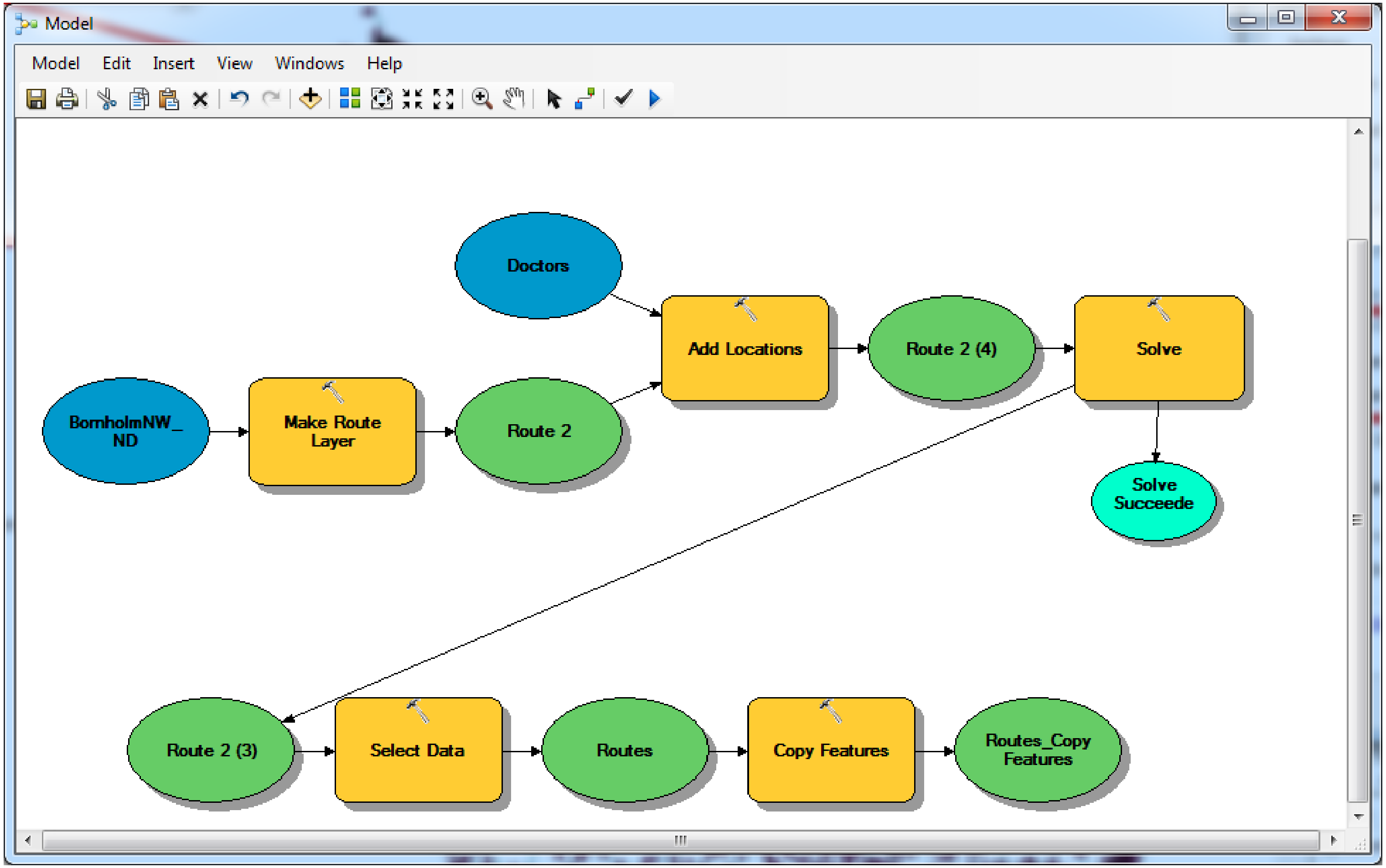
Example: A school (the centre) has a resource that is the available seats for pupils.
The number of pupils (nodes) makes up the demand.
Nodes are allocated to the schools via connections until the total number of pupils along at the of the connections is equal to the number of available seats.

ArcGIS geoprocessing environment for transportation networks

- Network Analyst Tools
  - Analysis
    - Add Field to Analysis Layer
    - Add Locations
    - Calculate Locations
    - Copy Traversed Source Features
    - Directions
    - Make Closest Facility Analysis Layer
    - Make Location-Allocation Analysis Layer
    - Make OD Cost Matrix Analysis Layer
    - Make Route Analysis Layer
    - Make Service Area Analysis Layer
    - Share As Route Layers
    - Solve
    - Solve Vehicle Routing Problem

- Network Analyst Tools
  - Analysis
  - Network Dataset
    - Build Network
    - Create Network Dataset
    - Create Network Dataset From Template
    - Create Template From Network Dataset
    - Dissolve Network
    - Make Network Dataset Layer
  - Turn Feature Class
    - Create Turn Feature Class
    - Increase Maximum Edges
    - Populate Alternate ID Fields
    - Turn Table To Turn Feature Class
    - Update by Alternate ID Fields
    - Update by Geometry

ArcGIS ModelBuilder workflow

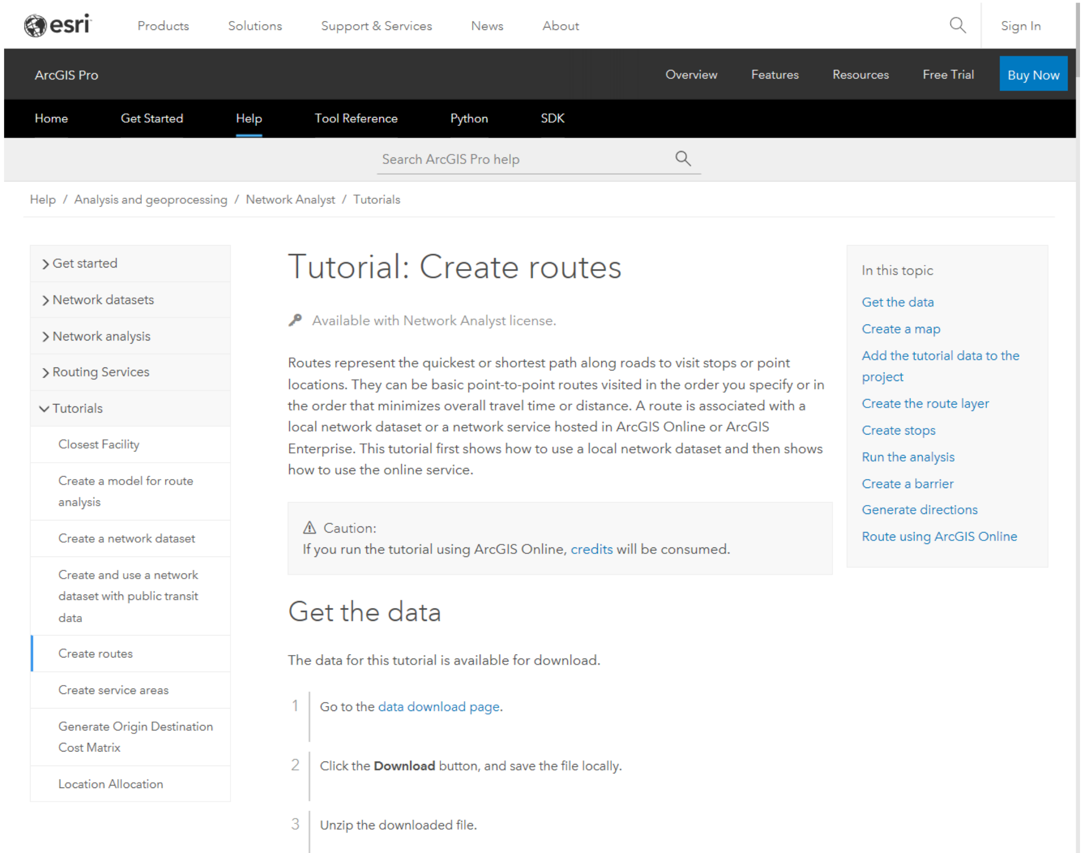


ArcGIS – try more

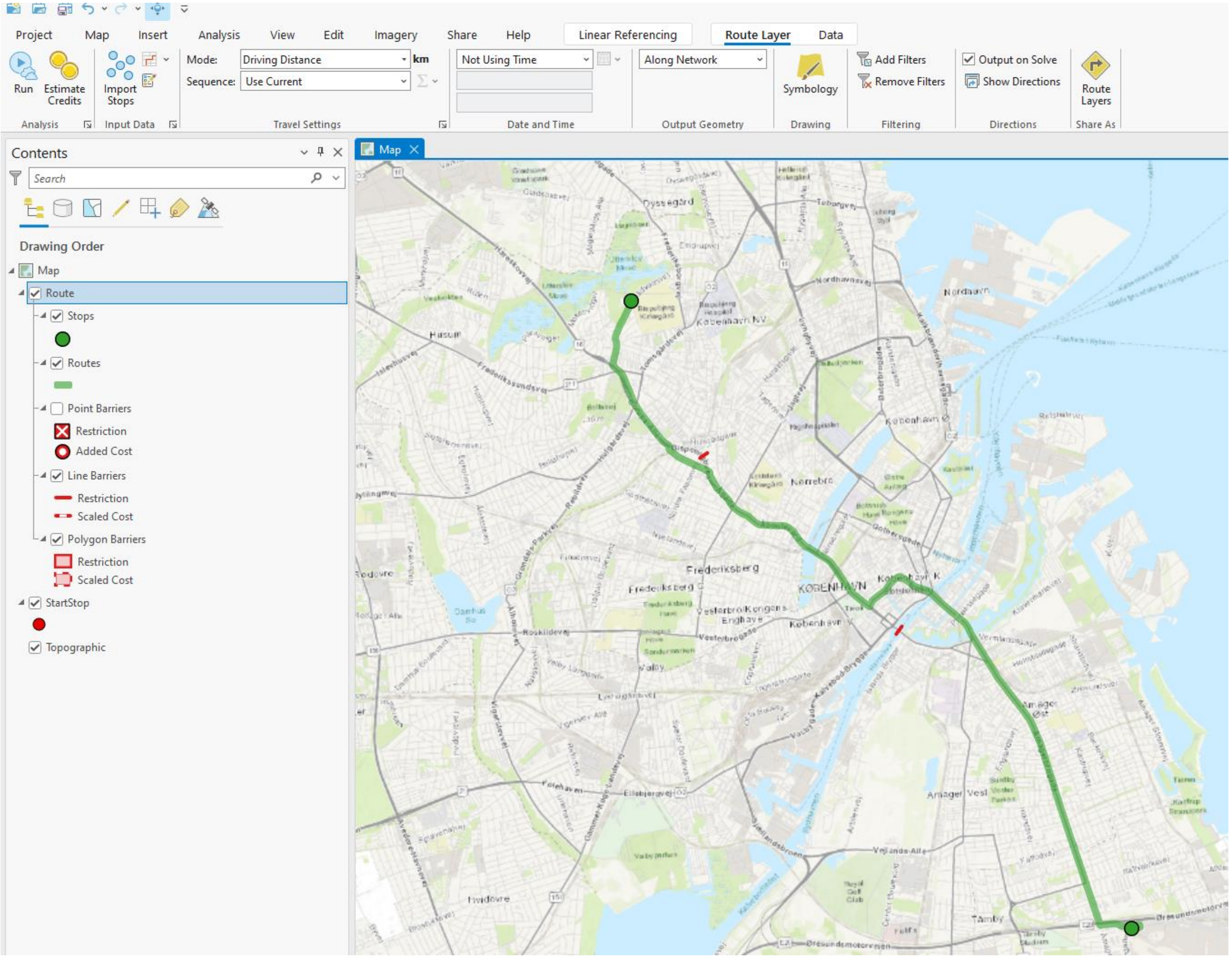
Explore the Network Analyst Tutorial.

Search for **ArcGIS Pro network analyst tutorial:**

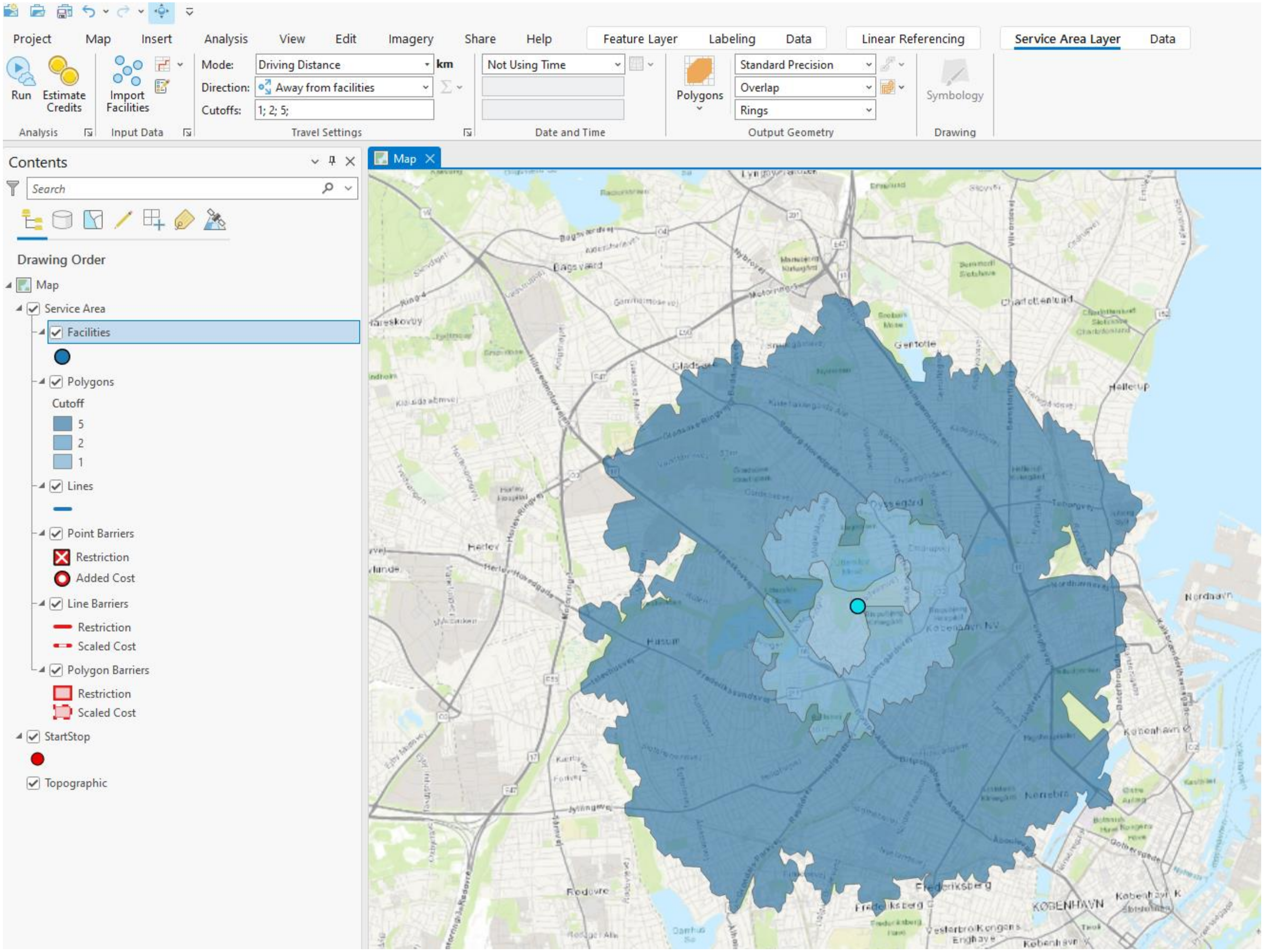
Network Analyst tutorials—ArcGIS Pro | Documentation



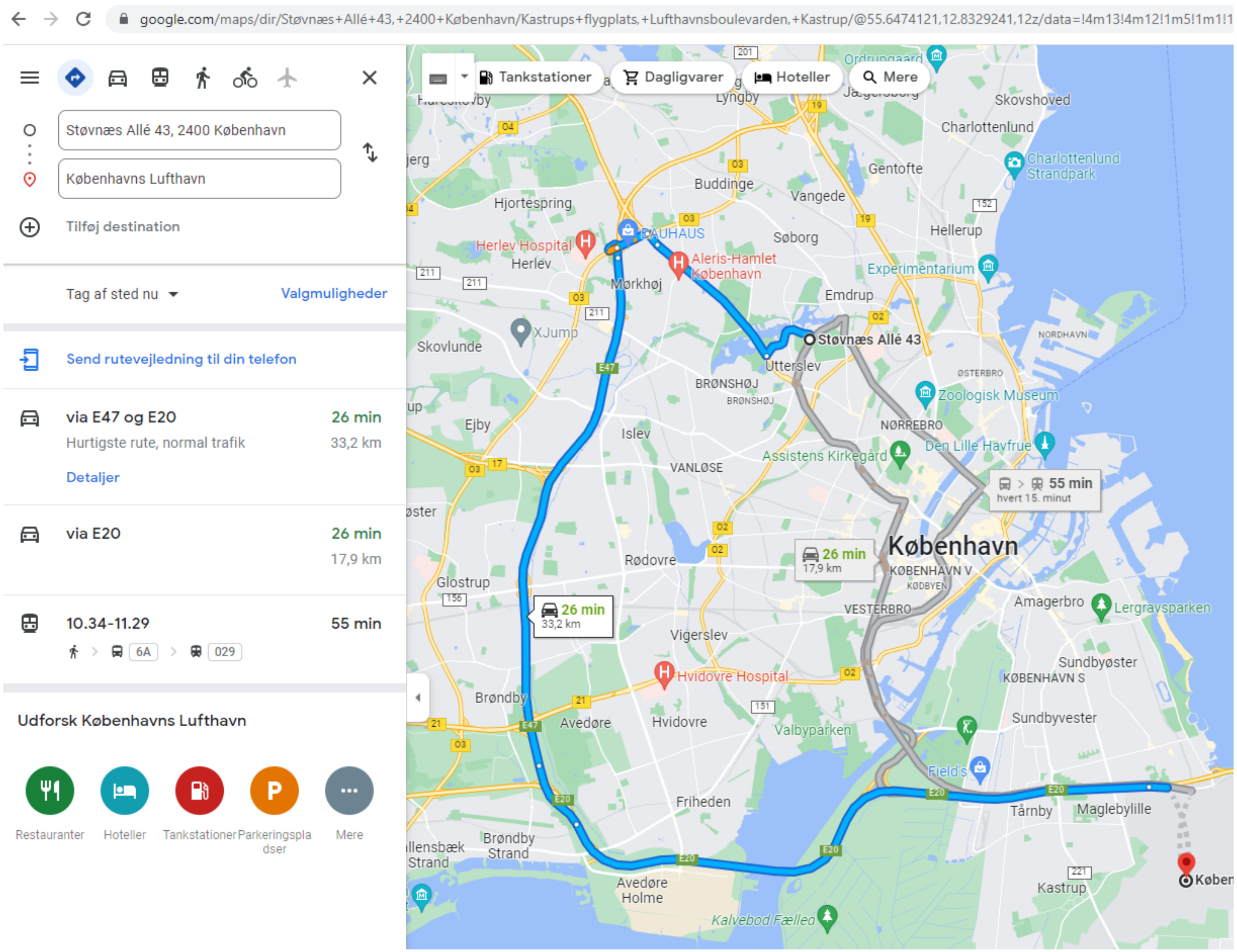
Network Analysis in ArcGIS Online – Find Routes



Network Analysis in ArcGIS Online – service areas



Online shortest path services right now – Google Maps



Online shortest path services, rush hour prediction Google Maps