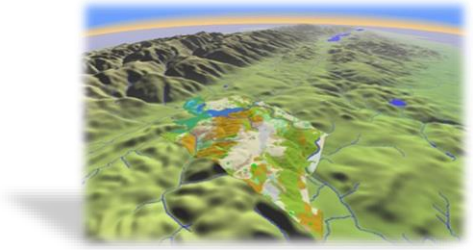
NICHOLAS SCHOOL OF THE ENVIRONMENT AND EARTH SCIENCES
DUKE UNIVERSITY



ENVIRON 761:
Network Analysis

Instructor: John Fay

Overview

What are 'network analyses'?

- Everyday examples of network analysis
- Using the Network Analyst extension in Arc

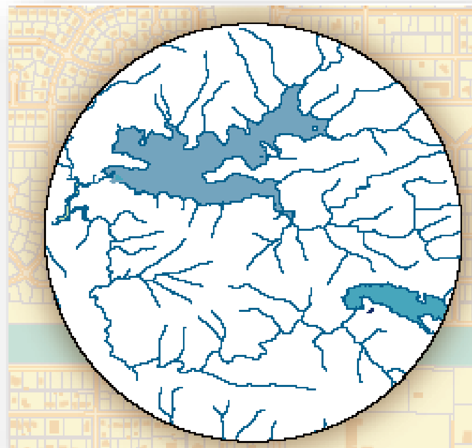
How network analysis works

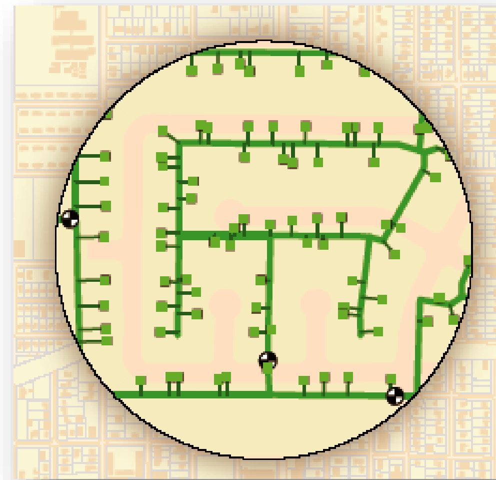
- Components of a network; graph theory
- Building a network dataset in Arc

Environmental applications of networks

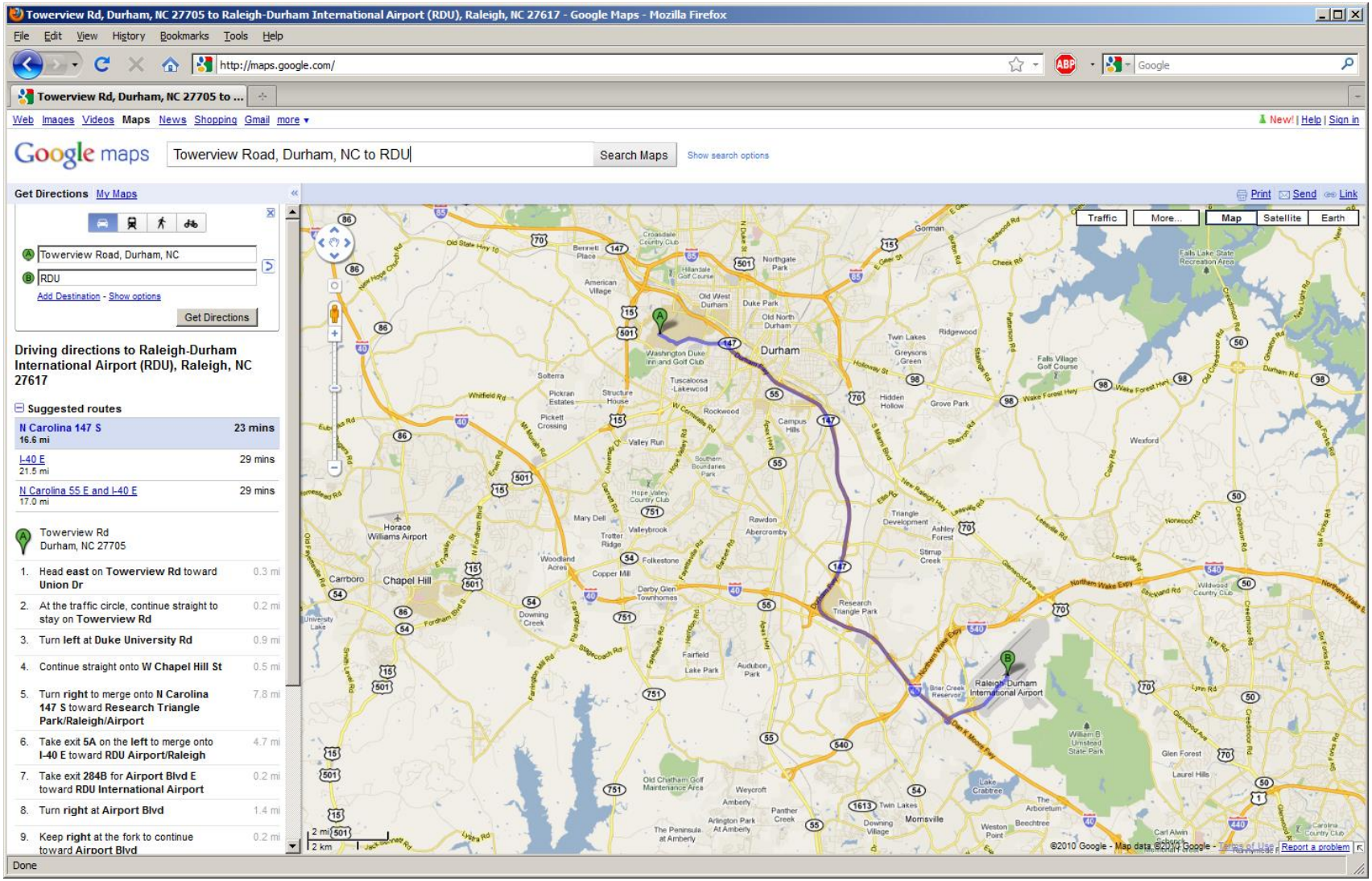
- Hydrologic analyses
- Ocean current analysis
- Habitat connectivity

Networks: Channeled movement

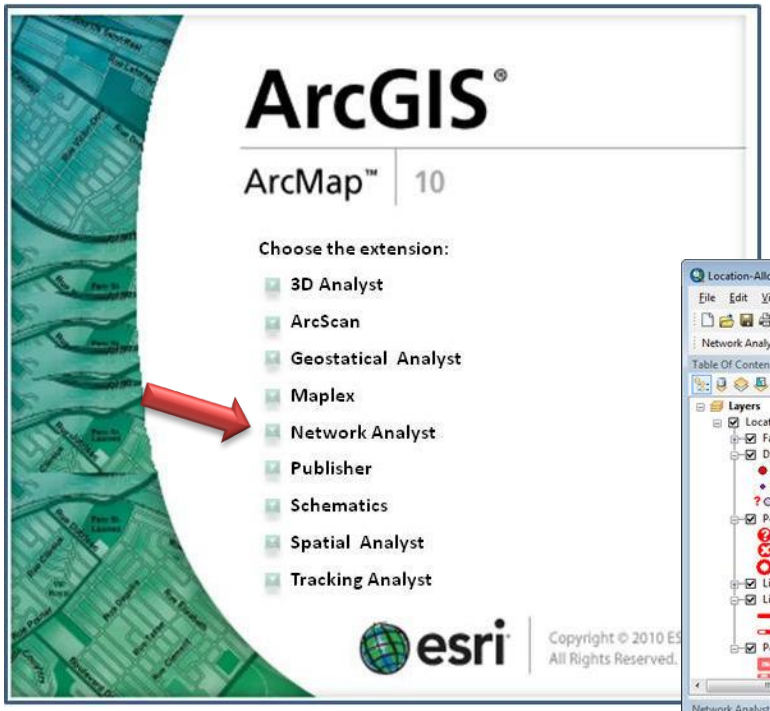


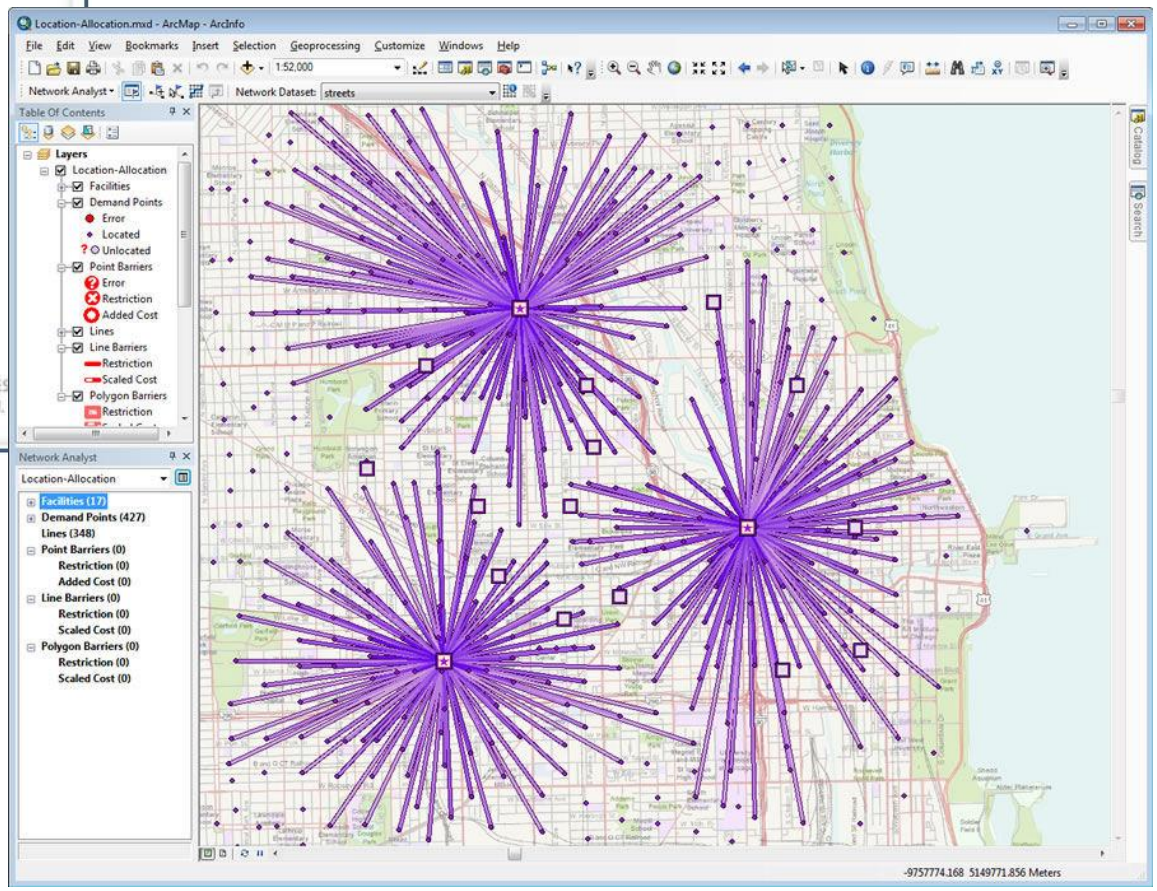


Example: Routes



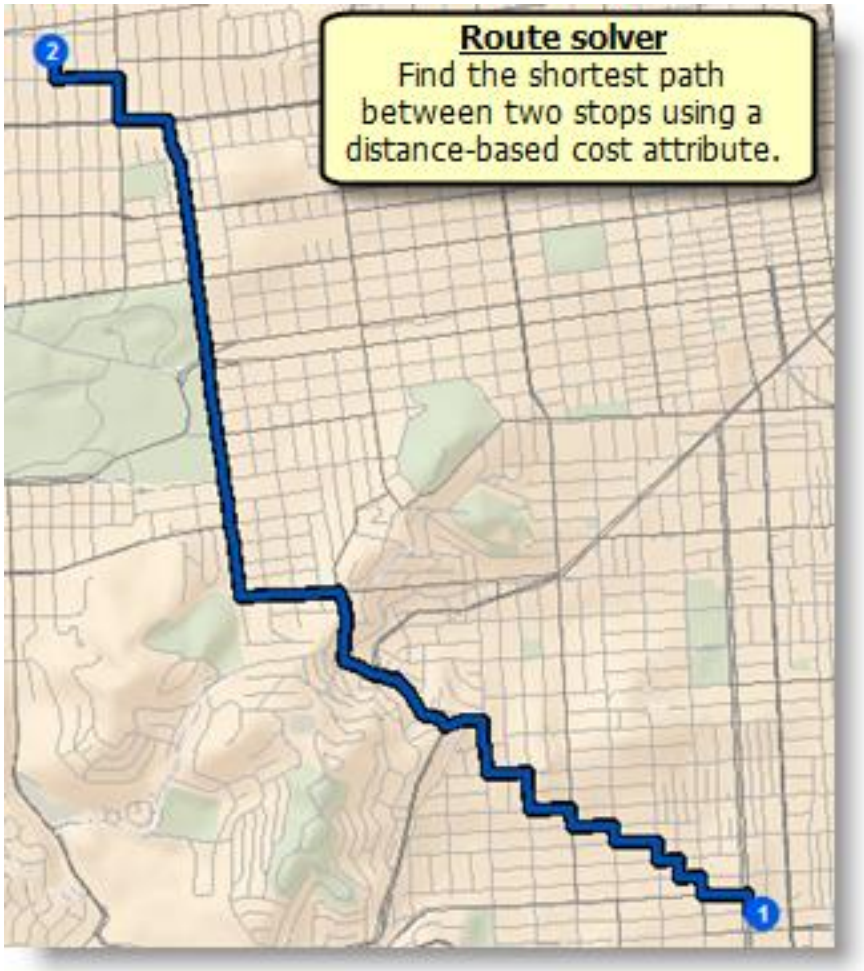
Network Analyst for ArcGIS

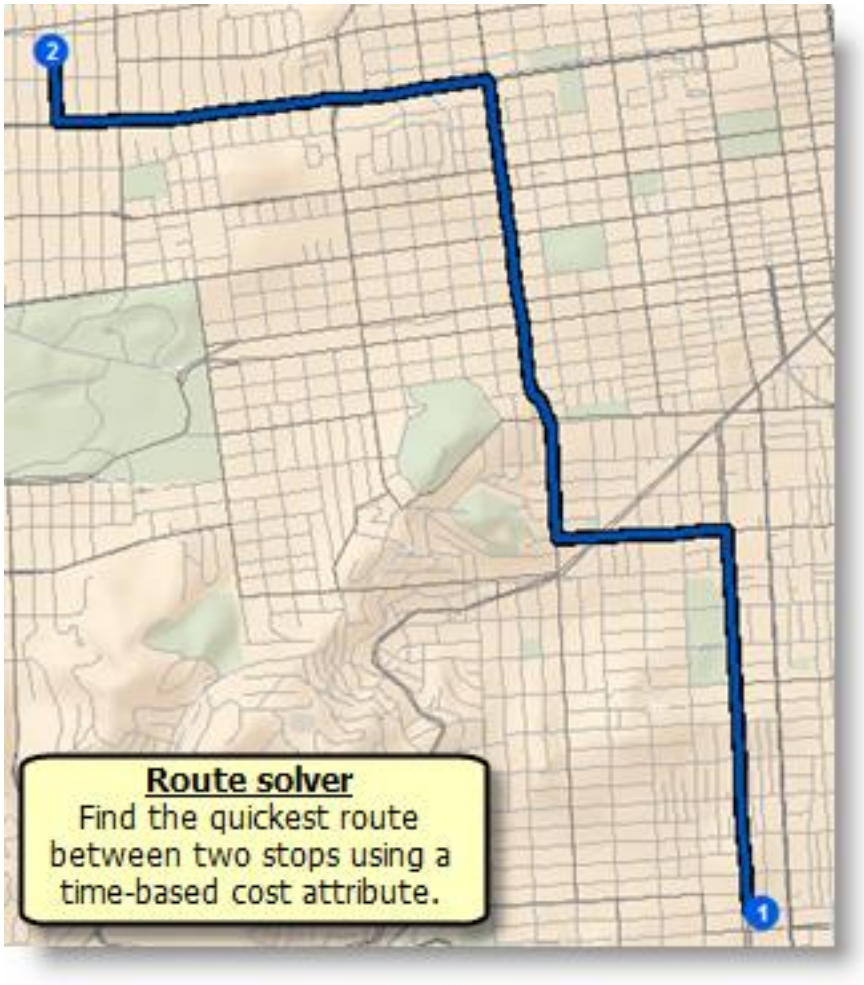




Examples: Routes

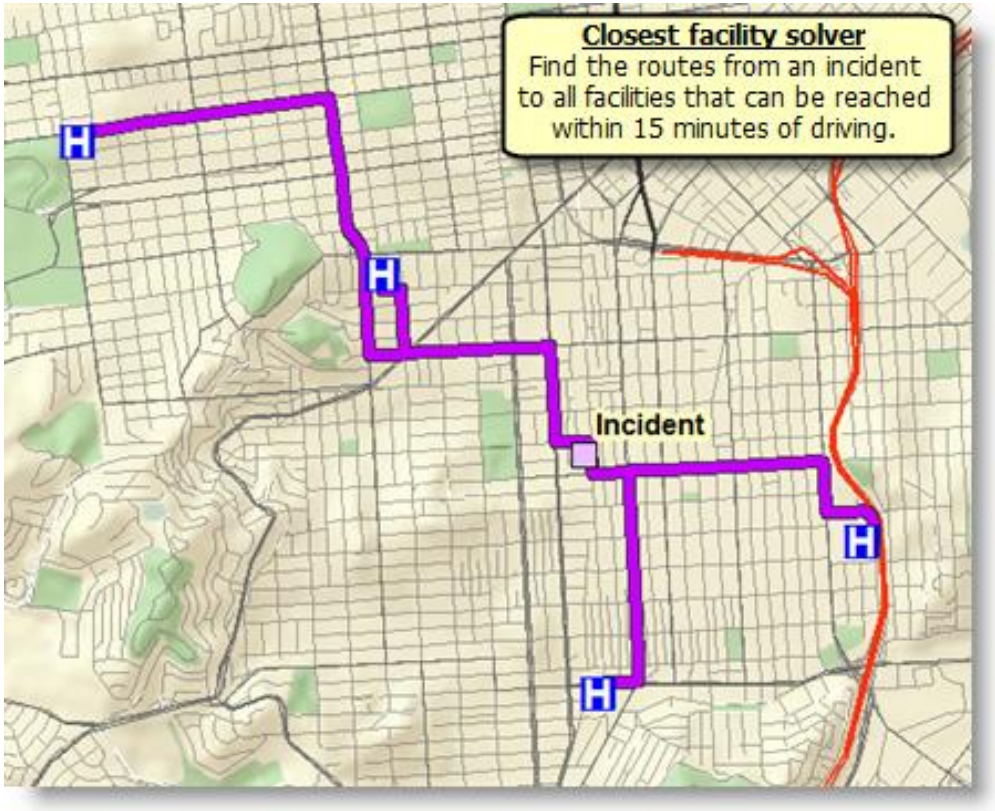
- What is the shortest/quickest way to get from point A to B





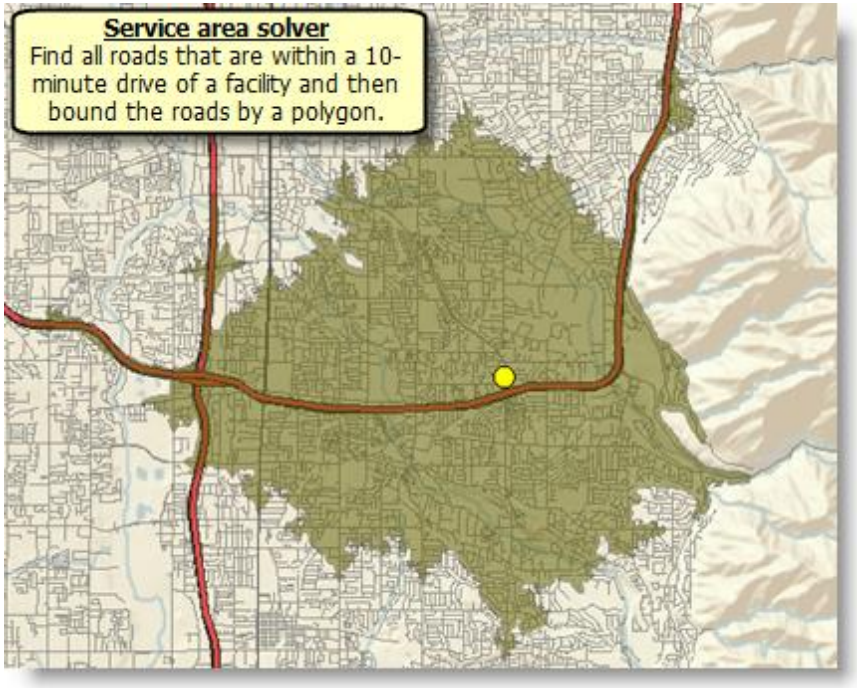
Examples: Closest Facility

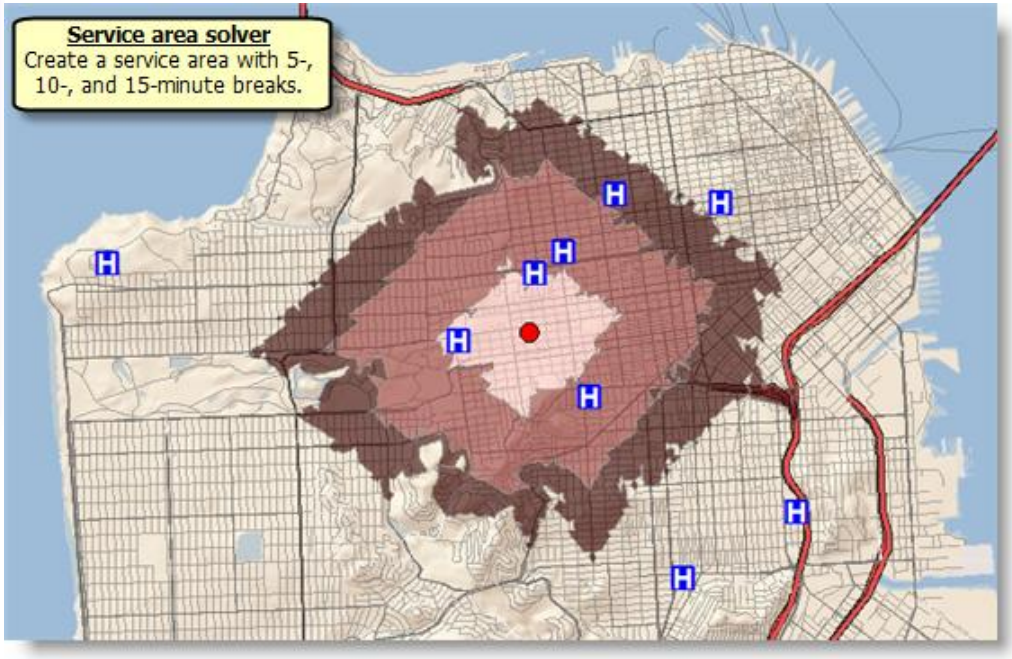
- A person wants to visit a store. Which branch should the potential customer visit to minimize travel time?
- Which ambulances or patrol cars can respond quickest to an incident?



Examples: Service Areas

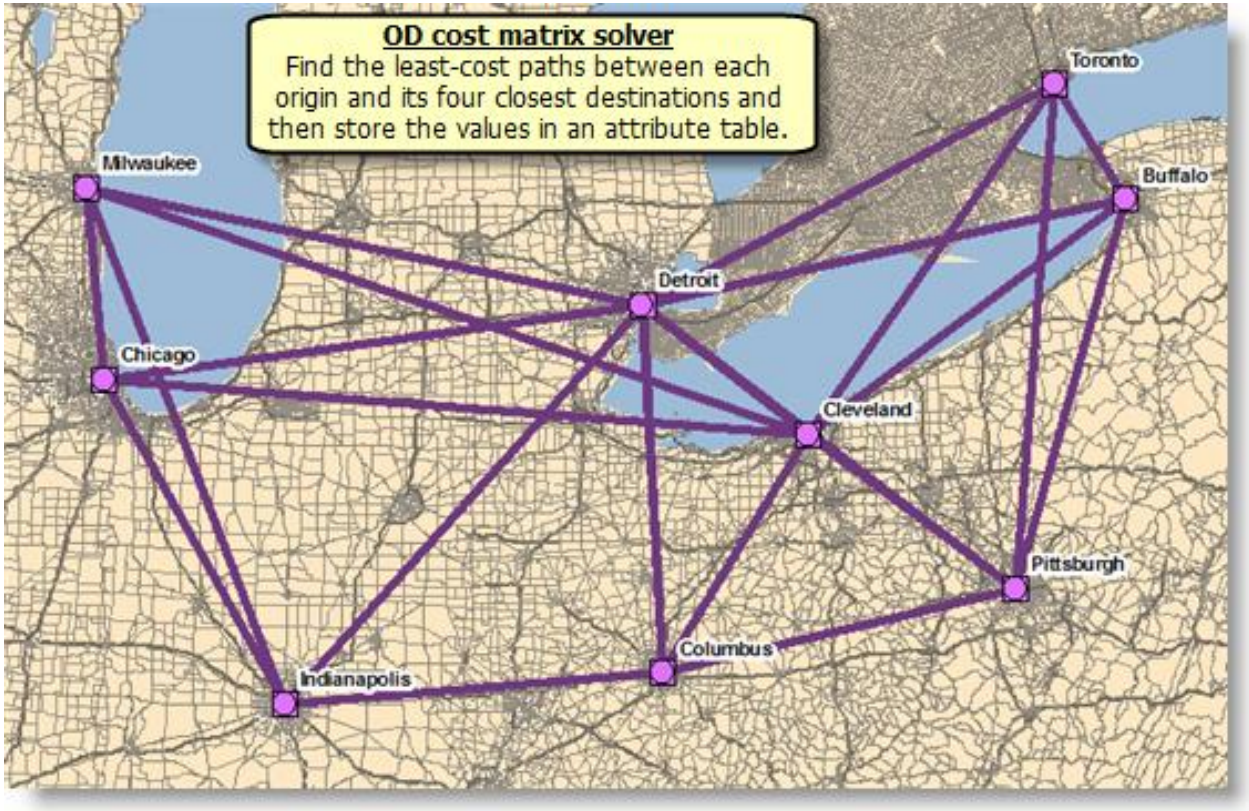
- Which houses are within five minutes of a fire station?
- What market areas does a business cover?





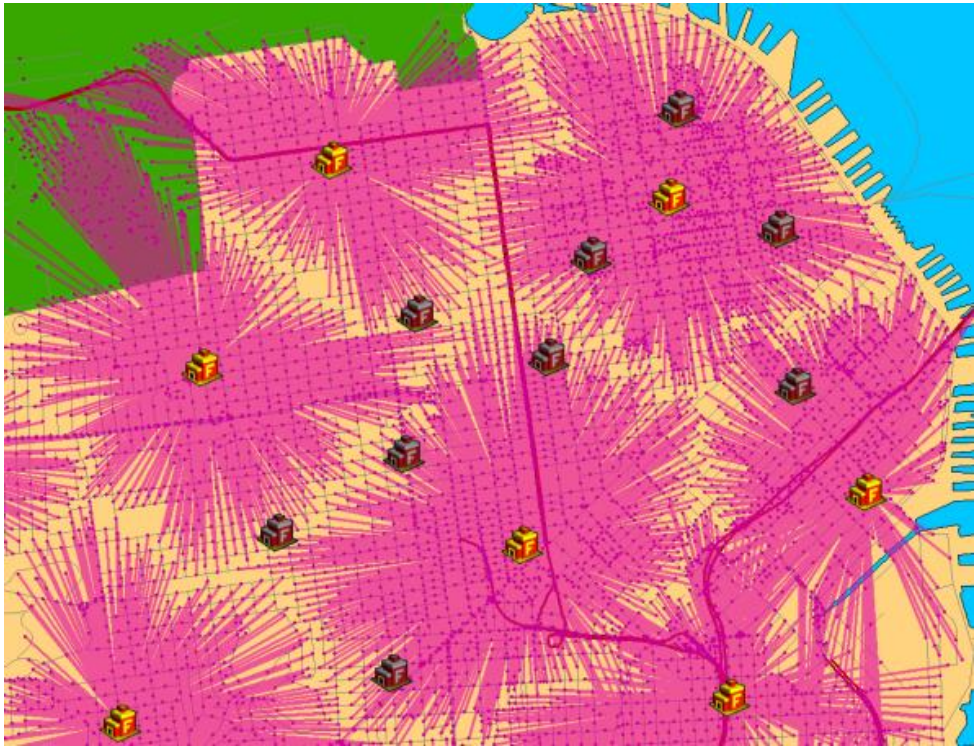
Examples: Cost/Distance Matrix

- List the costs/distances between pairs of origins and destinations…



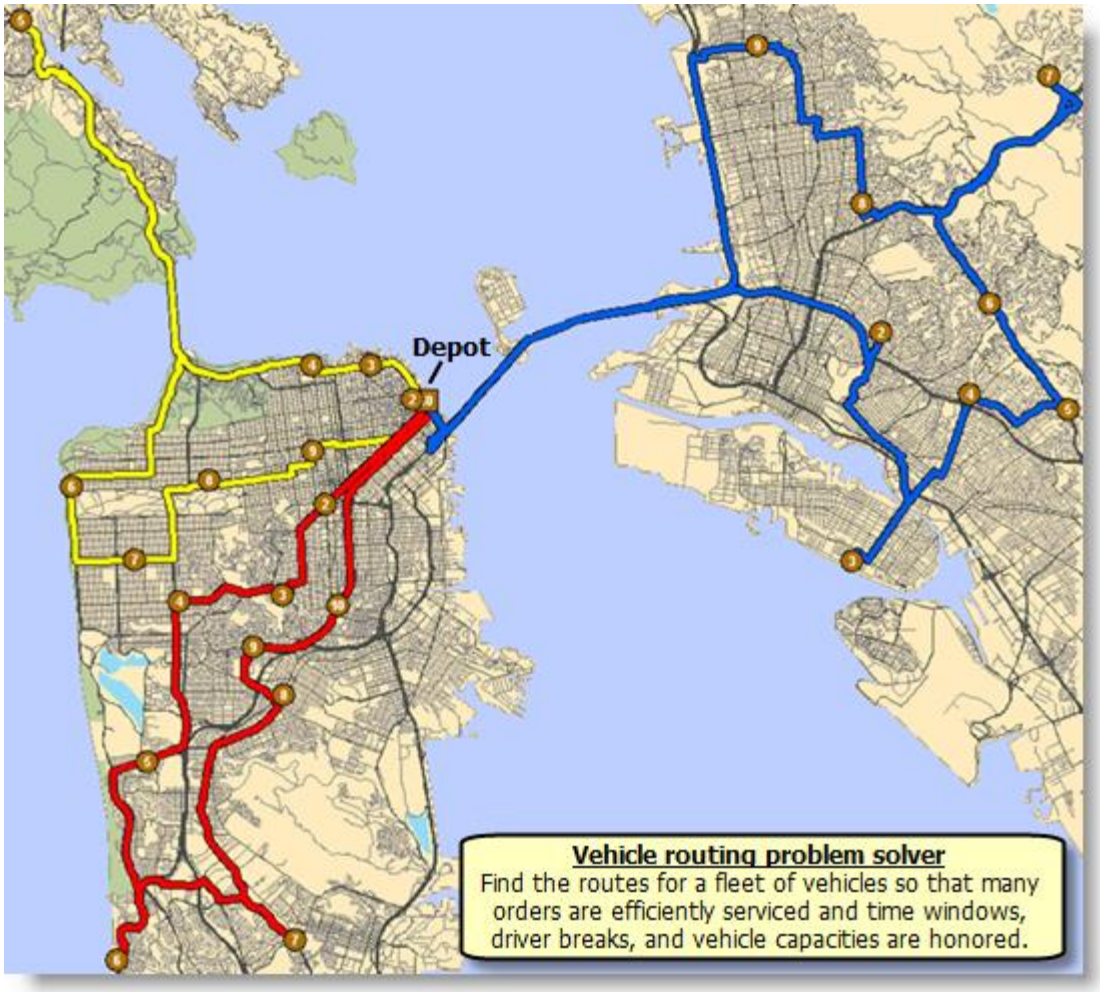
Examples: Location/Allocation

- Given a set of existing fire stations, which site for a new fire station would provide the best response times for the community?
- If a retail company has to downsize, which stores should it close to maintain the most overall demand?

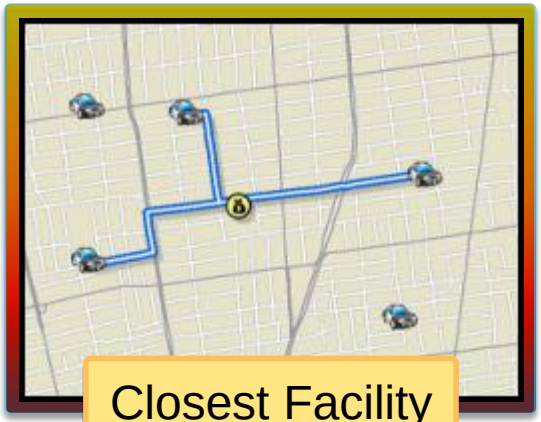


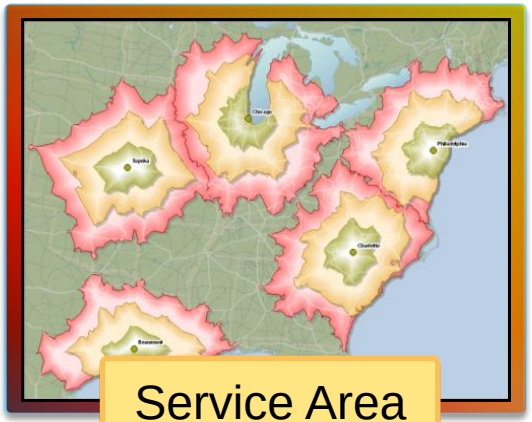
Examples: Vehicle Routing Optimization

- How can a fleet of delivery or service vehicles improve customer service and minimize transportation costs?

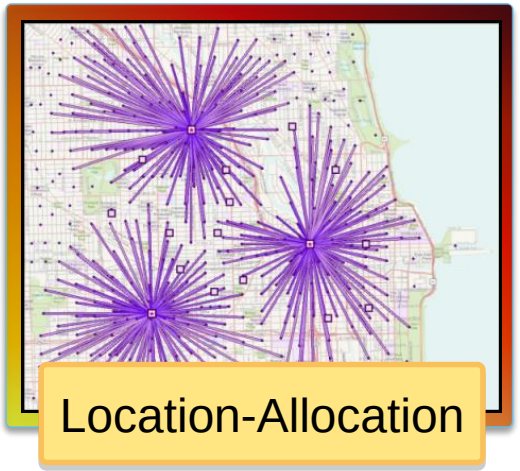


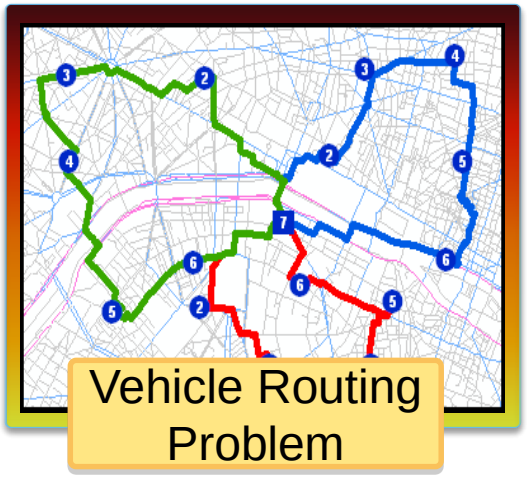
ArcGIS Network Analyst Extension

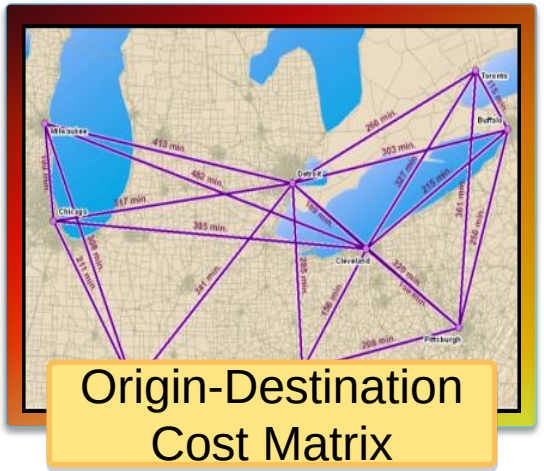




"Solving transportation problems"







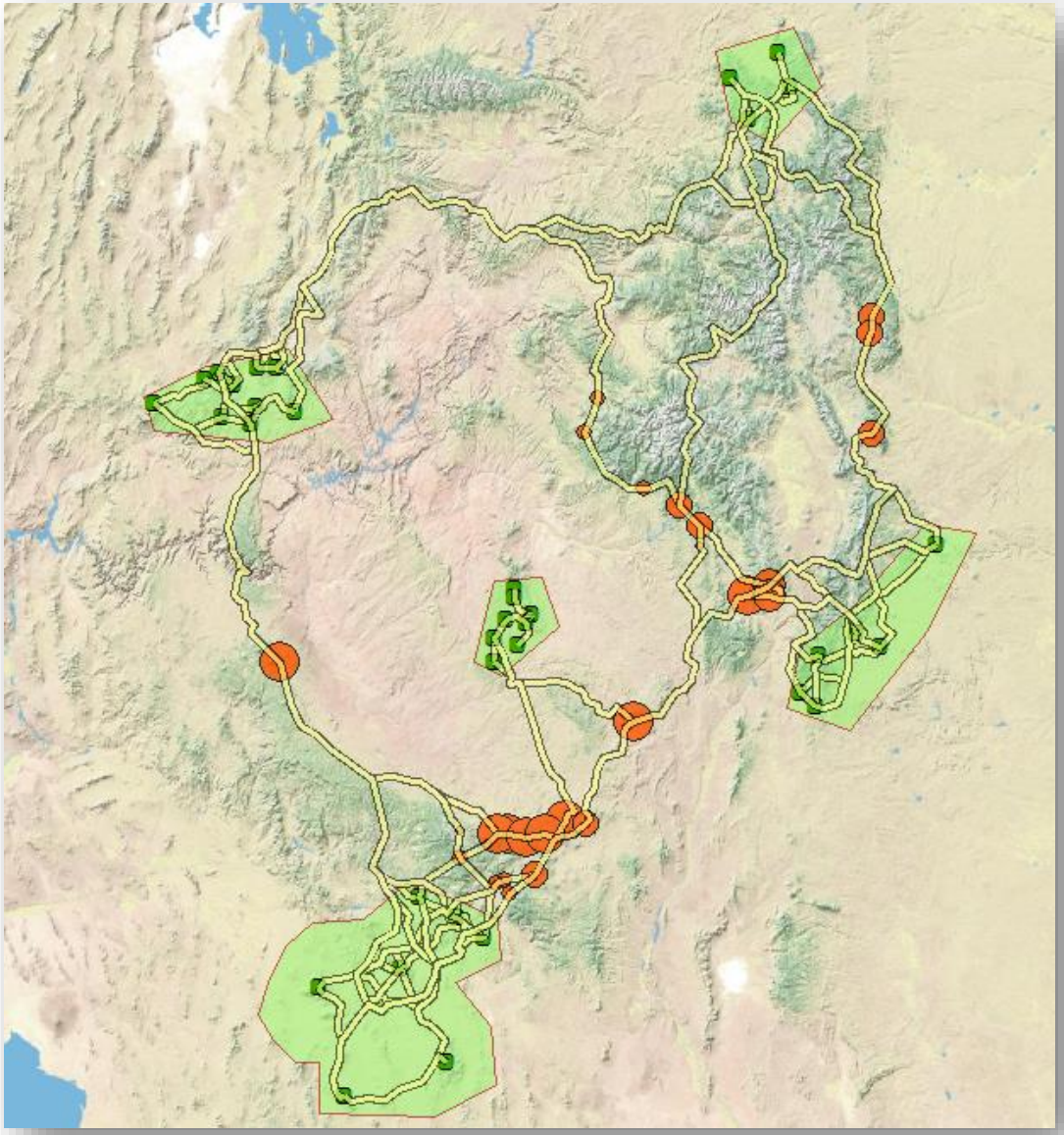
Resource Center » Professional Library » Extensions » Network Analyst » Network analysis

Network analysis for conservation

- Ecohydrology
  - Upstream analysis (alternative to raster-based)
- Connectivity
  - Identifying patch centrality
- Other…
  - Access to parks/recreation centers
  - Food deserts

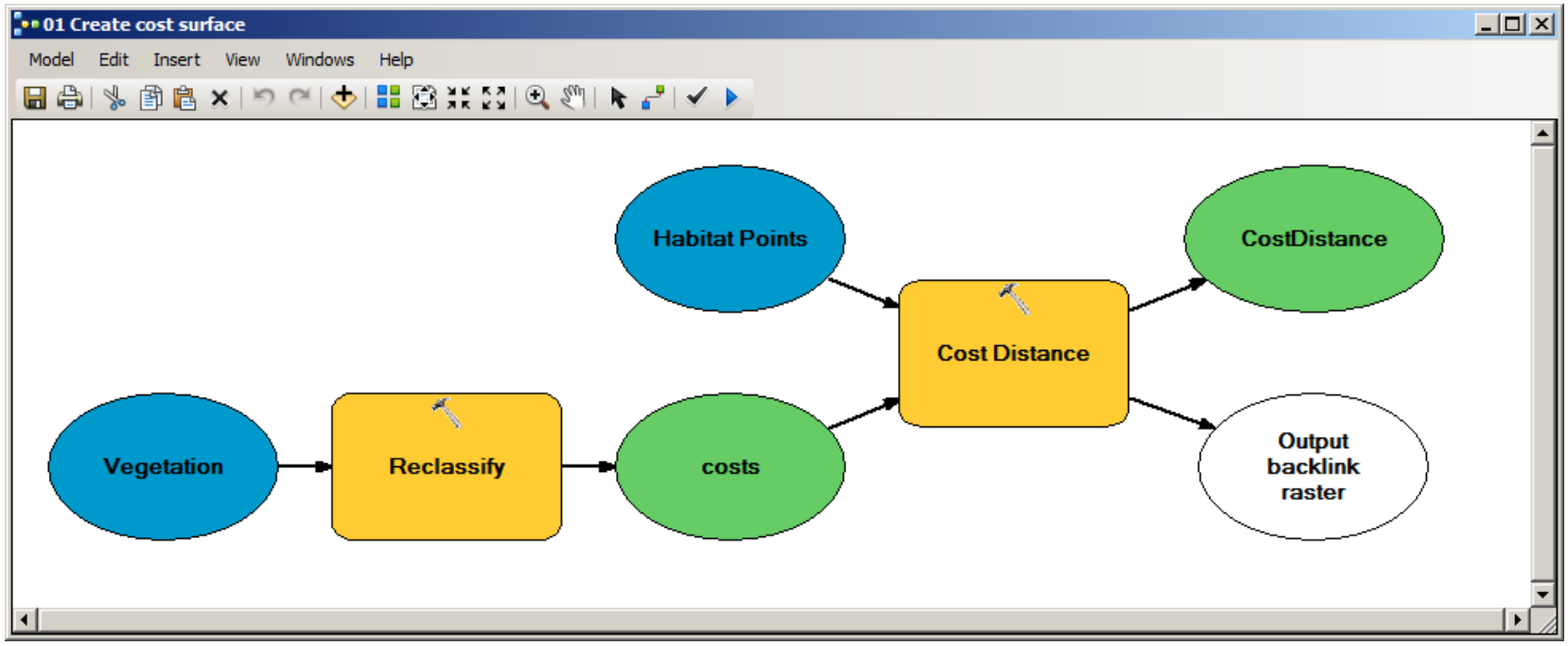
Demo

Network analysis & habitat connectivity



1. Creating a cost surface

- Determine cost (e.g. from land cover)
- Calculate travel away from habitat patches



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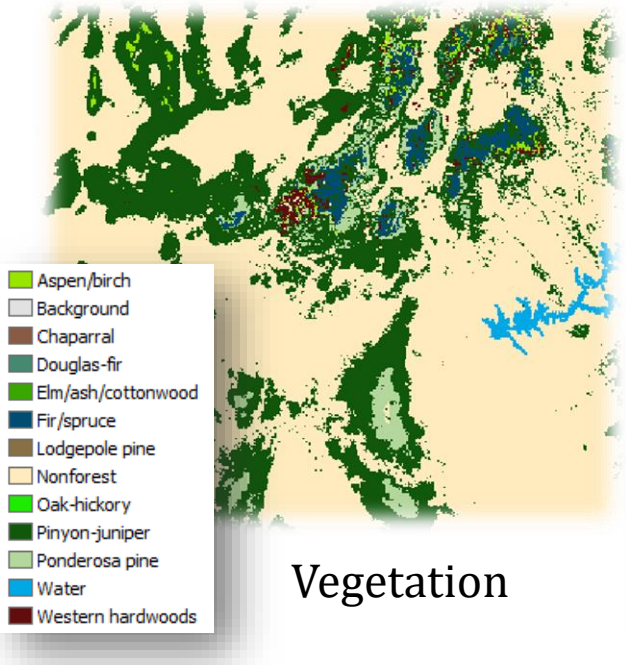
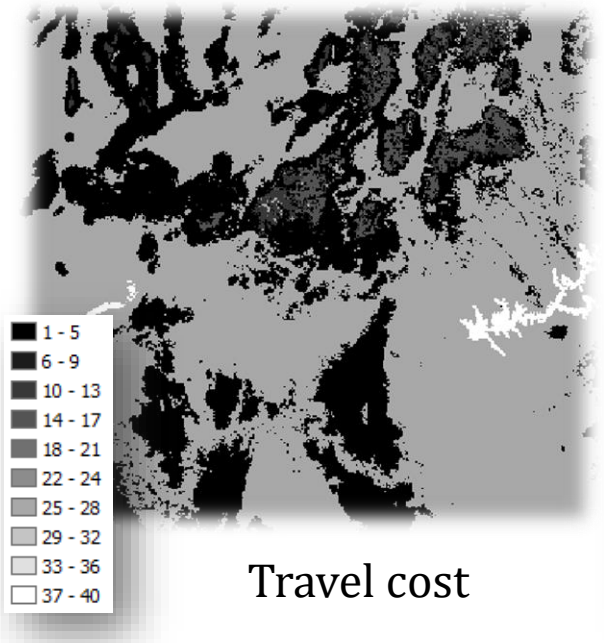
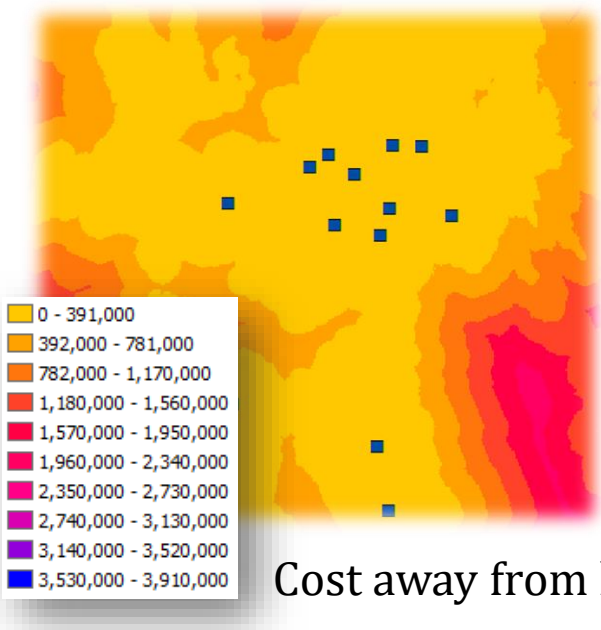


Vegetation



Travel cost

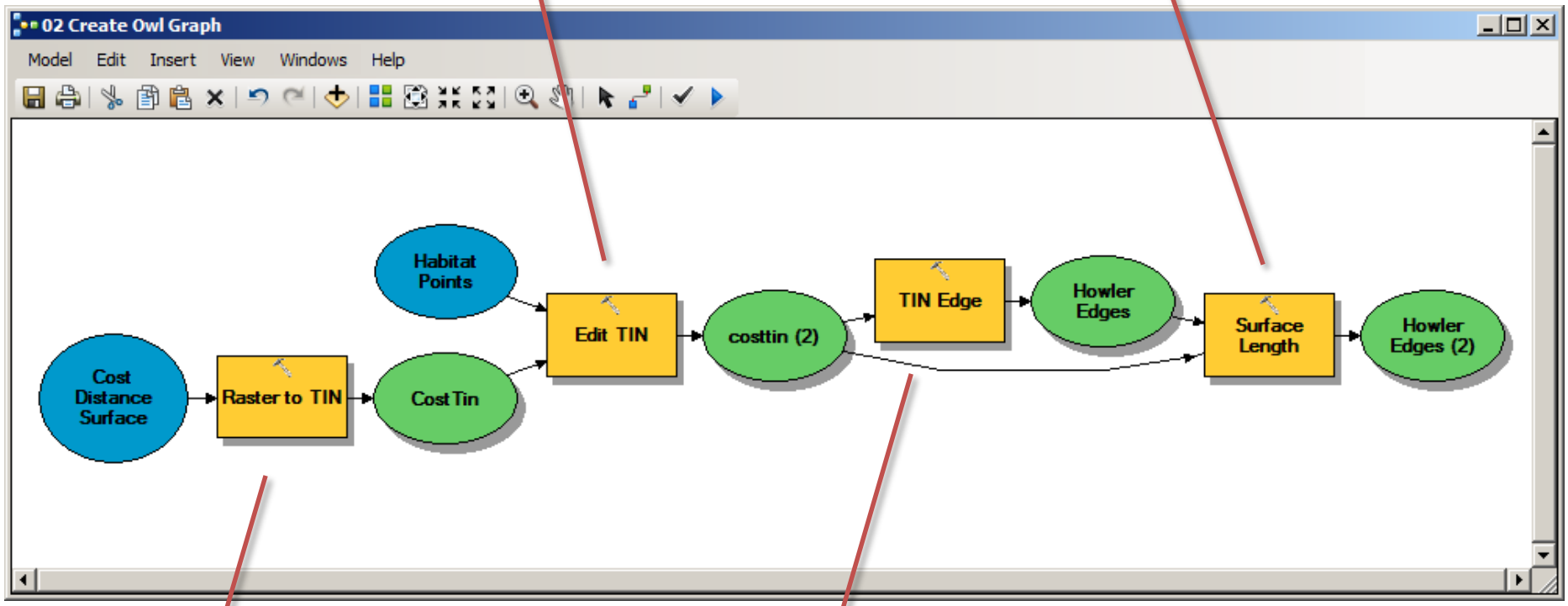


Cost away from ha

2. Creating the graph

"Pin" habitat patch centroids into TIN

Calculate edge cost as "uphill" component of TIN edge



Create TIN from cost distance

Extract edges of TIN as edges for graph

2. Creating the graph

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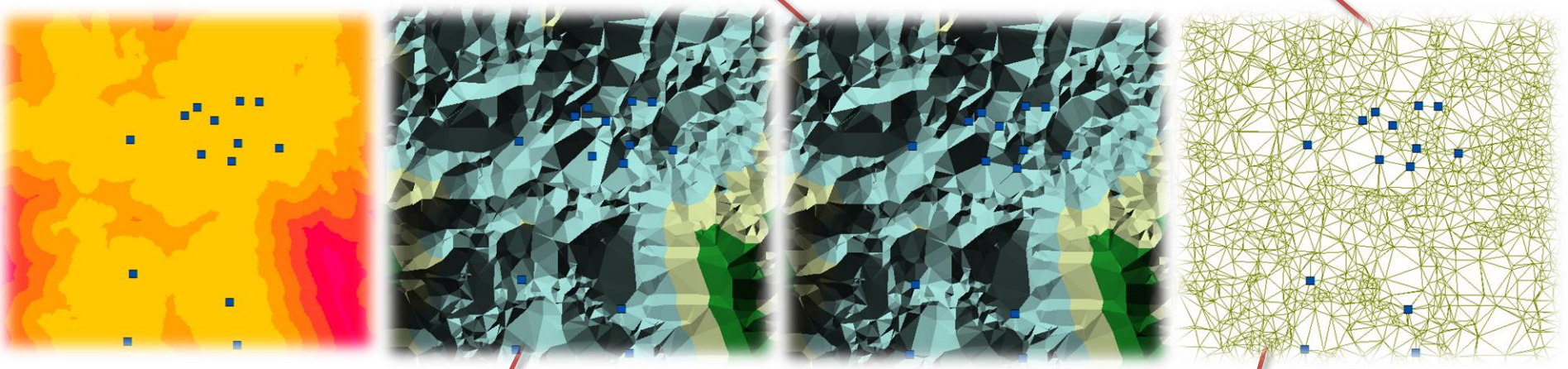
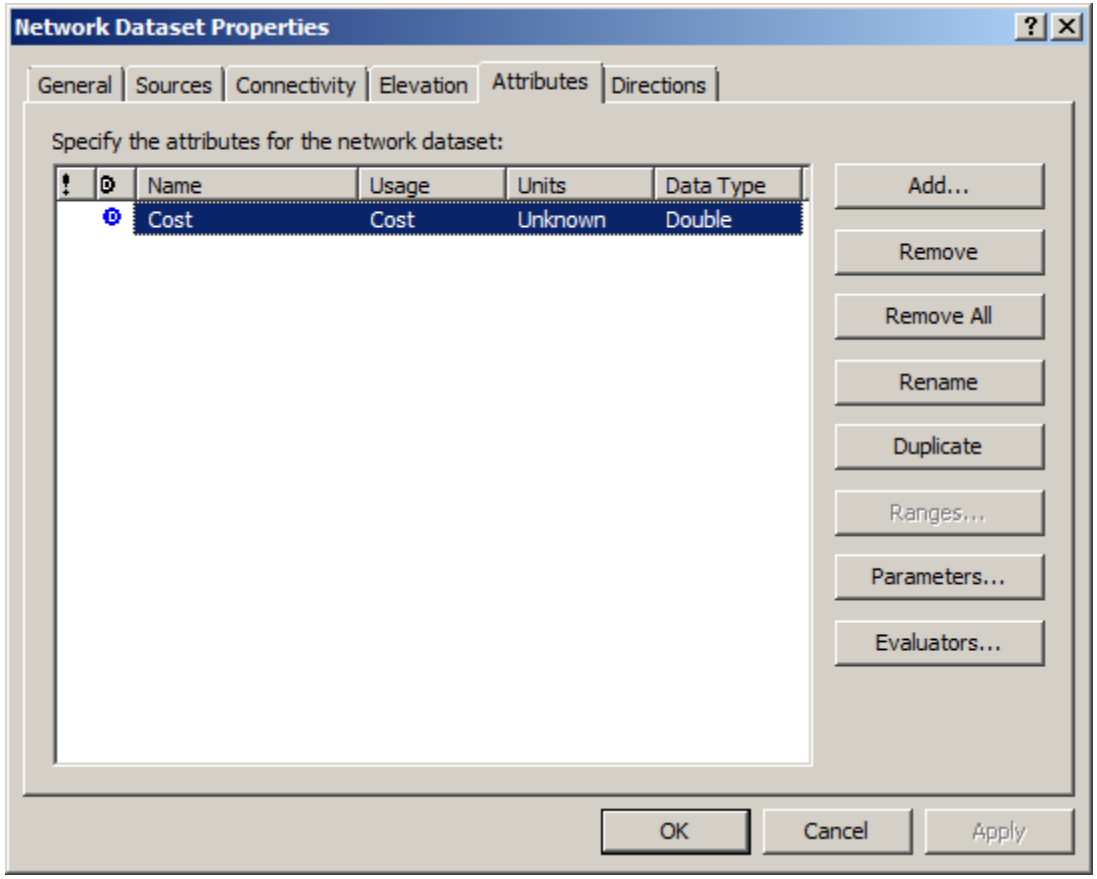
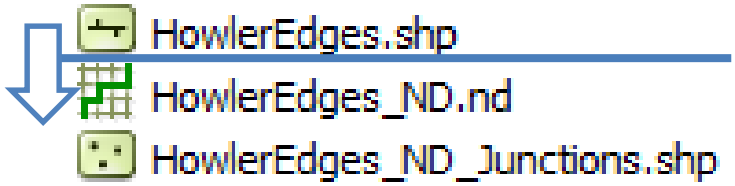


Create TIN from cost distance

Extract edges of TIN as edges for graph

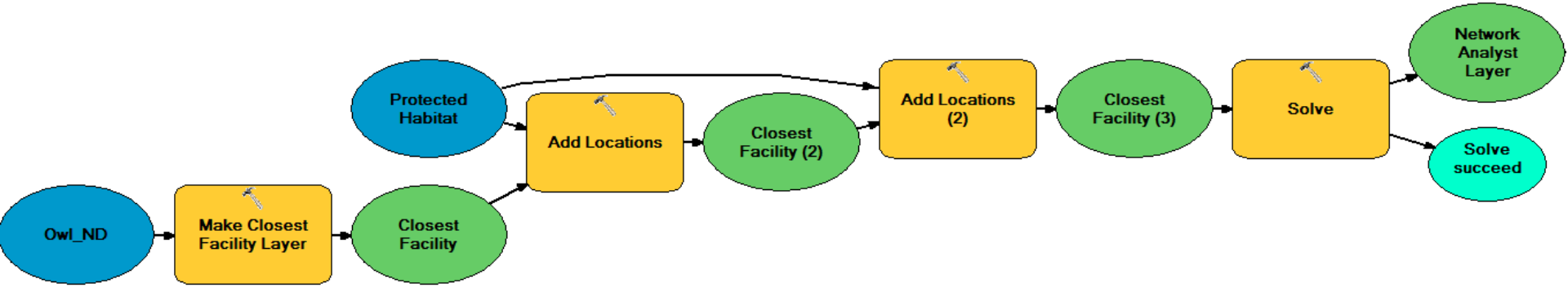
From graph to network dataset



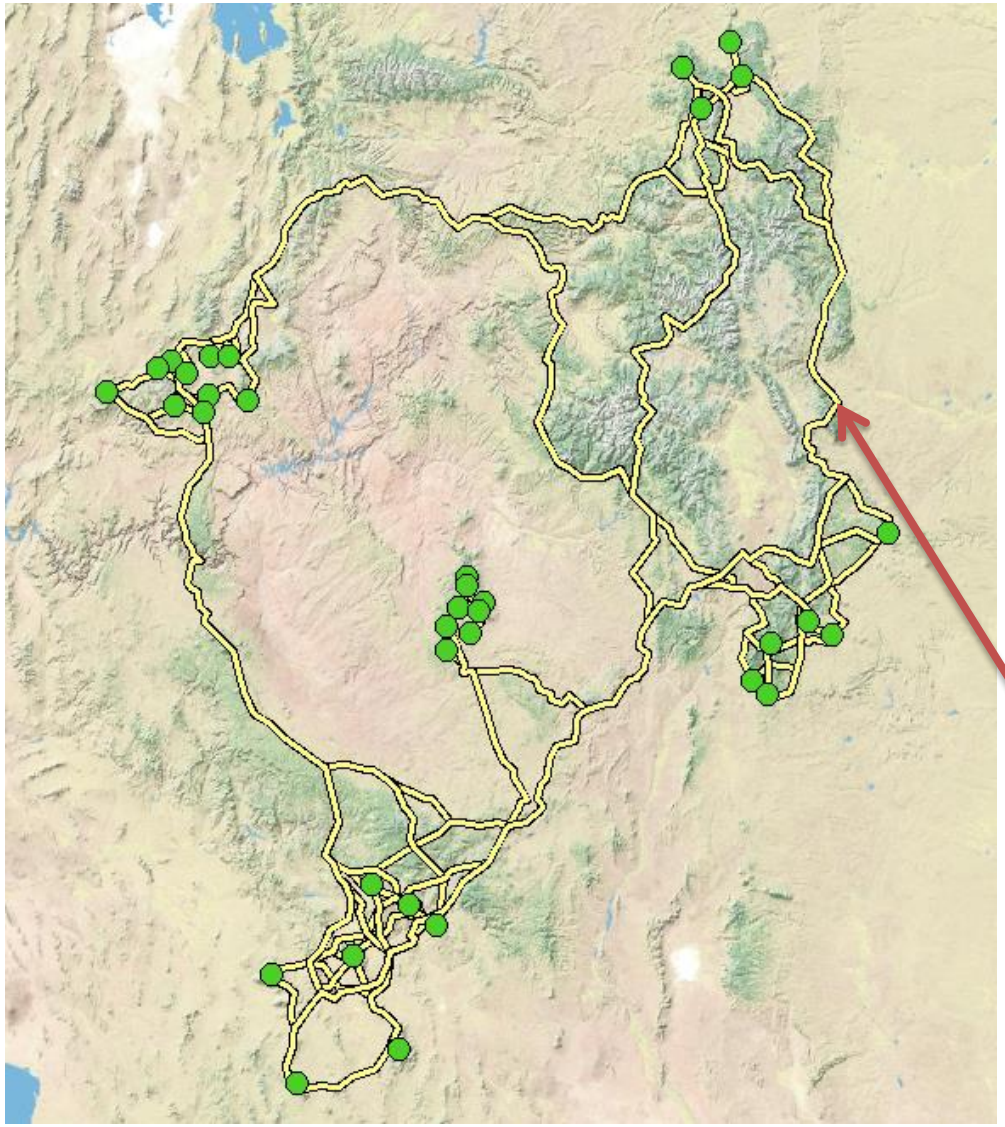


3. Calculating least cost paths

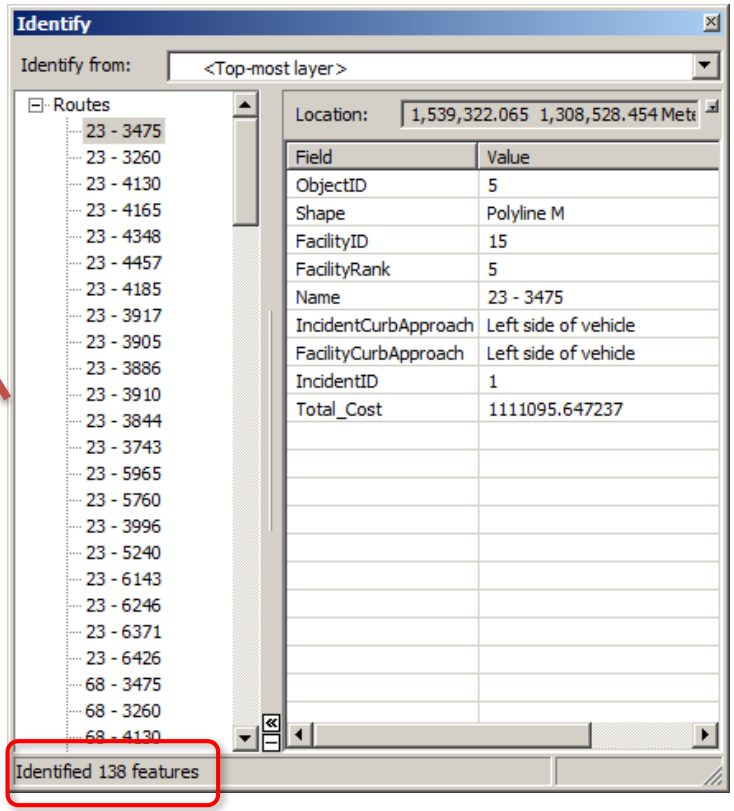
- Create a Closest Facility analysis layer
- Add all sites as both facilities and incidents
- Solve: solution contains least cost paths among all patch pairs



3. Calculating least cost paths

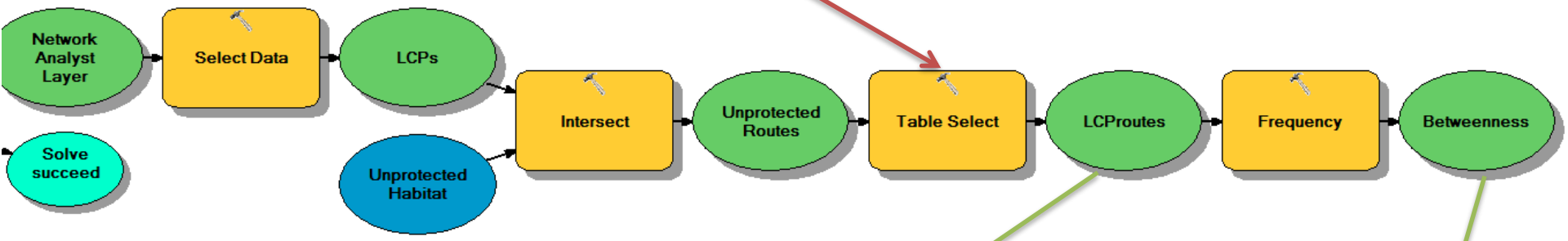


Click on any path to get a list of all the habitat patch pairs that use that path as a least cost pathway among them.



4. Determining betweenness

- Intersect candidate sites with least cost paths
- Count how many times a candidate site appears among all least cost paths
  - *Can omit paths above a cost threshold…*



Table

LCPRoutes

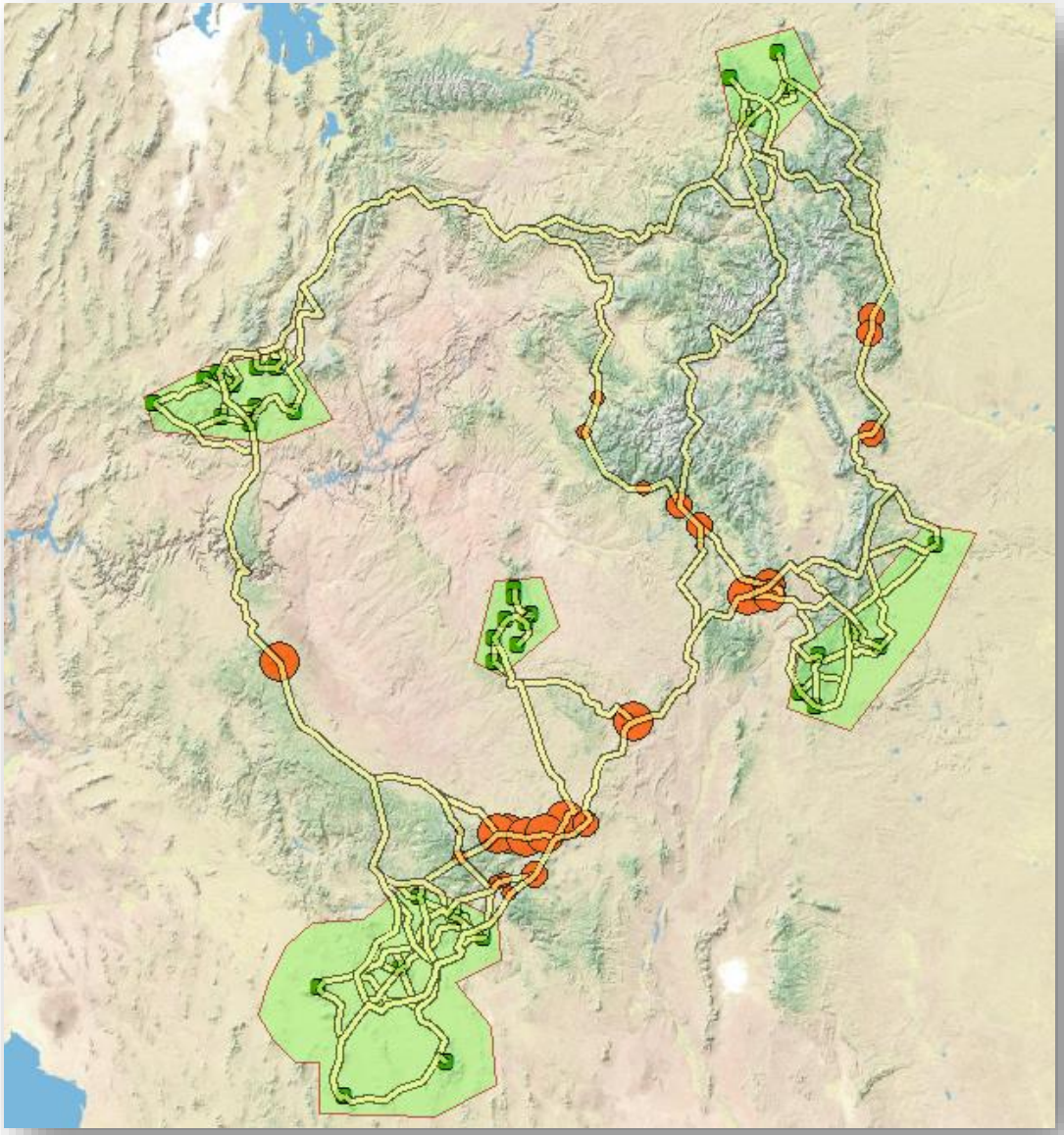
OBJECTID *	FacilityID	Name	IncidentID	Total_Cost	ID	POINT_X	POINT_Y
1	31	23 - 5965	1	2591262.279599	565	1179723	762505.09
2	31	68 - 5965	2	2795583.497655	565	1179723	762505.09
3	31	45 - 5965	3	2556721.032606	565	1179723	762505.09
4	31	411 - 5965	4	2701700.264361	565	1179723	762505.09
5	31	3475 - 5965	15	1649330.631071	565	1179723	762505.09

Table

Betweenness

OBJECTID *	FREQUENCY	ID
1	114	1250
2	114	1886
3	72	2416
4	72	2779
5	114	2862

4. Determining betweenness



Graph theory…

1736

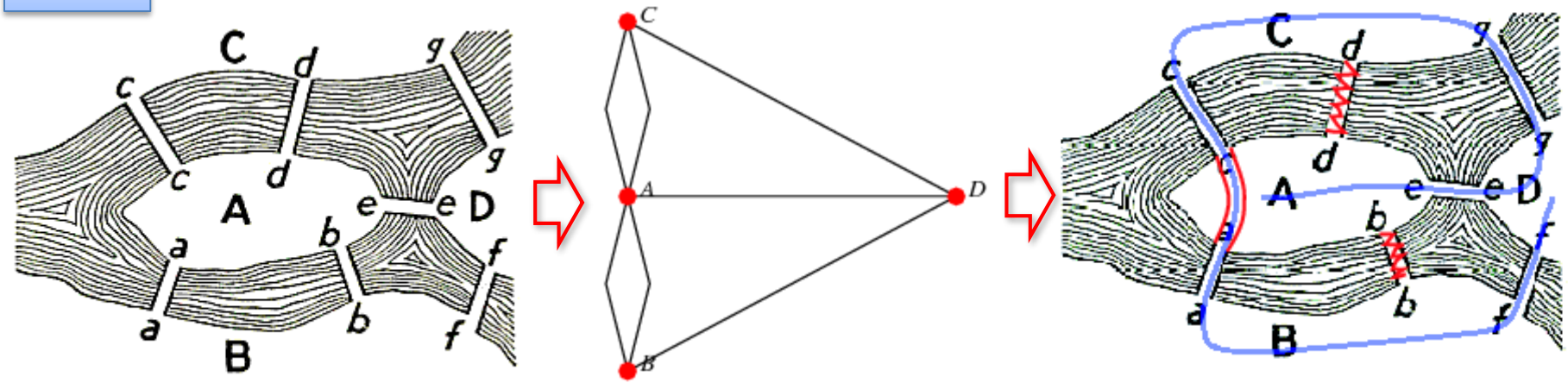


FIGURE 98. *Geographic Map: The Königsberg Bridges.*

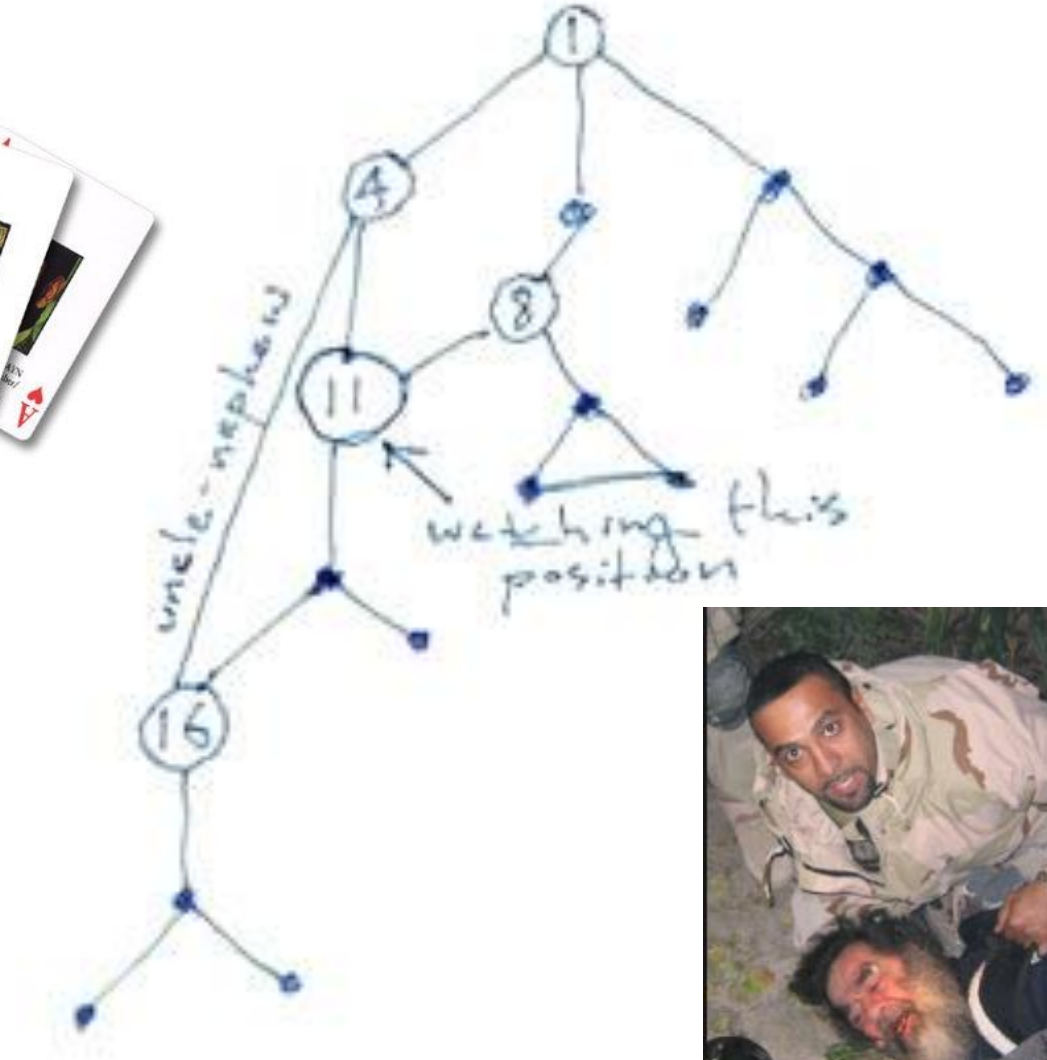
Brain Imaging and Behavior
DOI 10.1007/s11682-016-9528-3

2016

ORIGINAL RESEARCH

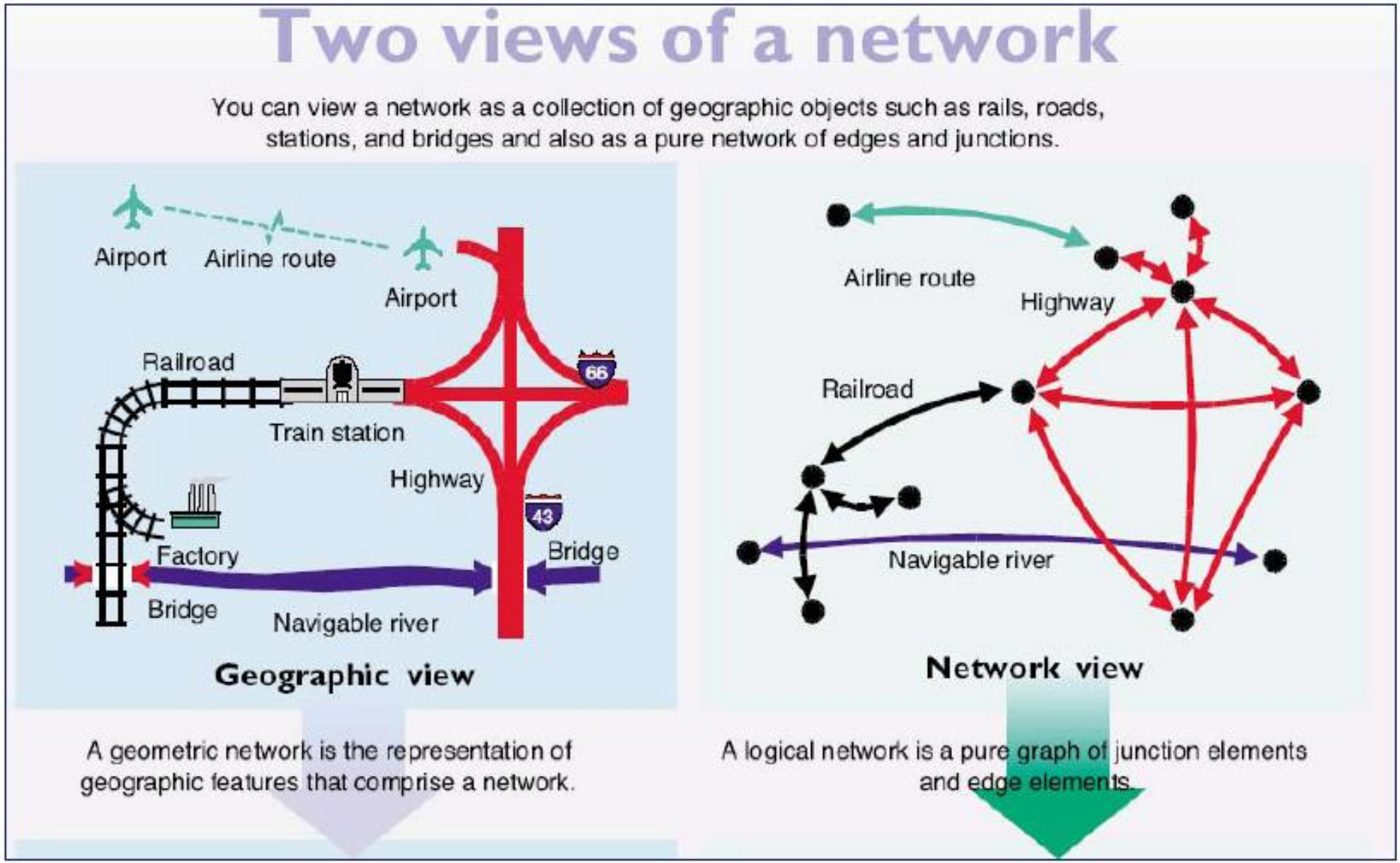
"Small World" architecture in brain connectivity and hippocampal volume in Alzheimer's disease: a study via graph theory from EEG data

Graph theory…

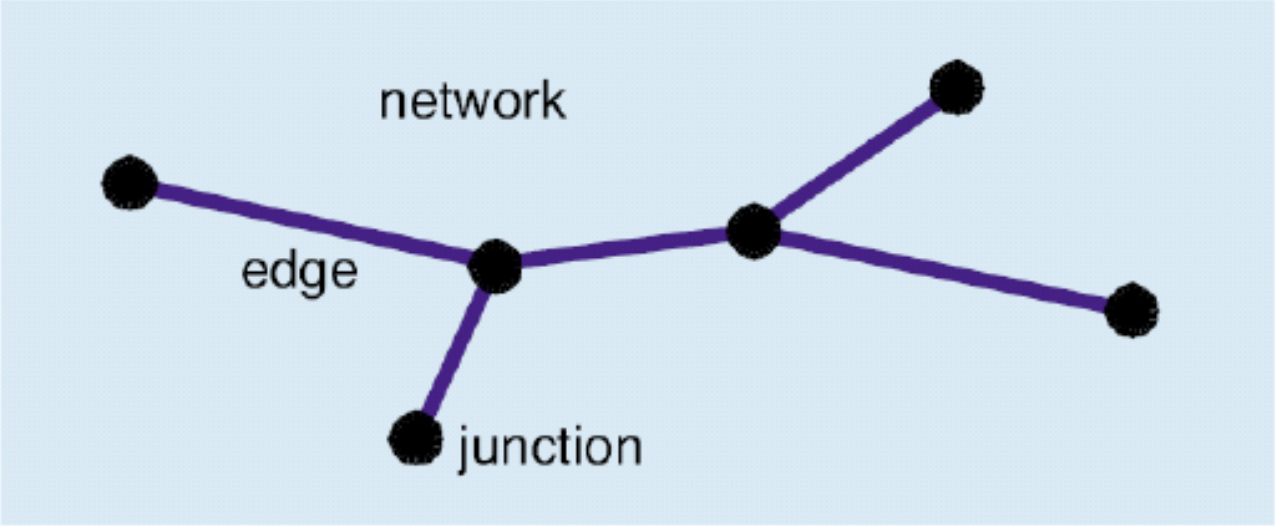


http://www.npr.org/templates/story/story.php?storyId=124052190

How network analysis works

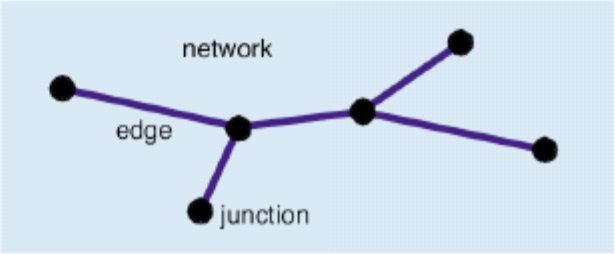


Geometric Networks / Graphs



Edges: linear features (streams, roads, pipes…)
Junctions: intersections (connections, nodes, hubs…)

Geometric Networks / Graphs



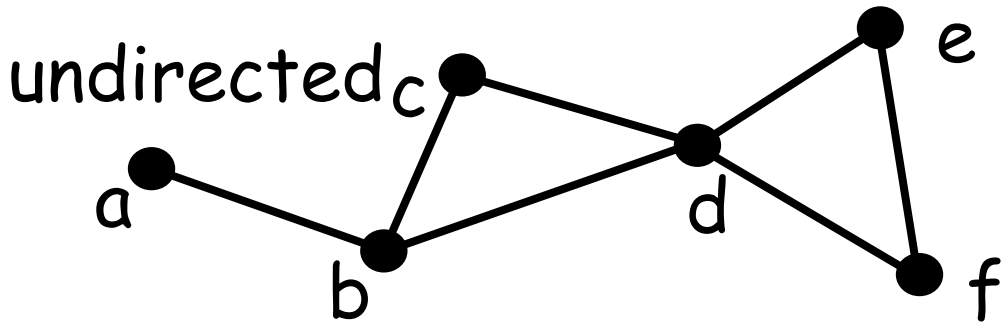
THE GEOMETRIC NETWORK

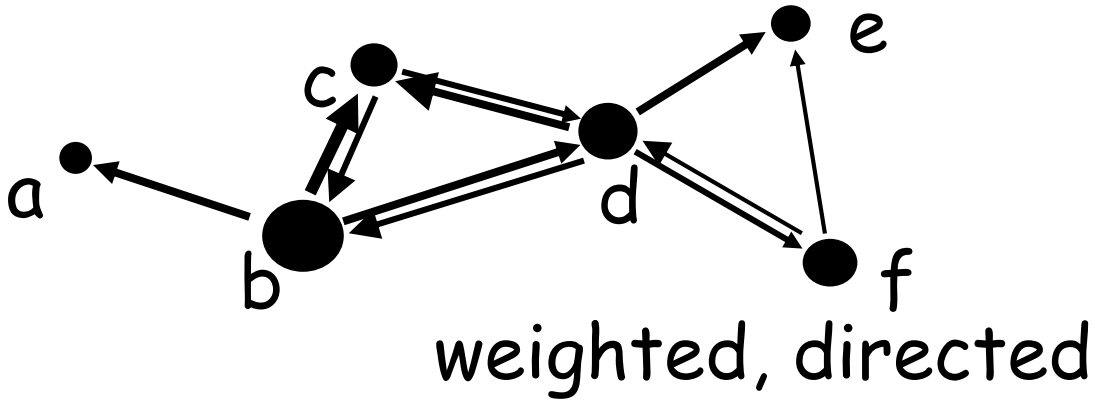
A ***geometric network*** is a collection of features that comprise a connected system of *edges* and *junctions*. An edge has two junctions and a junction can be connected to any number of edges.

Edge ***features*** can cross in two-dimensional space without intersecting. An example is a bridge over a road. This is called *nonplanarity*.

Edge attributes

- Directionality
- Cost/weights





Direction/weights affect connectivity and shortest path…

Cost attributes: Edges

Best Route: 8:00 a.m.

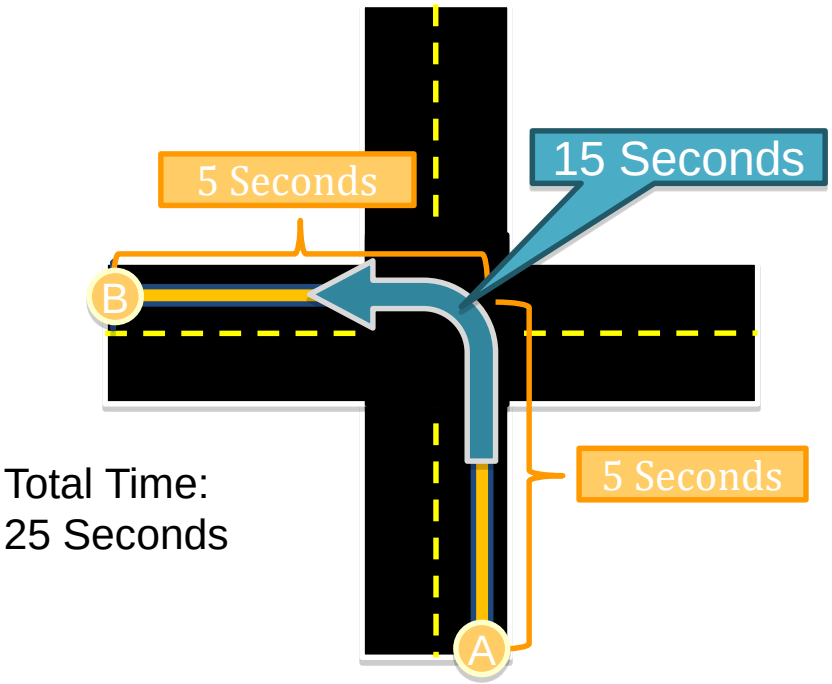
Best Route: 6:00 p.m.

- If cost = *distance*, then you are finding the <u>shortest</u> path...

- If cost = *time*, then you are finding the <u>fastest</u> path…

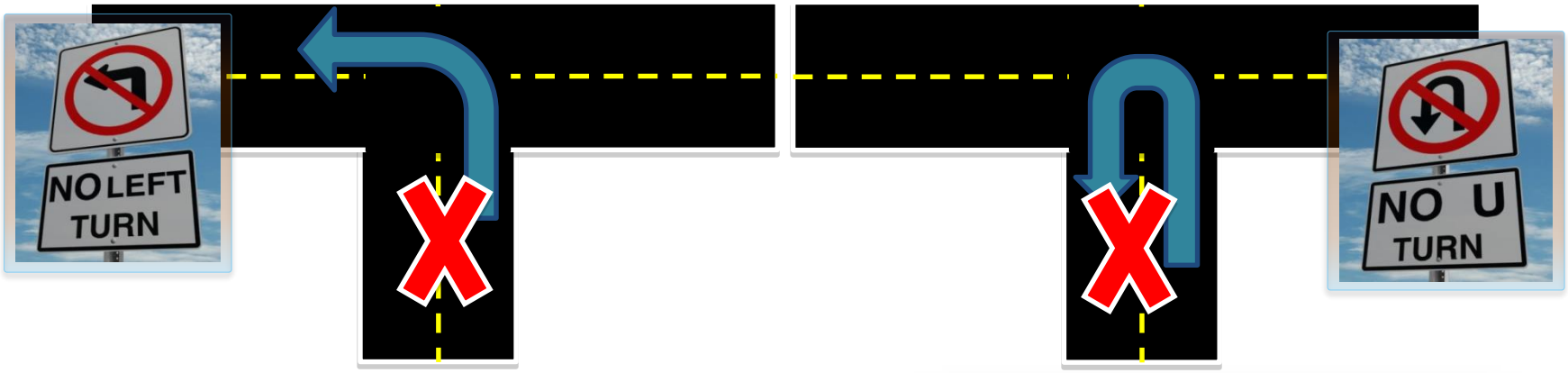
Cost attributes: nodes

- Turn Delays
  - Add cost to a specific turn



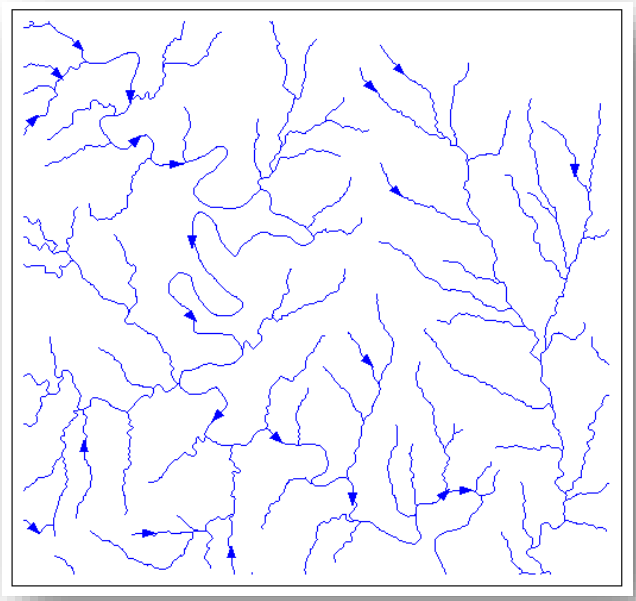
http://www.wired.com/autopia/2007/12/no-left-turn-so/

Restriction attributes



Restrictions allow *directionality*

- Turn restrictions…
- One-way streets…
- Flow in stream networks…



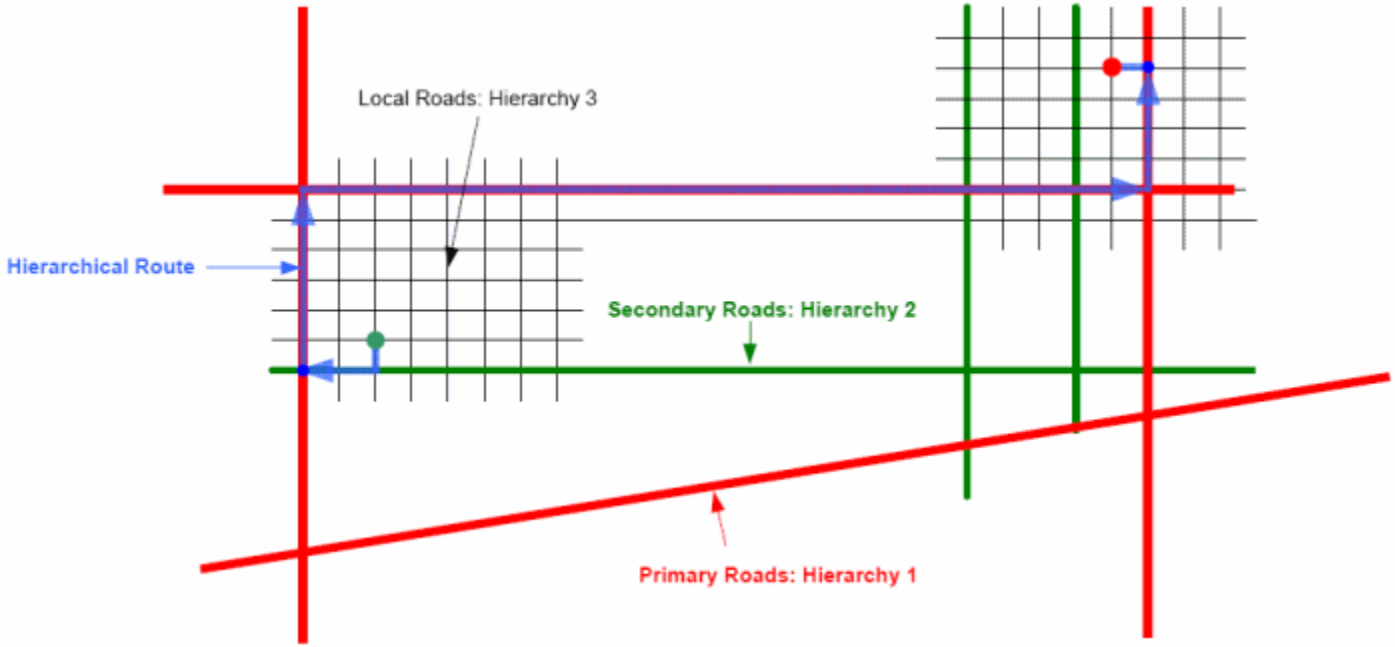
Descriptors attributes

Descriptors are node/edge attributes that describe characteristics of the network or its elements.

Descriptors might be used in conjunction with distance to calculate costs. (Or not…)

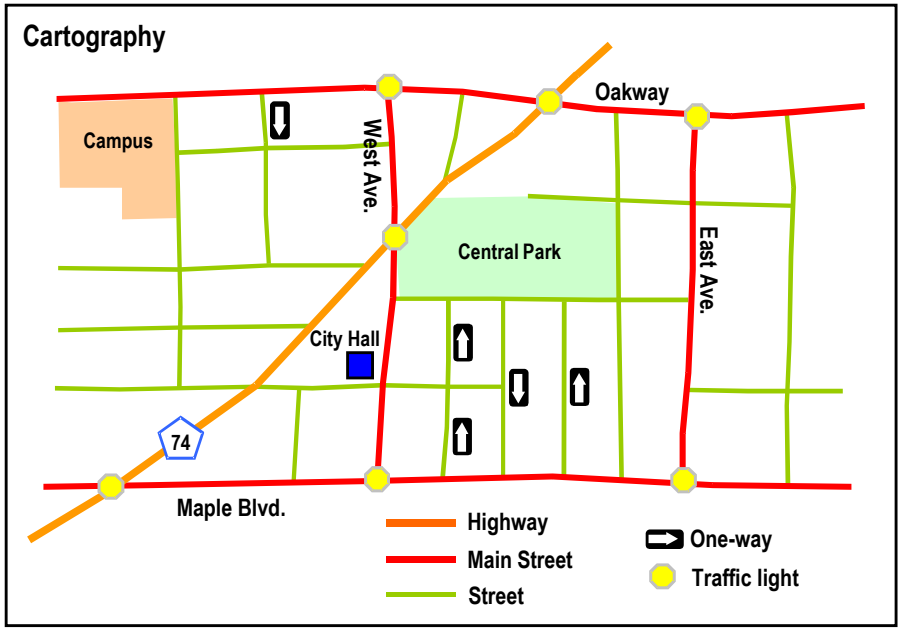
Edge Attributes: Hierarchies

Assigning edge hierarchies allows for questions like “What’s the fastest way to get from Durham to Beaufort *without using the Interstate*?”

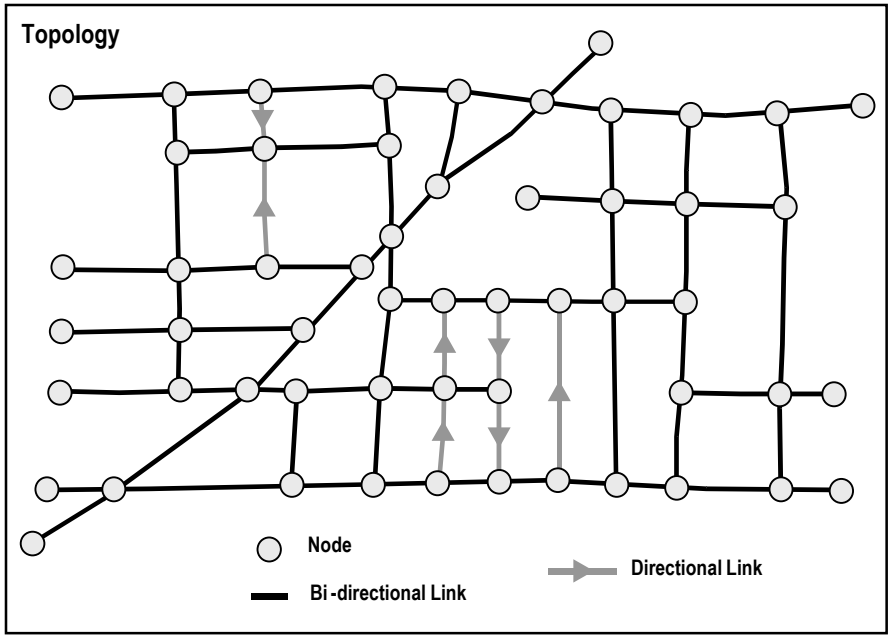


How Network Analysis Works

Cartography of a Network Data Model



Topology of a Network Data Model



Edge attributes
Junction attributes

Review

- Network analysis computes cumulative cost along a set of edges connected at junctions.
- Edge and node attributes can be used to optimize routes under different criteria:
  - Costs, restrictions, descriptors, hierarchies
- Results from network analysis can include:
  - Routes (and directions)
  - Service areas
  - Origin-destination mapping
  - Edge-list creation