GEOG653 – Spatial Analysis

Lecture 6

1

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Outline

- Updates
- Network Analysis
  - Part I
    - Overview
    - Routing Analysis
    - Service Area Analysis
  - Part II
    - Closest Facility Analysis
    - OD Cost Matrix Analysis
    - Location-Allocation Analysis
  - Network Analysis with Different Platforms
    - ArcMap, ArcGIS Pro, ArcGIS Online

Updates

- Office Hours
- Updates on ELMS
- Labs
- Exercises

Network Analysis

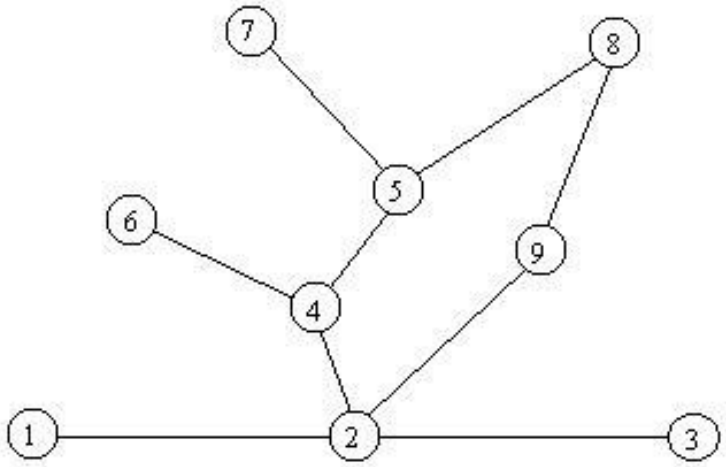
- Overview
  - Network analysis is used for identifying the most efficient routes or paths for allocation of services.
    - It involves finding the shortest or least-cost manner in which to visit a location or a set of locations in a network.
      - The "cost" in a network analysis is mostly distance or travel time.
    - Network analysis can also be used to optimize the allocation of resources.

Network Analysis

- Overview
  - What is a network?
    - An interconnected set of points and lines that represent possible routes from one location to another.
    - A network is a system of interconnected elements, such as lines connecting points.

Network Analysis

- Overview
  - Elements of a network:
    - Vertices/Junctions (i.e. points)
    - Segments/Edges (i.e. lines)
  - These elements must be interconnected to allow navigation over the network.



Network Analysis

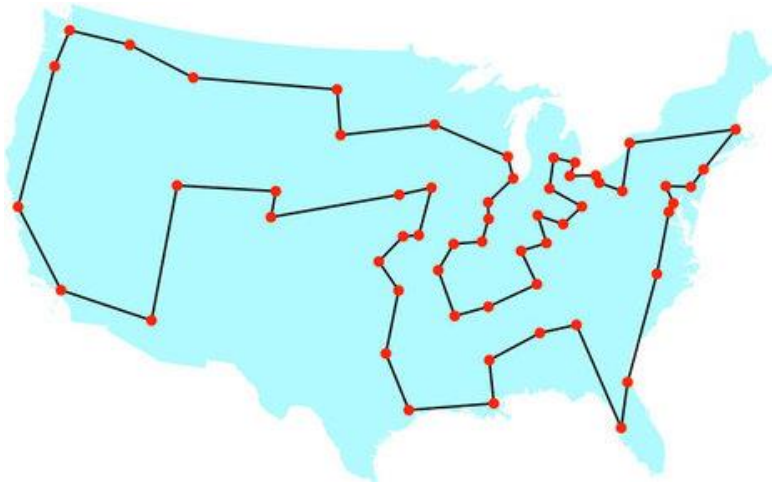
- Overview
  - The focus of network analysis is on connectivity:
    - How different segments (lines) are linked together.
    - How these segments (lines) are related to each other.
  - The connectivity is critical for any network analysis.

Network Analysis

- Overview
  - The most essential attribute of a network is how different links are connected to each other.
    - The connectivity matrix describe quantitatively how different links are joined together.
    - The analysis of the network must rely on the connectivity attribute.
  - Types of problems and questions we can ask
    - What is the shortest route between 2 cities?
    - What is the shortest route between 20 cities?

Network Analysis

- Overview
  - Traveling Salesman Problem (TSP)
    - Famous problem in computer science / graph theory
    - Given a list of cities and the distances between them, what is the shortest route that visits them all?
    - Each city can only be visited once
    - Must make a complete loop
    - Computation time increases exponentially with # cities



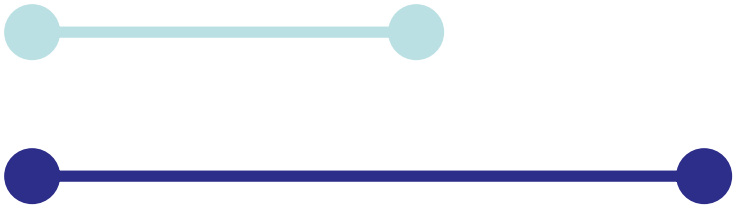
http://www.nytimes.com/interactive/2012/03/01/theater/201203-death-of-a-salesman-interactive.html

Network Analysis

- Overview
  - Connectivity
    - High Connectivity
      - Low Isolation, High Accessibility
      - Few Nodes, Many Links
    - Low Connectivity
      - High Isolation, Low Accessibility
      - Many Nodes, Few Links
    - A measure of accessibility without regard to distance
    - Areas of high connectivity are often considered important in that they are more accessible

Network Analysis

- Overview
  - Connectivity
    - Connectivity is based on topological distance
    - Topological Distance – The number of direct connections separating two nodes



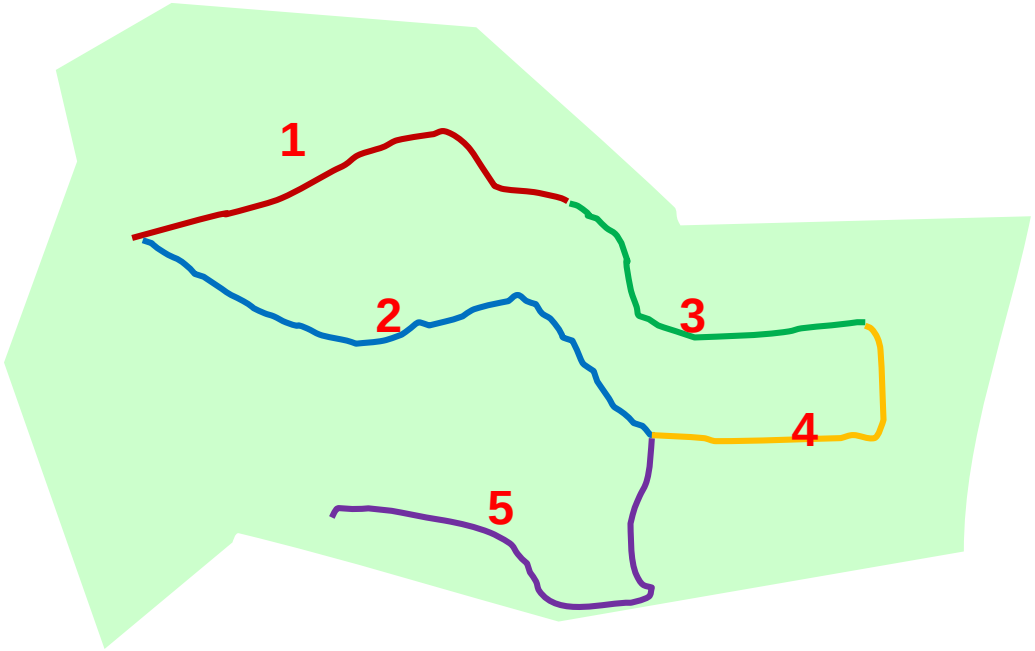
    - Both of these have a topological distance of 1

Network Analysis

- Overview
  - Connectivity matrix
    - Each link has a unique ID.
    - A cell in the matrix described the topological relationship between the two links denoted by the IDs in the corresponding row and column labels.
    - It is a binary matrix.
      - The cell has a value of 1 if the two links are directly joined to each other.
      - Otherwise, the cell has a value of 0.
      - A link is not connected to itself.
      - It is symmetrical.

Network Analysis

- Overview
  - Connectivity matrix
    - Example: It's all about "adjacency".



ID	1	2	3	4	5
1	0	1	1	0	0
2	1	0	0	1	1
3	1	0	0	1	0
4	0	1	1	0	1
5	0	1	0	1	0

Network Analysis

- Overview
  - Connectivity matrix
    - Connectivity of links is the most fundamental attributes of a network.
    - Without topological information, any network analysis can be flawed.

Network Analysis

- Overview
  - Connectivity Level
    - Given a set of vertices,
      - There are various ways that the vertices can be connected by segments to form different networks.
      - More segments → better connected networks → increases network connectivity

Network Analysis

- Overview
  - Connectivity Level
    - There is a minimum number of segments required to connect all the vertices to form a network.
      - $N_{min} = n - 1$
        - » n is the number of vertices
    - If the number of segments is below this minimum number, not all the vertices will be connected together to form a network.
    - If a network has a number of segments equal to this minimum number, then the network is a minimally connected network.
      - In such case, if any segment is removed, the network will break up into unconnected subnetworks.

Network Analysis

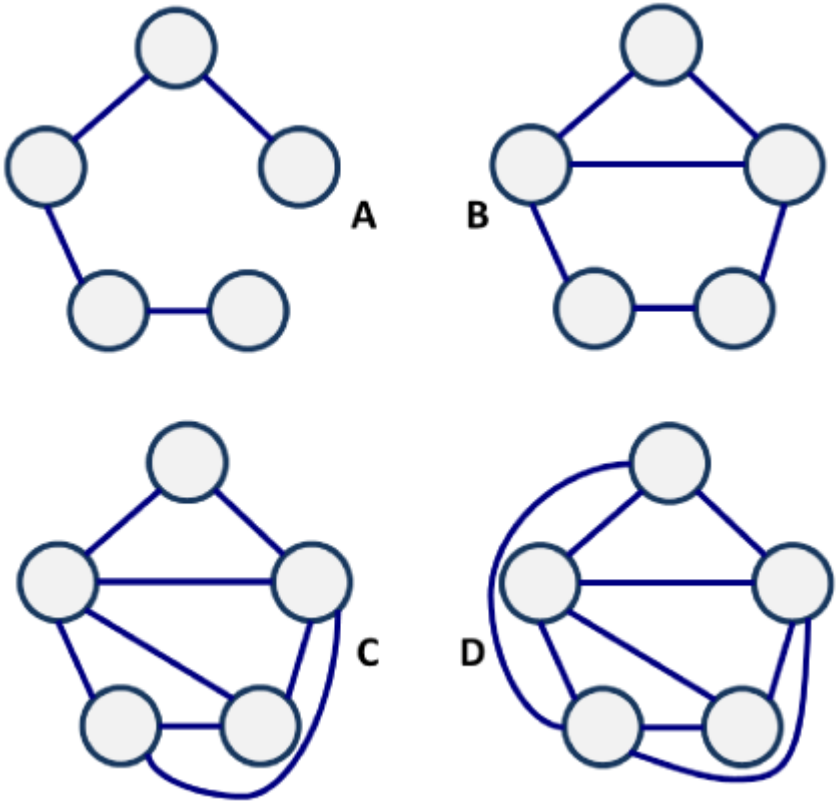
- Overview
  - Connectivity Level
    - There is a maximum number of segments one can connect all the vertices to form a network.
      - $N_{max} = 3*(n - 2)$
        - » *n* is the number of vertices
    - Assumption: segments can not cross or intersect with each other. (Otherwise, new vertices will be formed.)

Network Analysis

- Overview
  - Measuring Connectivity Level
    - Gamma Index
      - The ratio of the actual number of segments to the maximum possible number of edges in the network.
      - $\gamma = N / N_{max}$
        - » N is the number of segments in the network.
      - $N_{max} = 3 * (n - 2)$
        - » n is the number of nodes / vertices
      - Evaluation:
        - » $\gamma \sim 0 \rightarrow$ Low Connectivity
        - » $\gamma \sim 1 \rightarrow$ High Connectivity

Network Analysis

- Overview
  - Measuring Connectivity Level
    - Gamma Index



$$\gamma = \frac{e}{3(v-2)}$$

	e	*3(v-2)*	Gamma
A	4	9	0.44
B	6	9	0.66
C	8	9	0.88
D	9	9	1.0

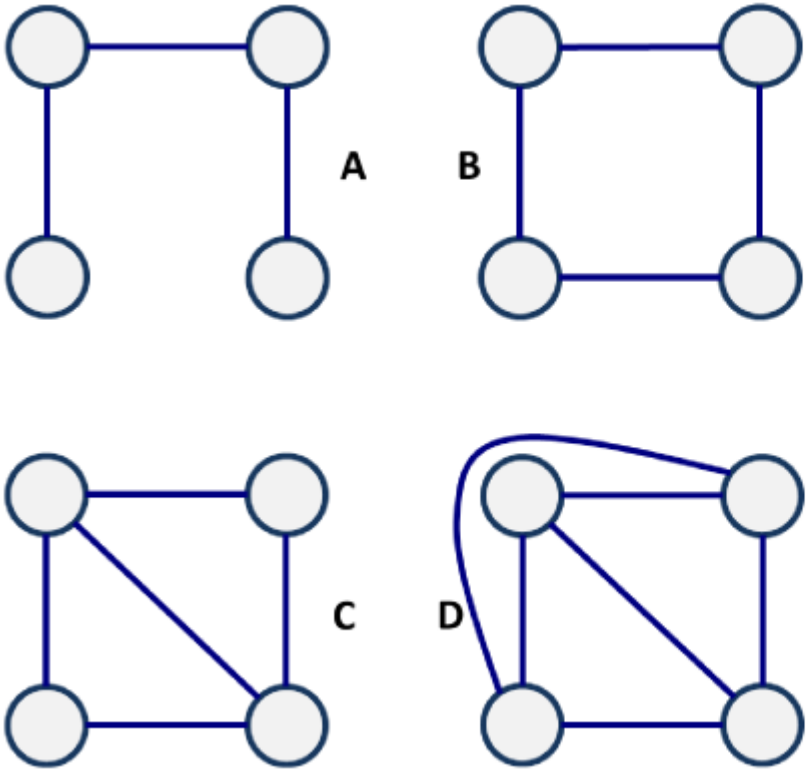
http://people.hofstra.edu/geotrans/eng/methods/alphaindex.html

Network Analysis

- Overview
  - Measuring Connectivity Level
    - Alpha Index
      - The ratio of the number of actual circuits to the number of maximum possible circuits.
      - A circuit is a closed loop along a network.
        - » Example: A → B → C → D → A
      - The existence of circuits implies that there are multiple paths to connect any two vertices in the network.
      - The maximum possible number of circuits in a network is (2n-5) where n is the number of vertices.
      - $\alpha = (N-n+1)/(2n-5)$

Network Analysis

- Overview
  - Measuring Connectivity Level



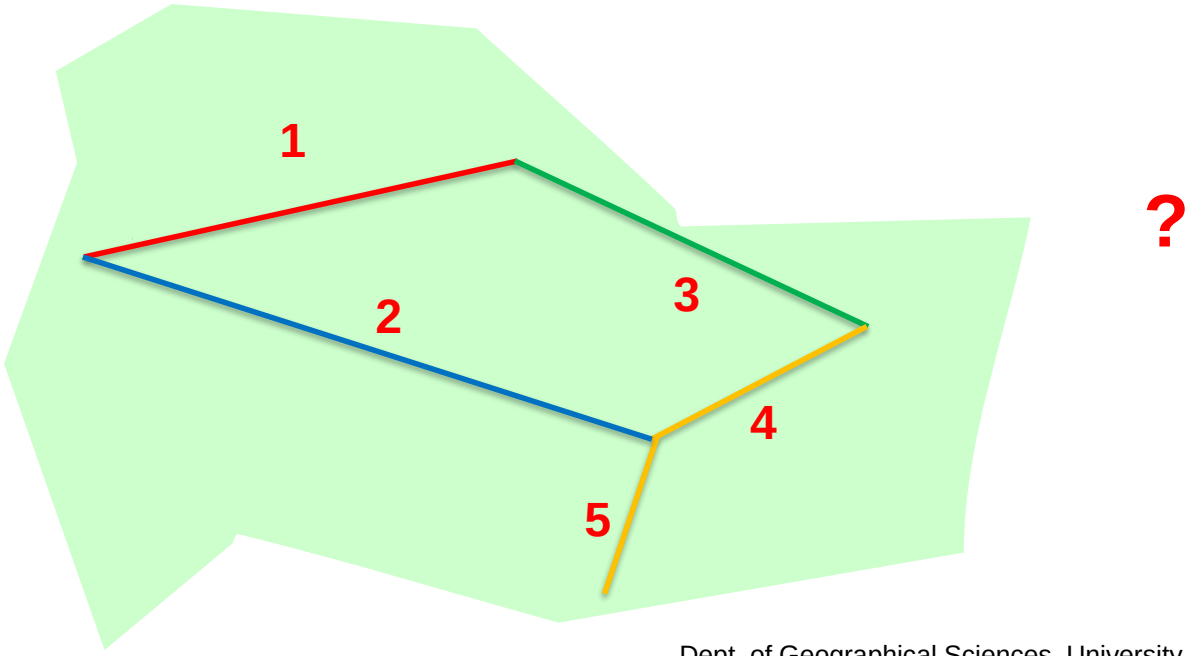
$$\alpha = \frac{u}{2v-5}$$

	u (e-v+p)	*2v-5*	Alpha
A	0	3	0.0
B	1	3	0.33
C	2	3	0.66
D	3	3	1.0

http://people.hofstra.edu/geotrans/eng/methods/alphaindex.html

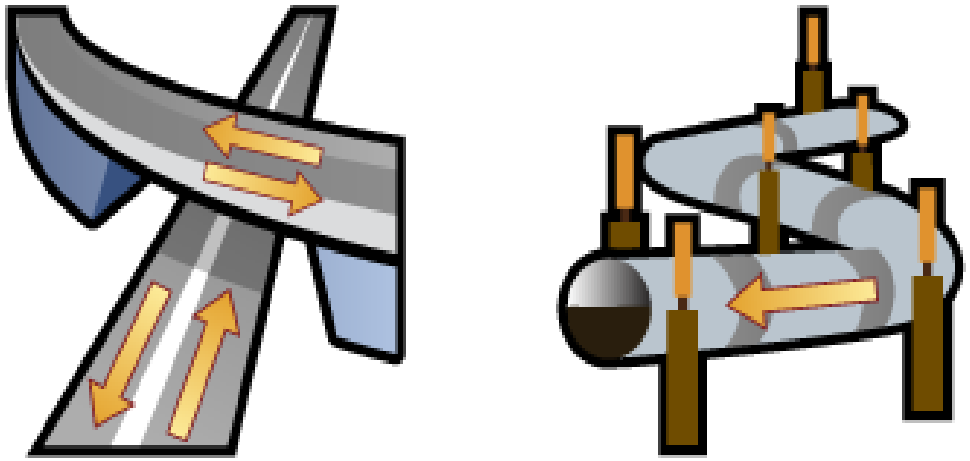
Network Analysis

- Overview
  - Measuring Connectivity Level
    - Example:
      - Gamma Index: $\gamma = N / N_{max}$
      - Alpha Index: $\alpha = (N-n+1)/(2n-5)$



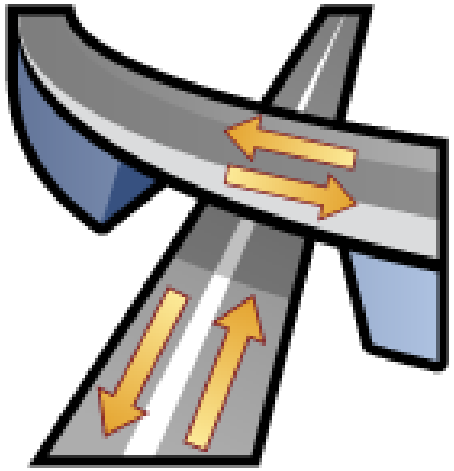
Network Analysis

- Overview
  - Two types of networks:
    - Transportation Networks
    - Utility and River Networks



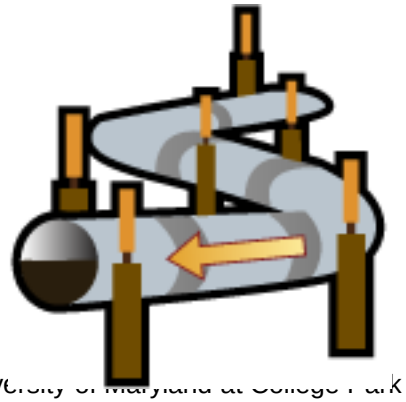
Network Analysis

- Overview
  - Two types of networks:
    - Transportation Networks
      - Network datasets
      - Undirected
      - Each edge has no associated direction of flow.
      - Examples: roads, streets, pedestrian paths, railroads
      - Exception: one-way roads (restrictions)



Network Analysis

- Overview
  - Two types of networks:
    - Utility and River Networks
      - Geometric networks
      - Each edge has an associated flow direction.
      - Travel on edges in only one direction at a time.
      - Direction predetermined
        - » Determined by external forces such as gravity, electromagnetism, water pressure, etc.
      - Examples: sewage network, electrical transmission lines, natural gas pipelines, water lines

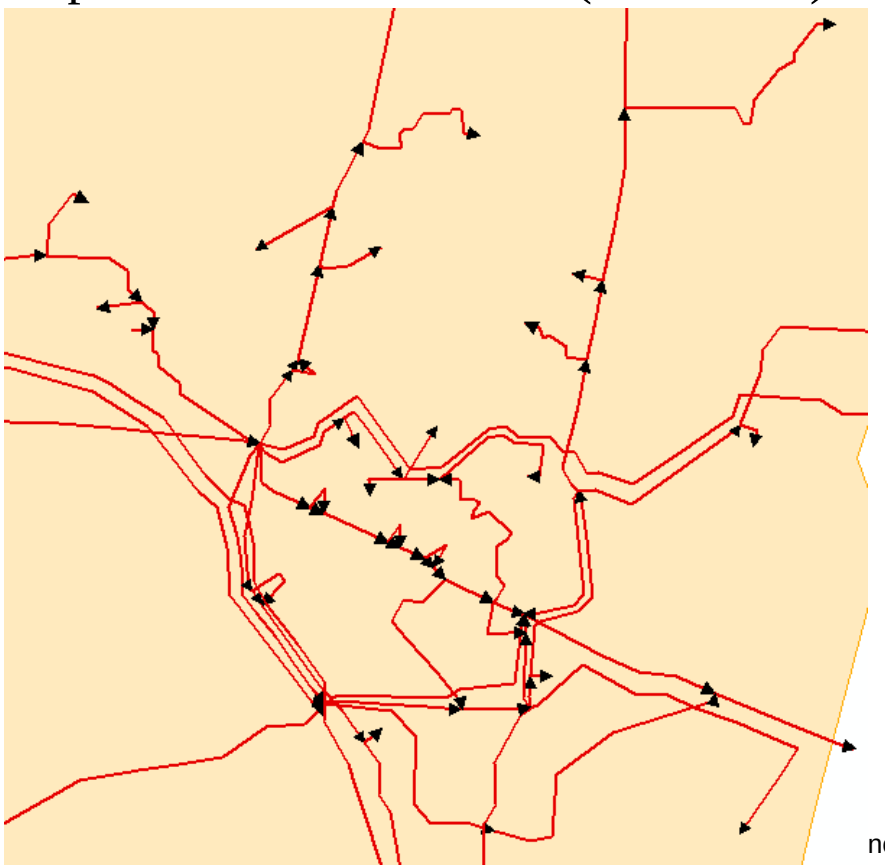


Network Analysis

- Overview
  - Two types of networks:
    - Transportation Network
      - Examples: road systems in Prince George's County, MD

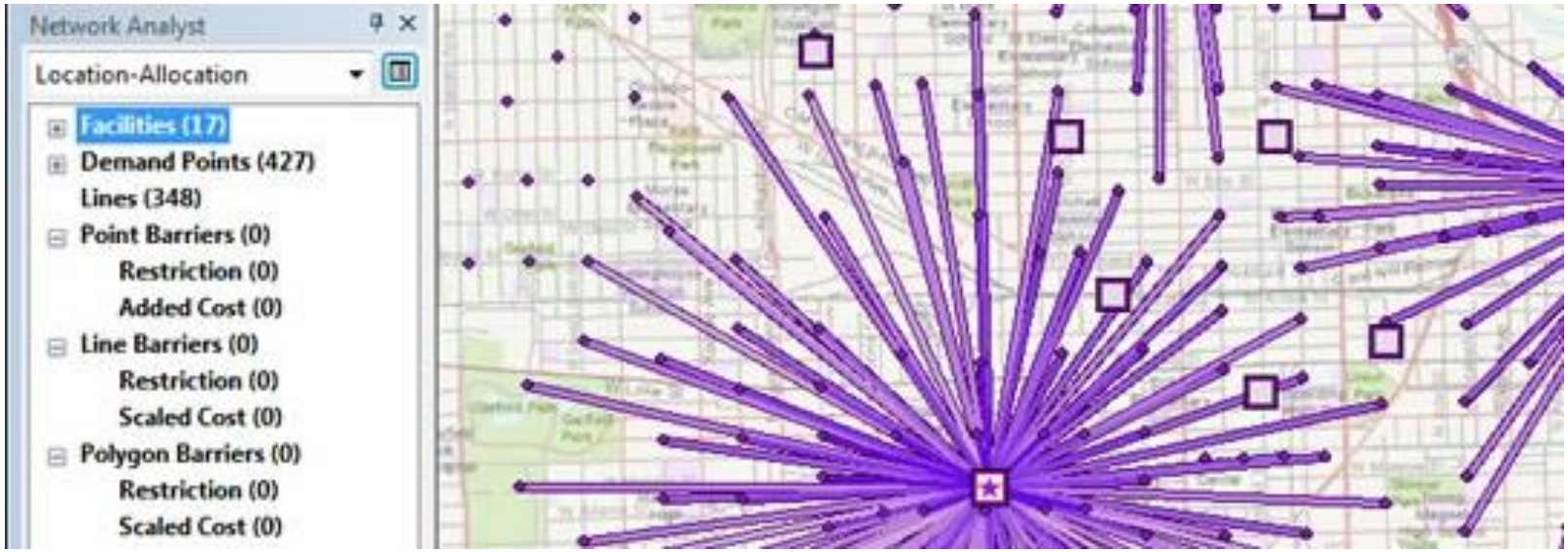
Network Analysis

- Overview
  - Two types of networks:
    - Utility Network
      - Example: Transmission lines (>=110KV) in Albany area, NYS



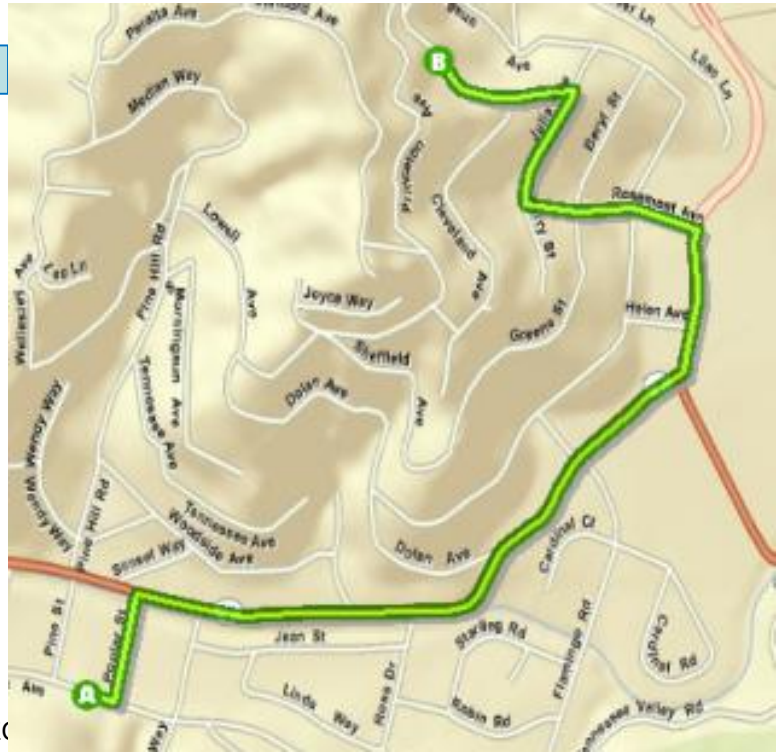
Network Analysis

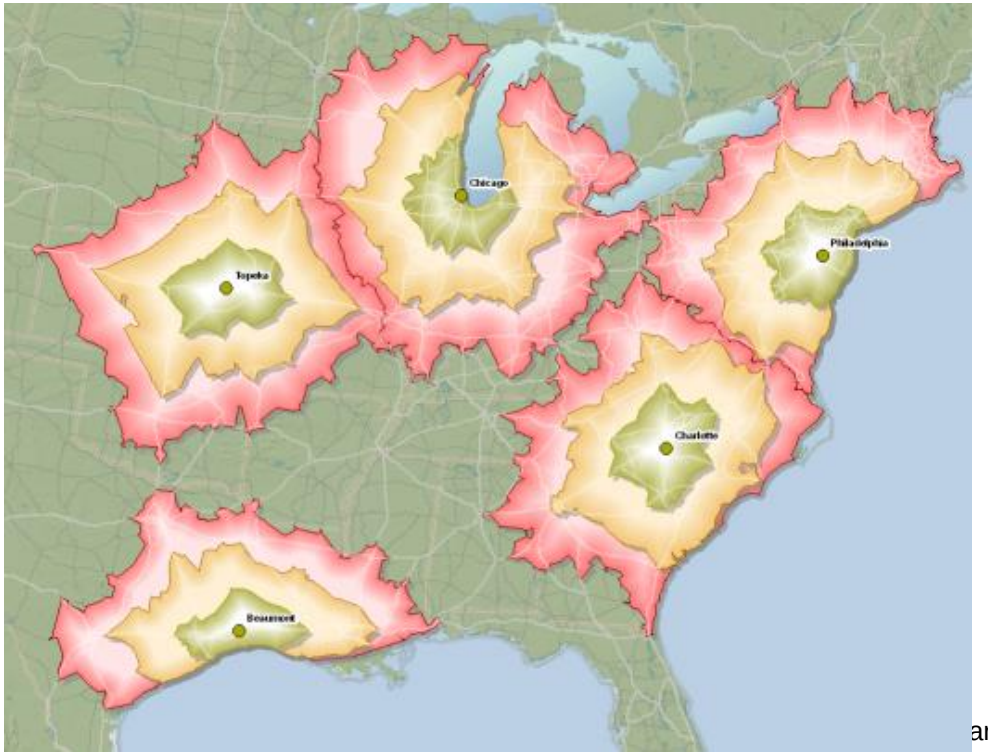
- Overview
  - ArcGIS Network Analyst is a powerful extension that provides network-based spatial analysis including routing, travel directions, closest facility, and service area analysis.



Network Analysis

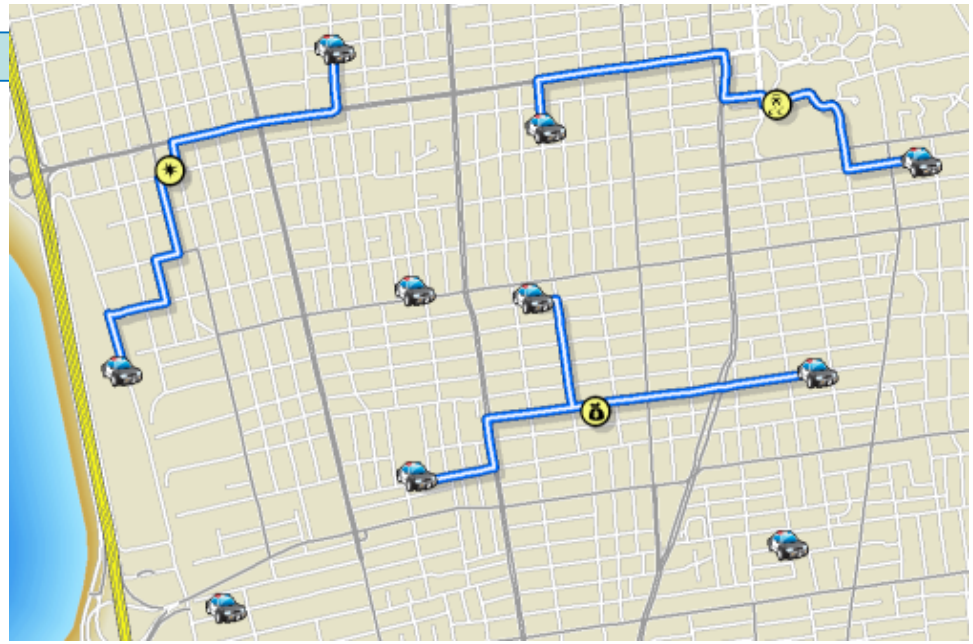
- Overview
  - Examples:
    - What is the quickest way from point A to point B?
    - What market areas does a business cover?

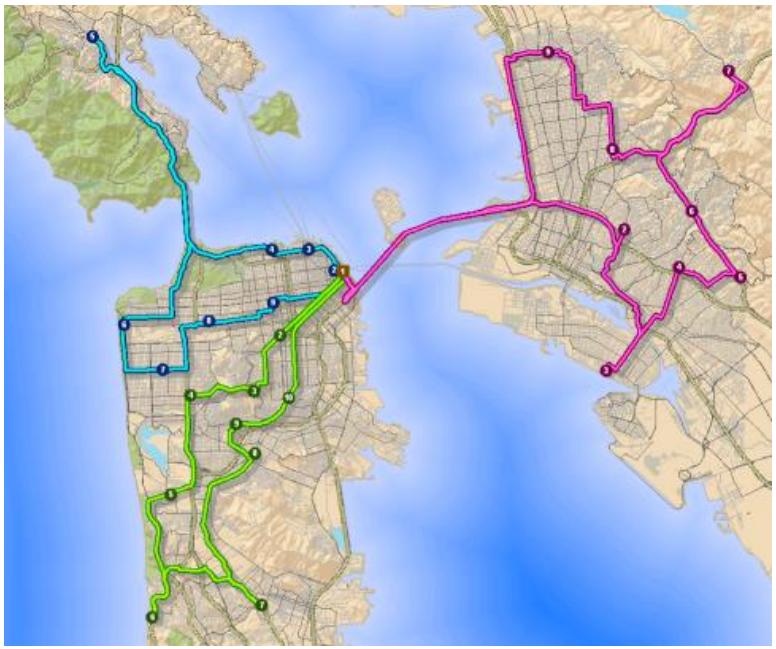




Network Analysis

- Overview
  - Examples:
    - Which patrol cars can respond quickest?
    - How can delivery vehicles minimize trans. costs?





Network Analysis

- Overview
  - ArcGIS Network Analyst can benefit the following industries:
    - Transportation
    - Logistics
    - Health care
    - Public safety
    - Education
    - Utilities
    - Local government
    - Business

Network Analysis

- Overview
  - ArcGIS Network Analyst
    - Data
      - Network dataset
        - » A collection of topologically connected network elements (edges, junctions, and optionally turns).
        - » It stores the connectivity of features.
        - » Any network analysis in ArcGIS Network Analyst requires a network dataset, which is a logical network.
      - Network sources
        - » Source features are the line and point features used to create a network dataset.
        - » No topology embedded within the feature
      - Junctions feature classes

Network Analysis

- Overview
  - ArcGIS Network Analyst
    - Data
      - Network dataset is a logical network created based on the source features.
      - Network datasets have their own attributes that are separate from their source features' attributes.
      - Network elements:
        - » Edges
        - » Junctions
        - » Turns
          - » Store information that can affect movement between two or more edges.

Network Analysis

- Overview
  - ArcGIS Network Analyst
    - Data
      - Network datasets' attributes usually include the following:
        - » The cost of traversing network elements (e.g. distance, time)
        - » Flow restrictions of elements
          - » Typically prohibits certain movements on network elements but can also avoid or even prefer elements.
          - » Examples: one-way streets; illegal turns; weight limits; barriers

Network Analysis

- Overview
  - ArcGIS Network Analyst
    - Data
      - Network datasets' attributes usually include the following: ('continued)
        - » Hierarchy level
          - » Stratifies a network mainly for the purpose of solving network analyses faster.
          - » Example: highway, arterial, local road
        - » Other information

Network Analysis

- Routing
- Service Area
- Closest Facility
- OD Cost Matrix
- Location-Allocation Analysis
- Network Analysis with Different Platforms
  - ArcMap
  - ArcGIS Pro
  - ArcGIS Online

Network Analysis

- Routing
  - Find the best way to get from one location to another or the best way to visit several locations.
  - The locations can be specified interactively by:
    - Placing points on the screen
    - Using points in an existing feature class or feature layer.

Network Analysis

- Routing
  - What is the best route?
    - The best route can mean different things in different situations.
      - Quickest (time)
      - Shortest (distance)
    - The best route can be defined as the route that has the lowest impedance.

Network Analysis

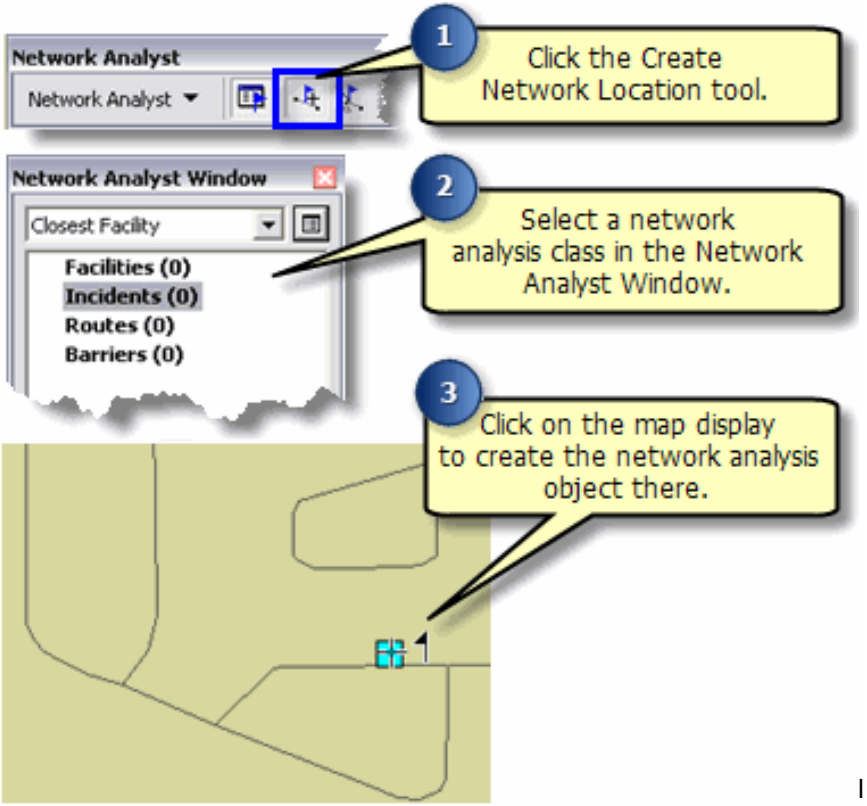
- Routing
  - What is the best route?
    - Global Turns are rules that can be set to provide restrictions or preferences.
      - For example: In ArcGIS routing analysis, all left turns have a delay of 15 seconds.
    - The advantage of Global Turns is that you do not need to create individual turn features for rules that apply to every turn in the network.

Network Analysis

- Routing
  - Components of routing analysis:
    - Stops feature layer
      - This layer stores the network locations that are used as stops in route analysis.
    - Barriers feature layer
      - Barriers are used in route analysis to denote points where a route can't traverse.
    - Route feature layer
      - The Route feature layer stores the resultant route of a route analysis.

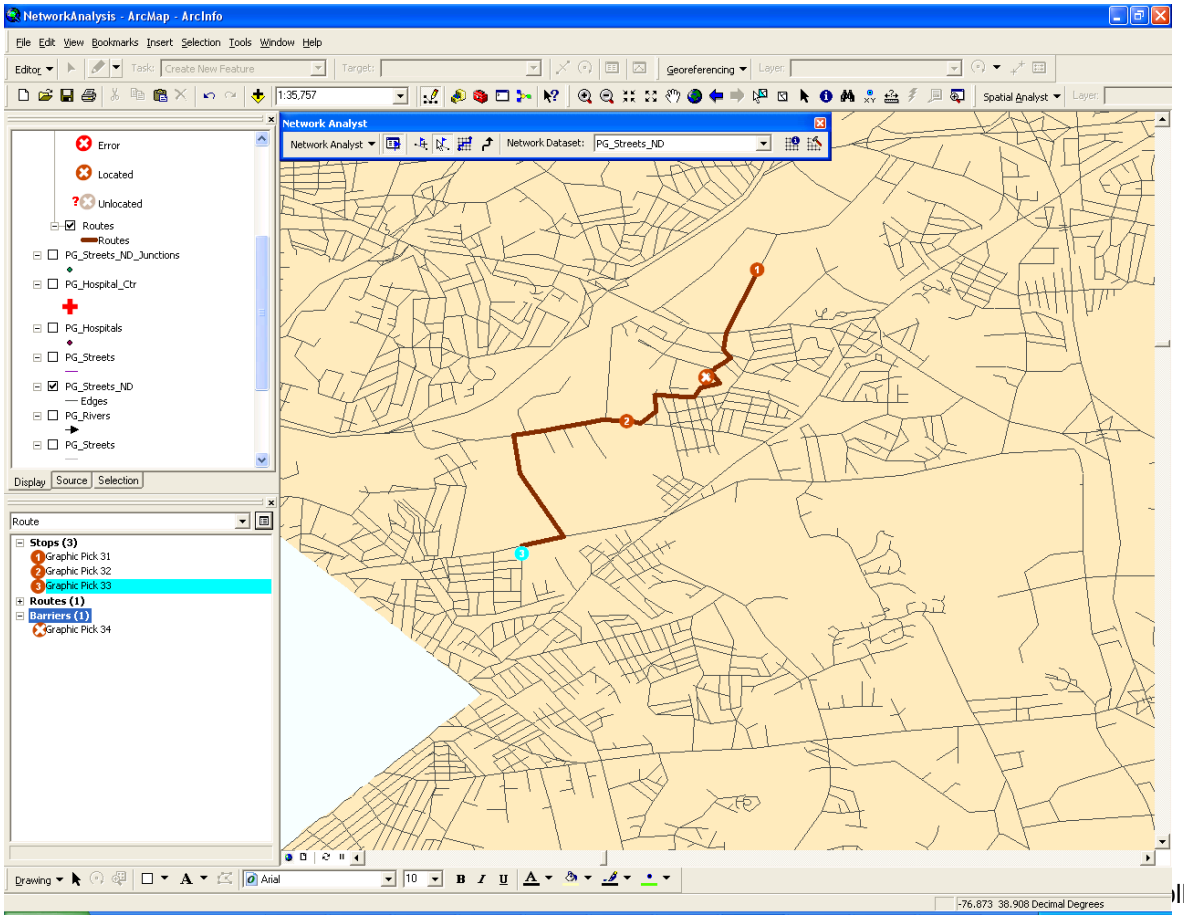
Network Analysis

- Routing
  - Two ways to add stops and/or barriers:
    - From a point feature class
    - Adding points to the display



Network Analysis

- Routing
  - Two ways to add stops and/or barriers:
    - Adding points to the display
    - Example:



Network Analysis

- Routing
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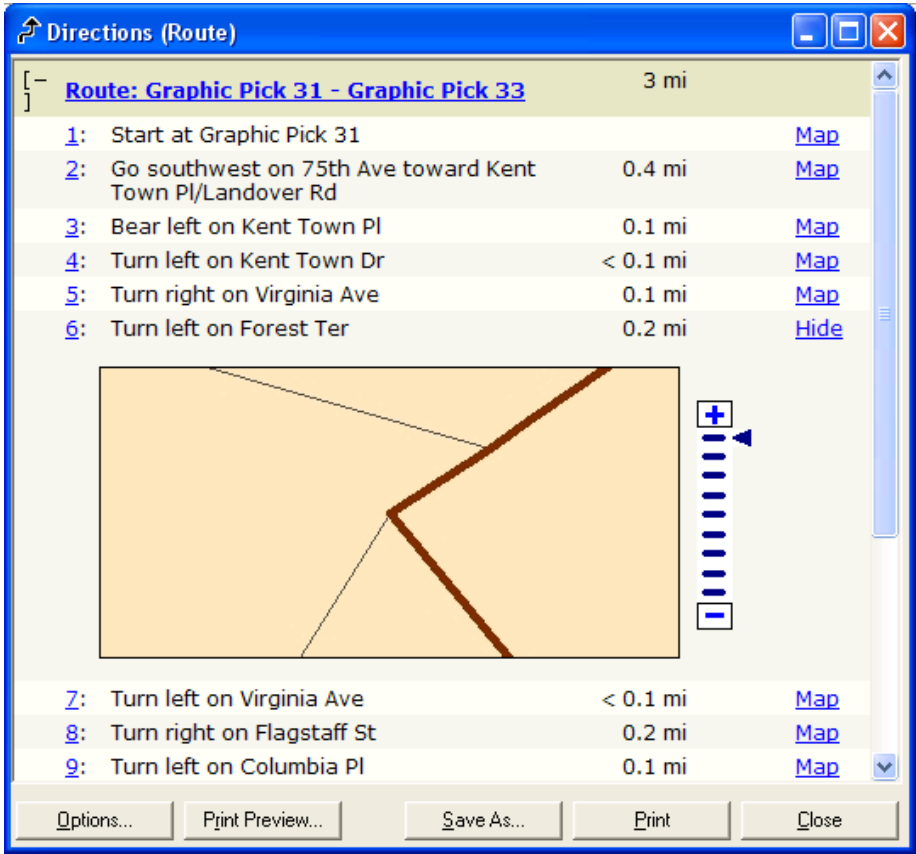
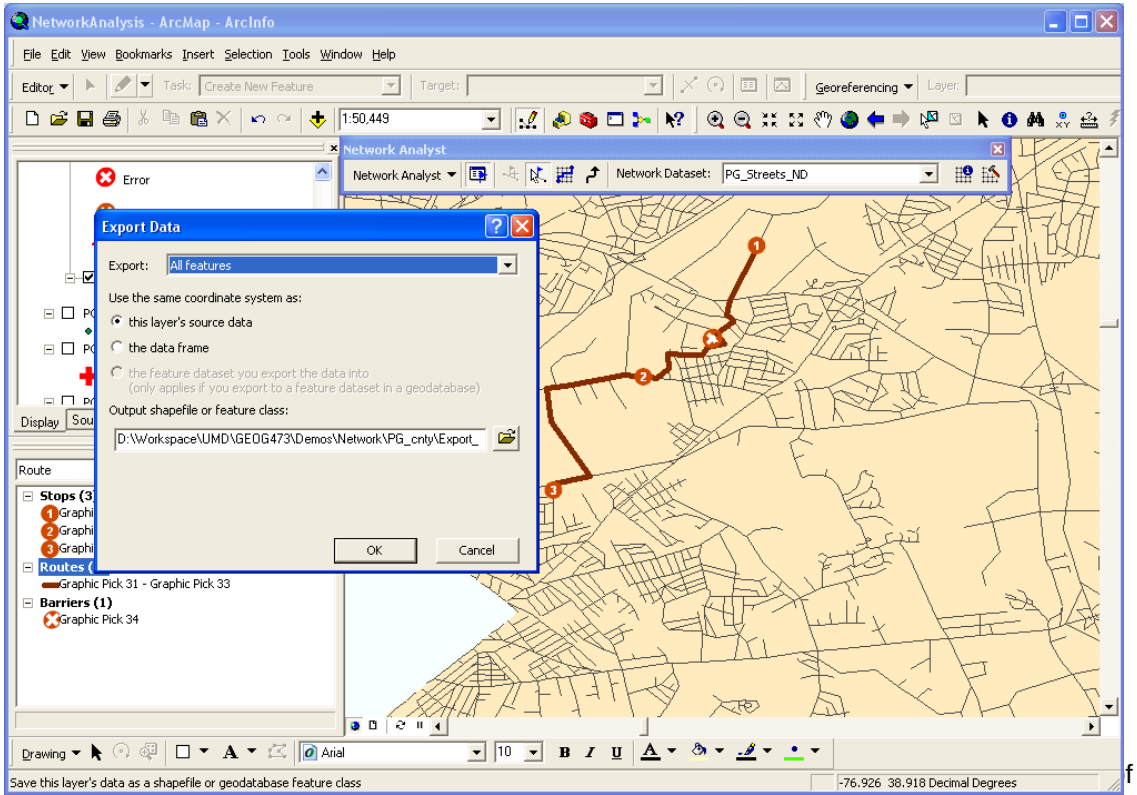
    - Example:



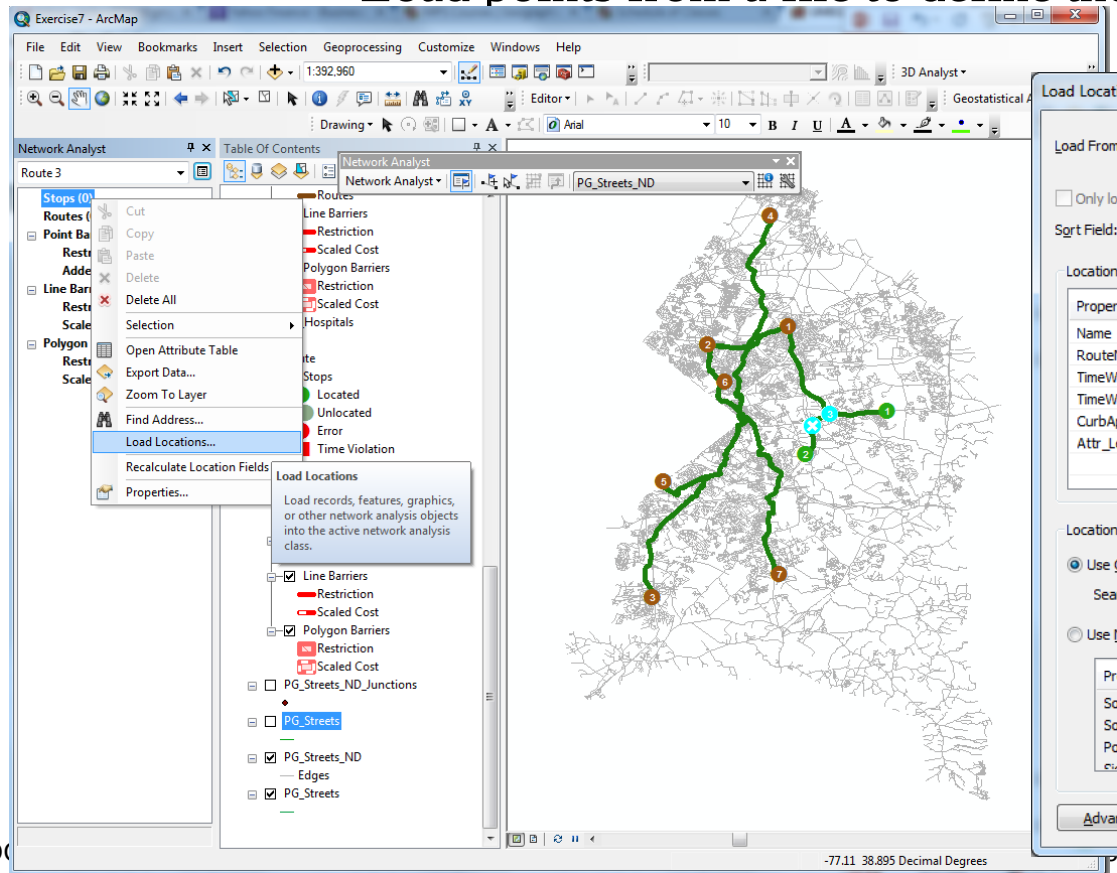
Network Analysis

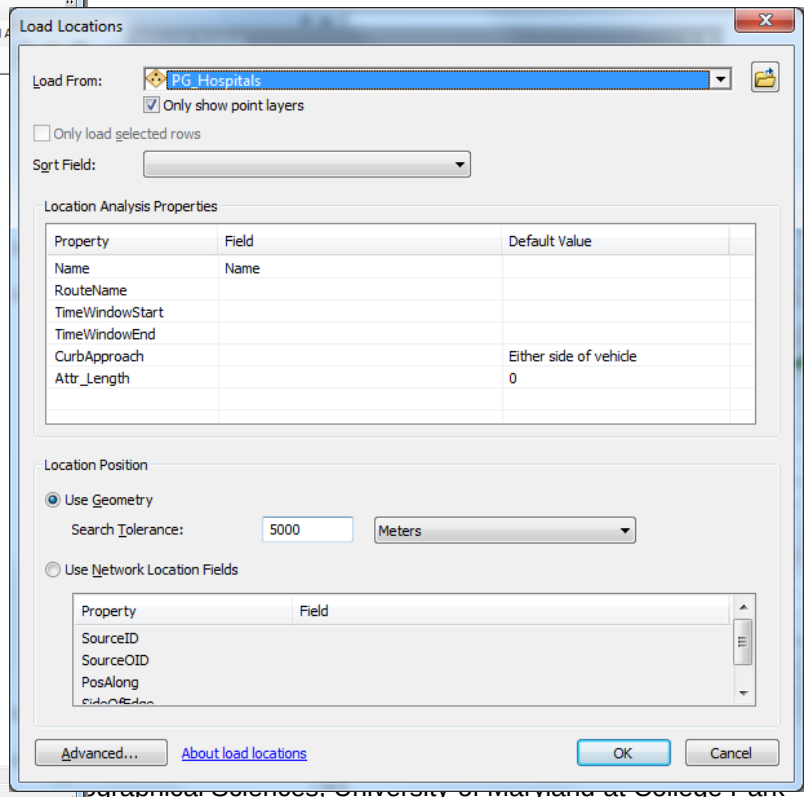
- Routing
  - Two ways to add stops and/or barriers:
    - Adding points to the display
      - Best route can be saved and exported as a shapefile by right-click on “Routes (1) in the Network Analyst Window.



Network Analysis

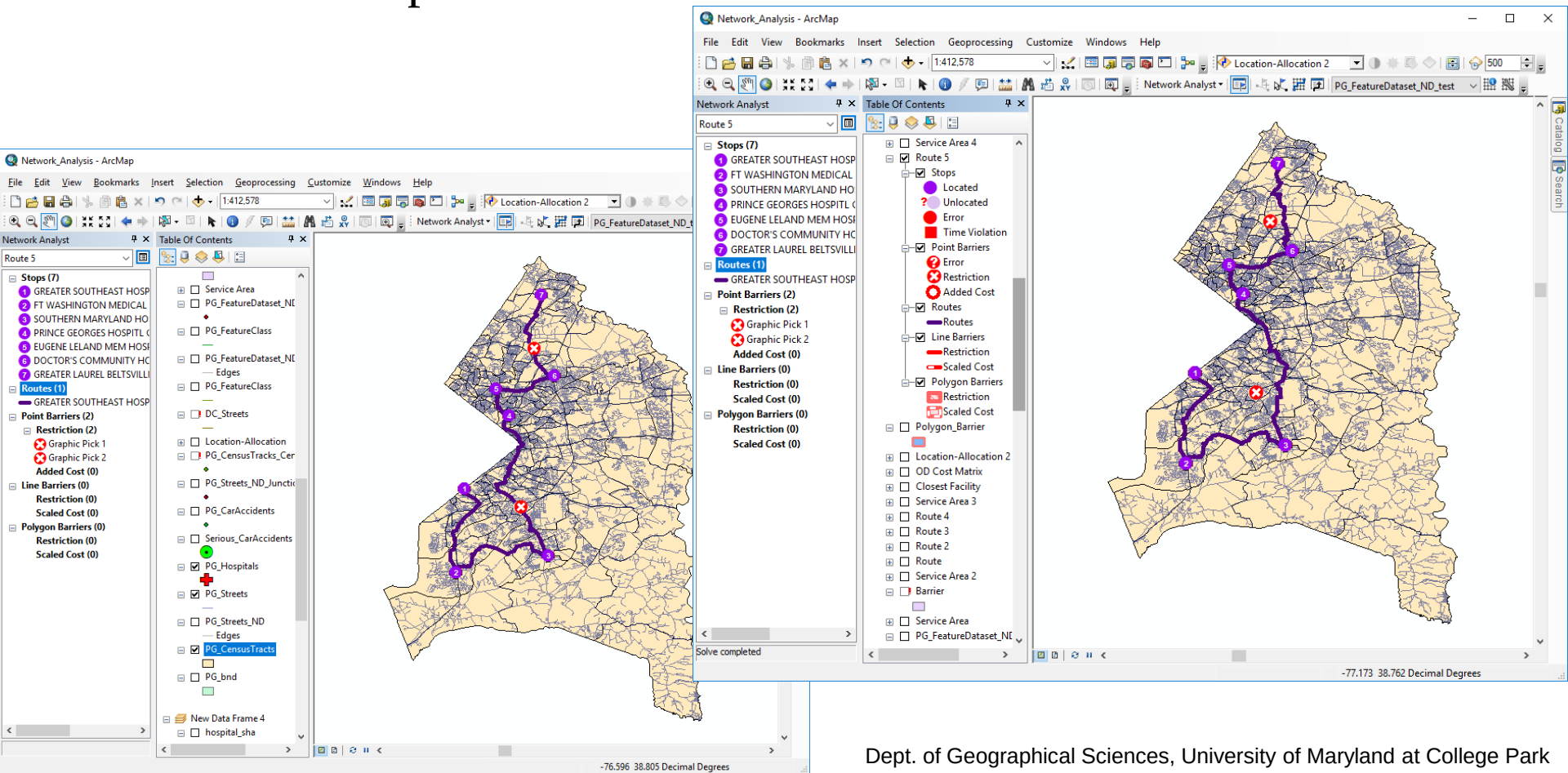
- Routing
  - Two ways to add stops and/or barriers:
    - From a point feature class
      - Load points from a file to define the stops.





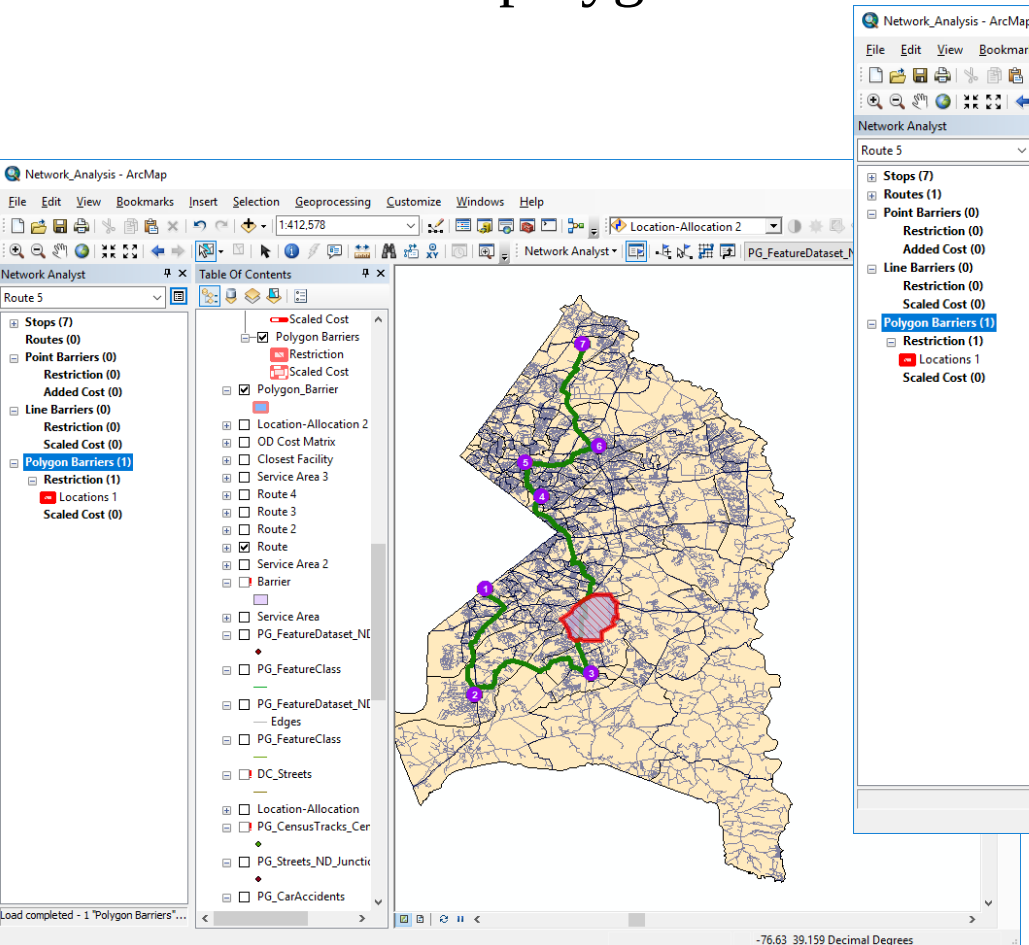
Network Analysis

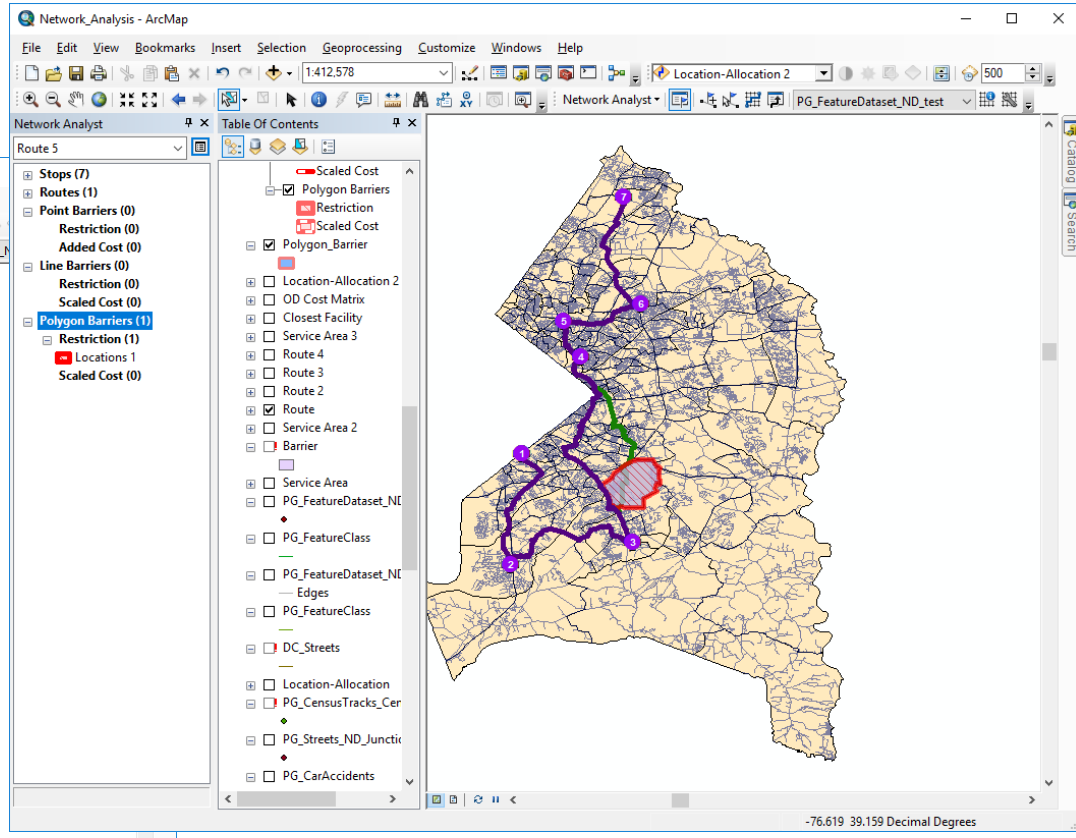
- Routing
  - Two ways to add stops and/or barriers:
    - With point barrier



Network Analysis

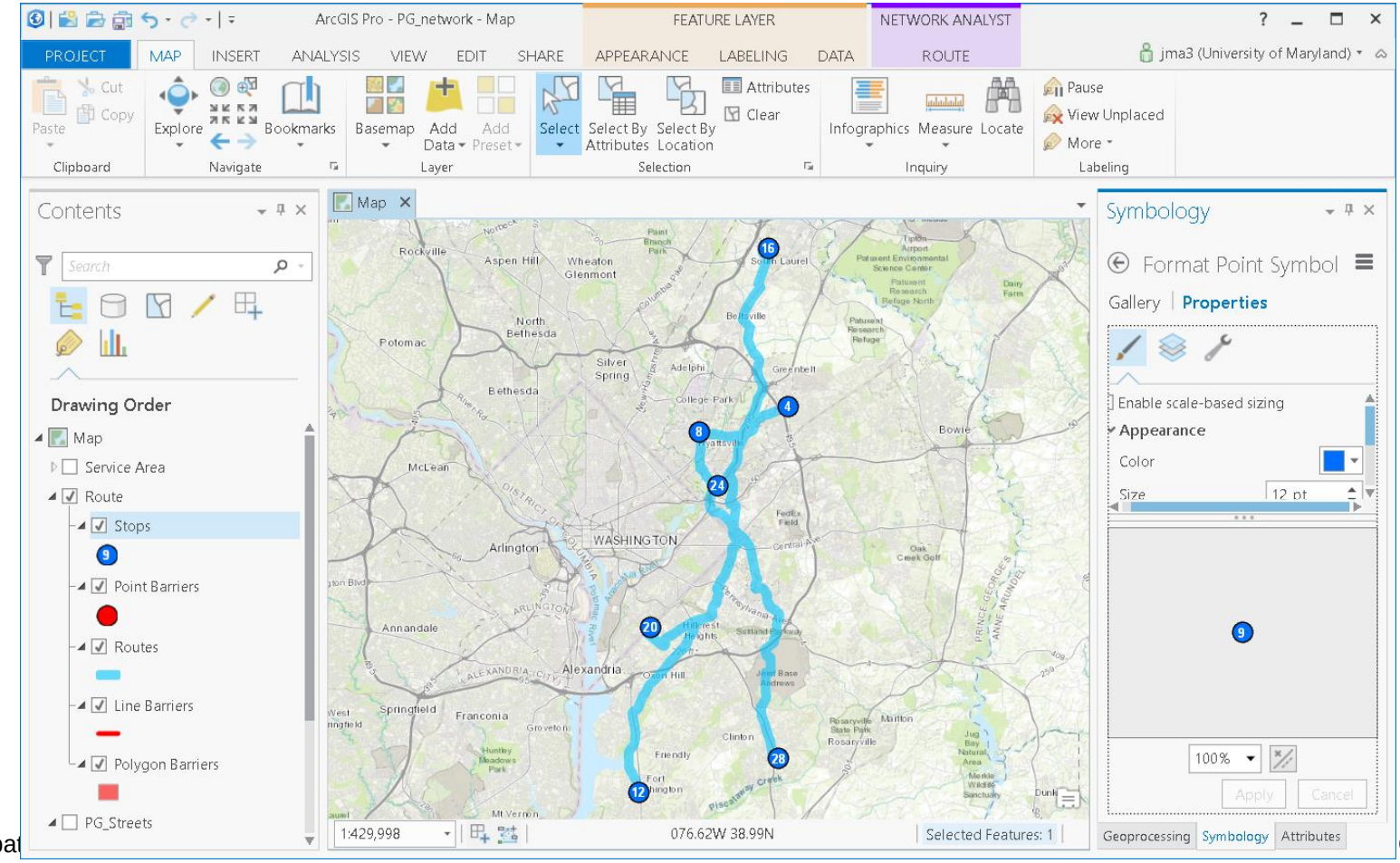
- Routing
  - Two ways to add stops and/or barriers:
    - With polygon barrier





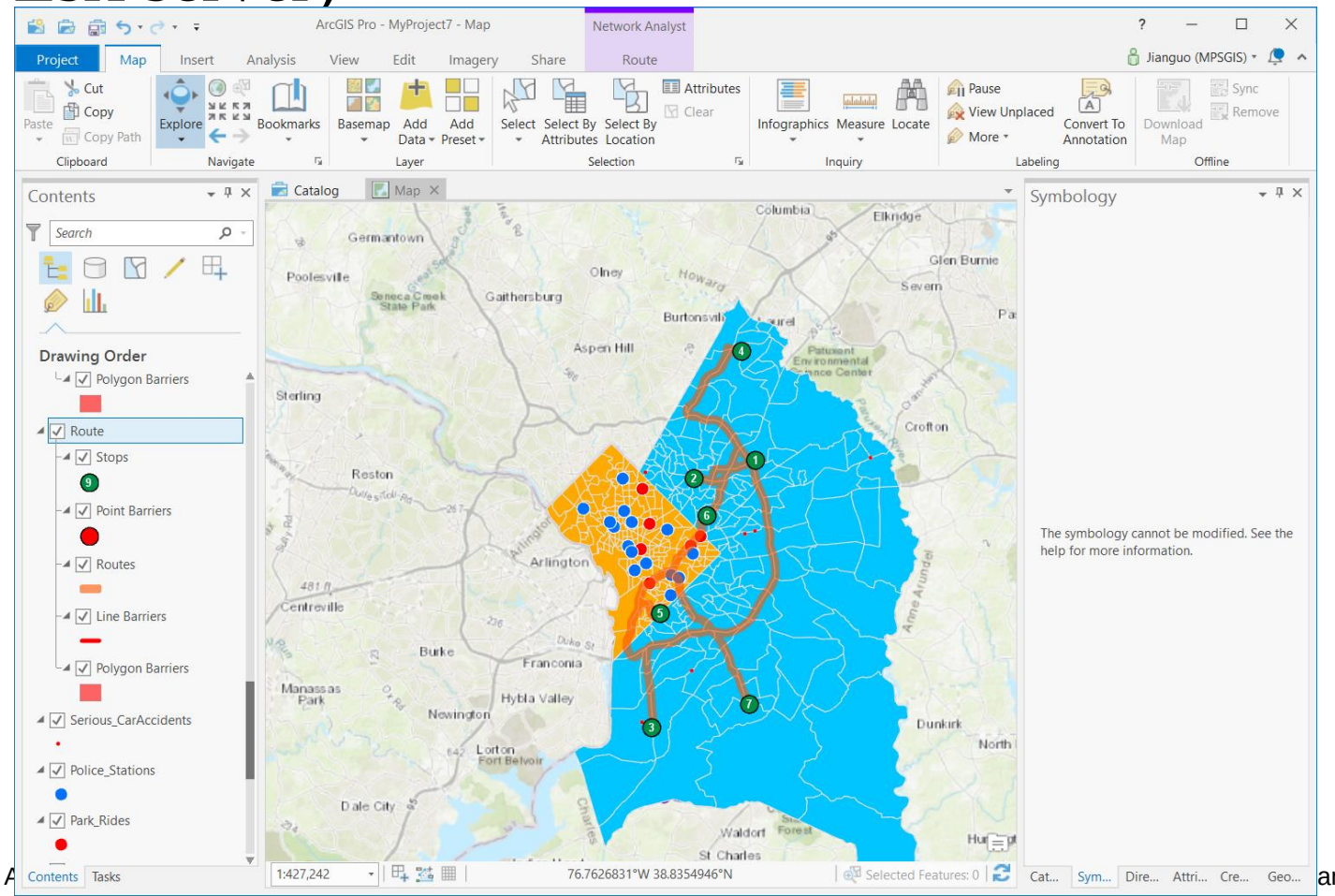
Network Analysis

- Routing
  - Example in ArcGIS Pro (using own data source)



Network Analysis

- Routing
  - Example in ArcGIS Pro (using data source from Esri server)



Network Analysis

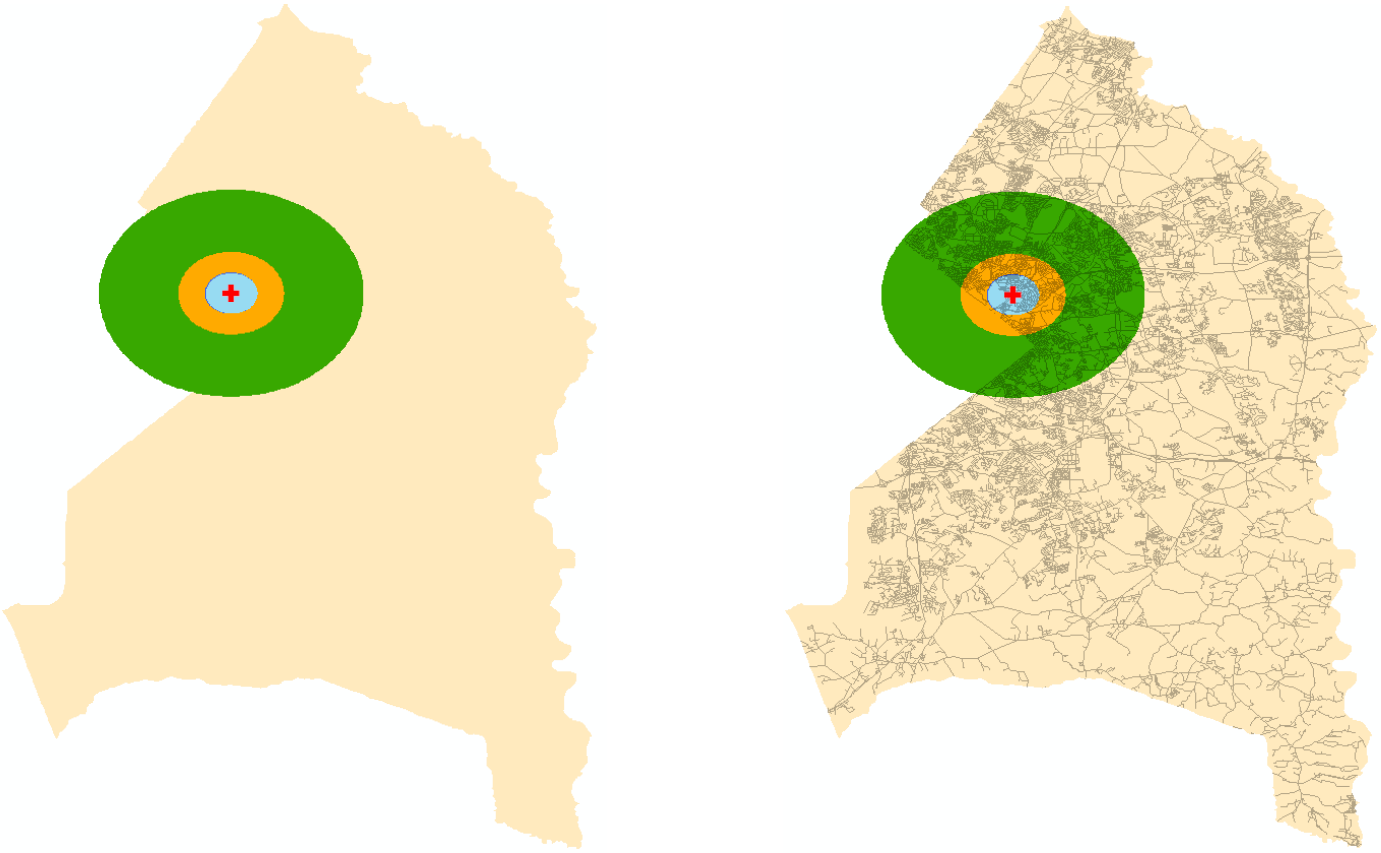
- Service Area
  - A network service area is a region that encompasses all accessible streets, that is, streets that lie within a specified impedance.
    - Example: The 15-minute service area for Prince George's Hospital Center includes all the streets that can be reached within fifteen minutes from this facility.

Network Analysis

- Service Area
  - Network Analyst allows to generate service areas surrounding a facility based on driving time or driving distance.
    - Simple ring (i.e. ring buffer)
      - Euclidean distance
      - Not accurate
      - This method doesn't reflect the actual accessibility to the site.
    - Service area based on a network

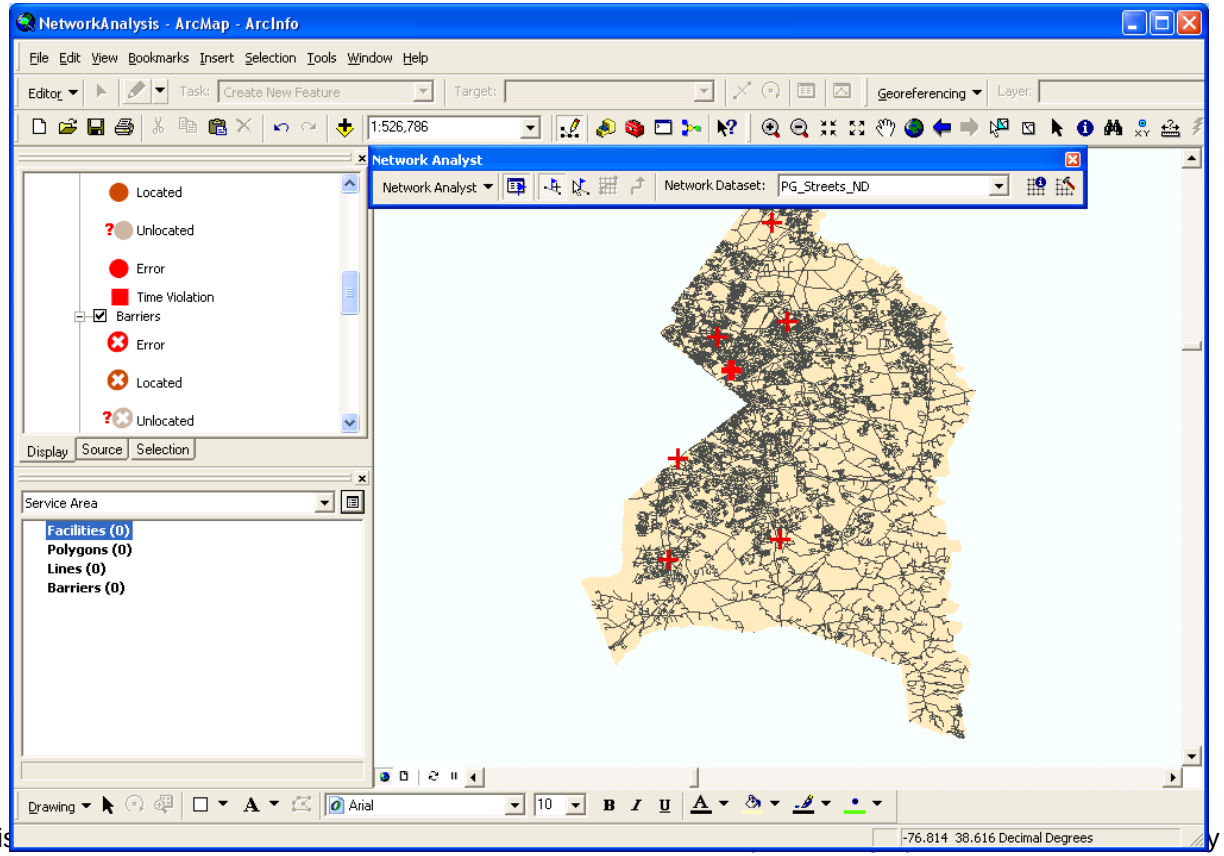
Network Analysis

- Service Area
  - Simple ring (i.e. ring buffer)
    - Example: The service areas within 1-mile, 2-mile, and 5-mile from Prince George's Hospital Center.



Network Analysis

- Service Area
  - Service area based on network
    - Example: finding service areas for each hospital located in Prince George's County



Network Analysis

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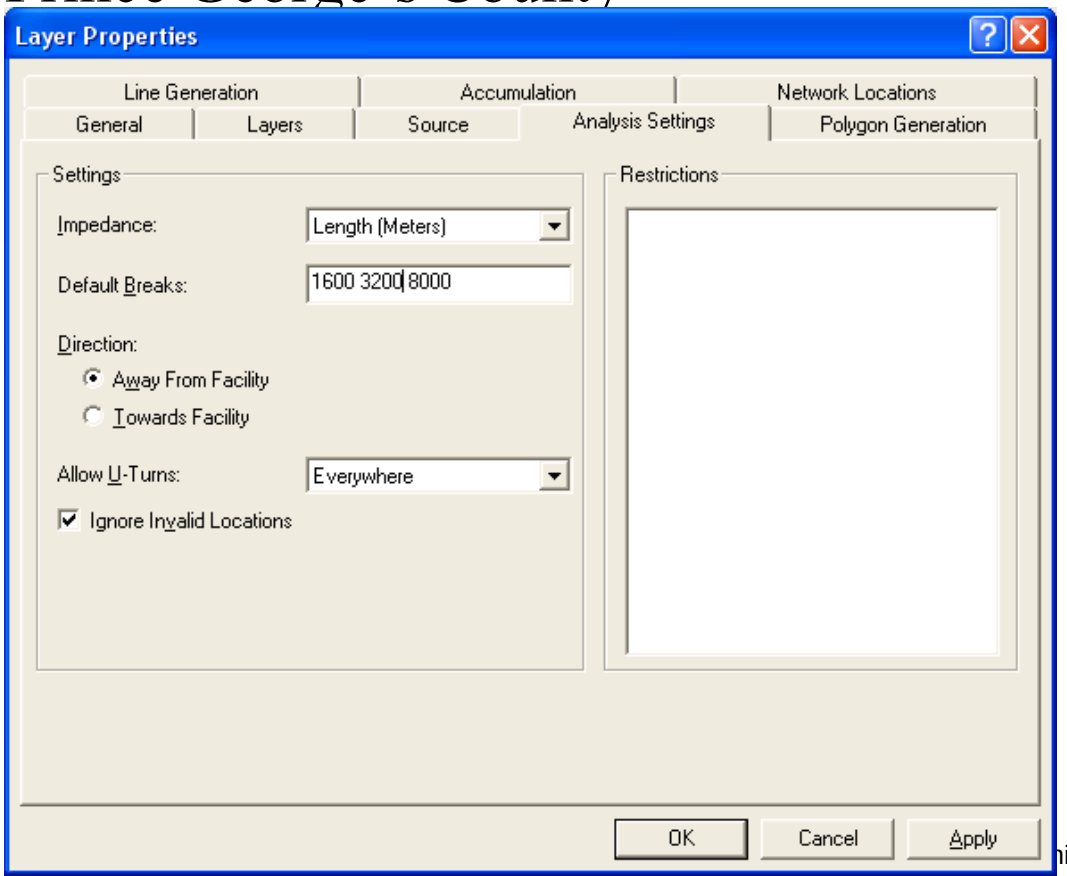

Network Analysis

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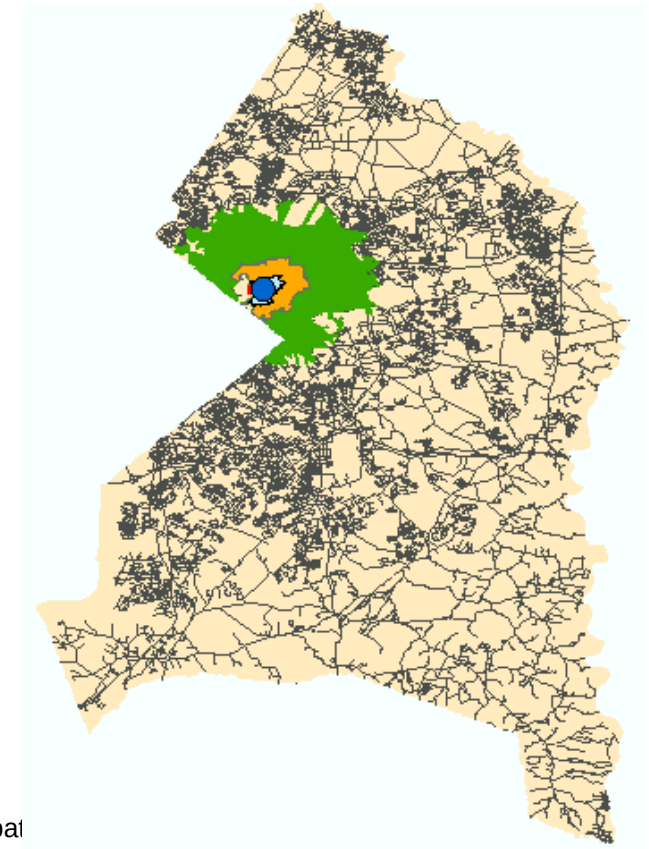
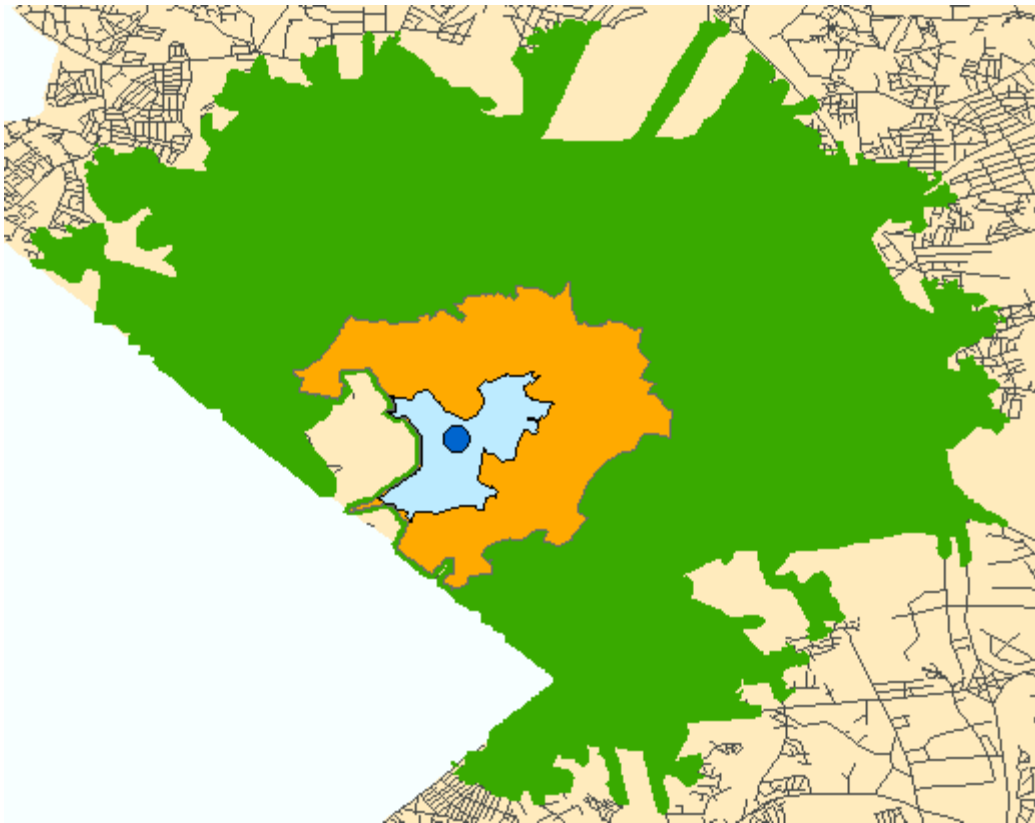
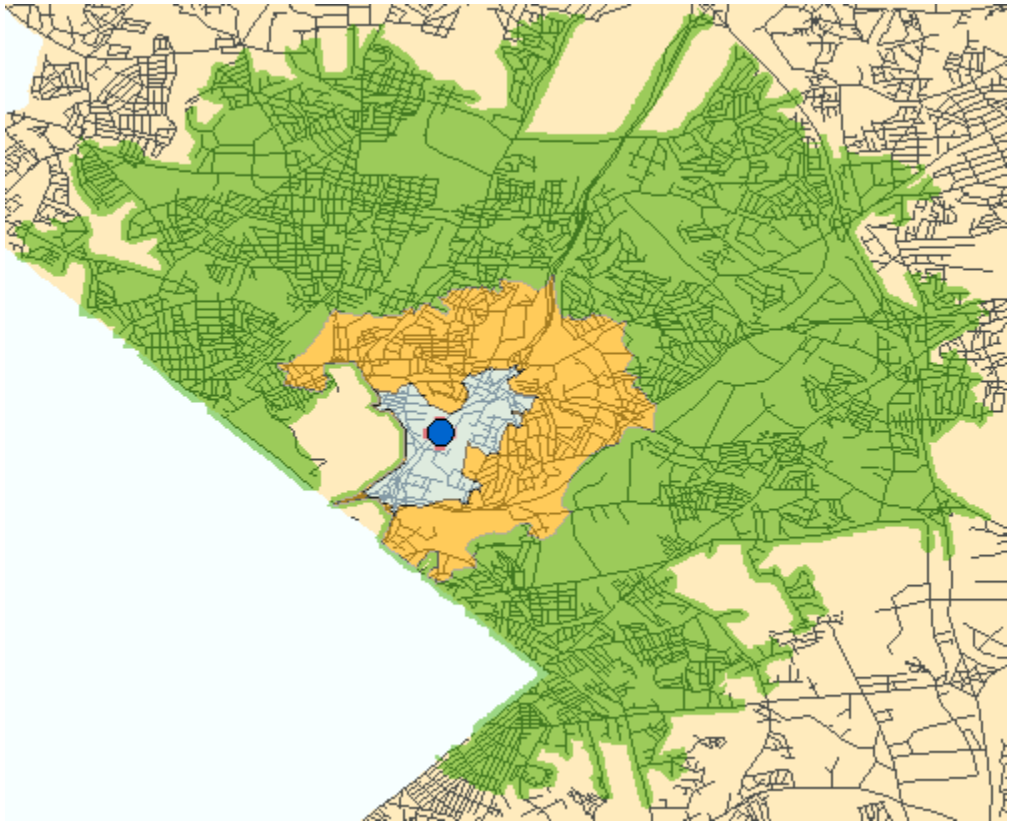




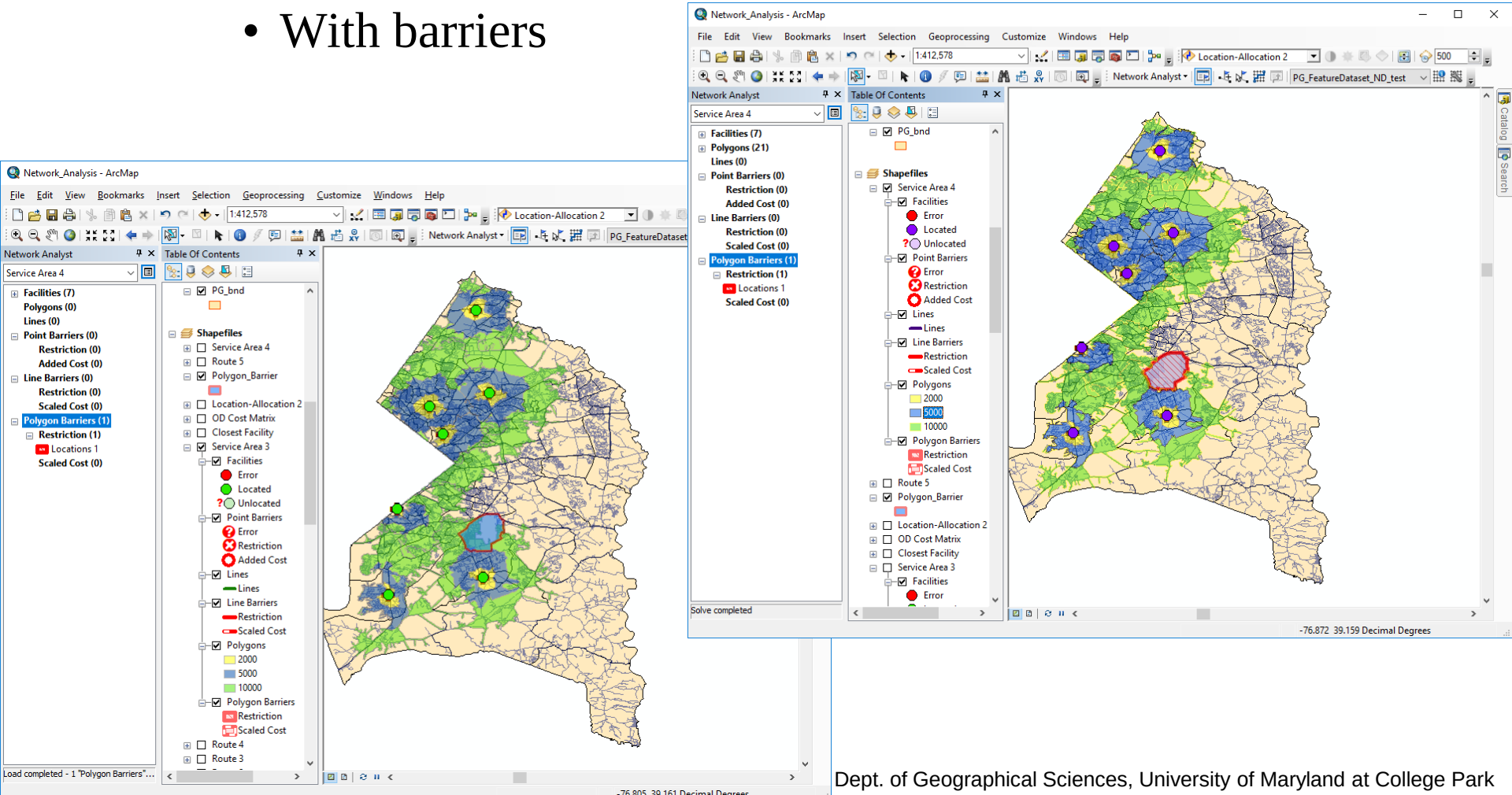
Network Analysis

- Service Area
  - Service area based on network
    - Example: finding service areas for each hospital located in Prince George's County



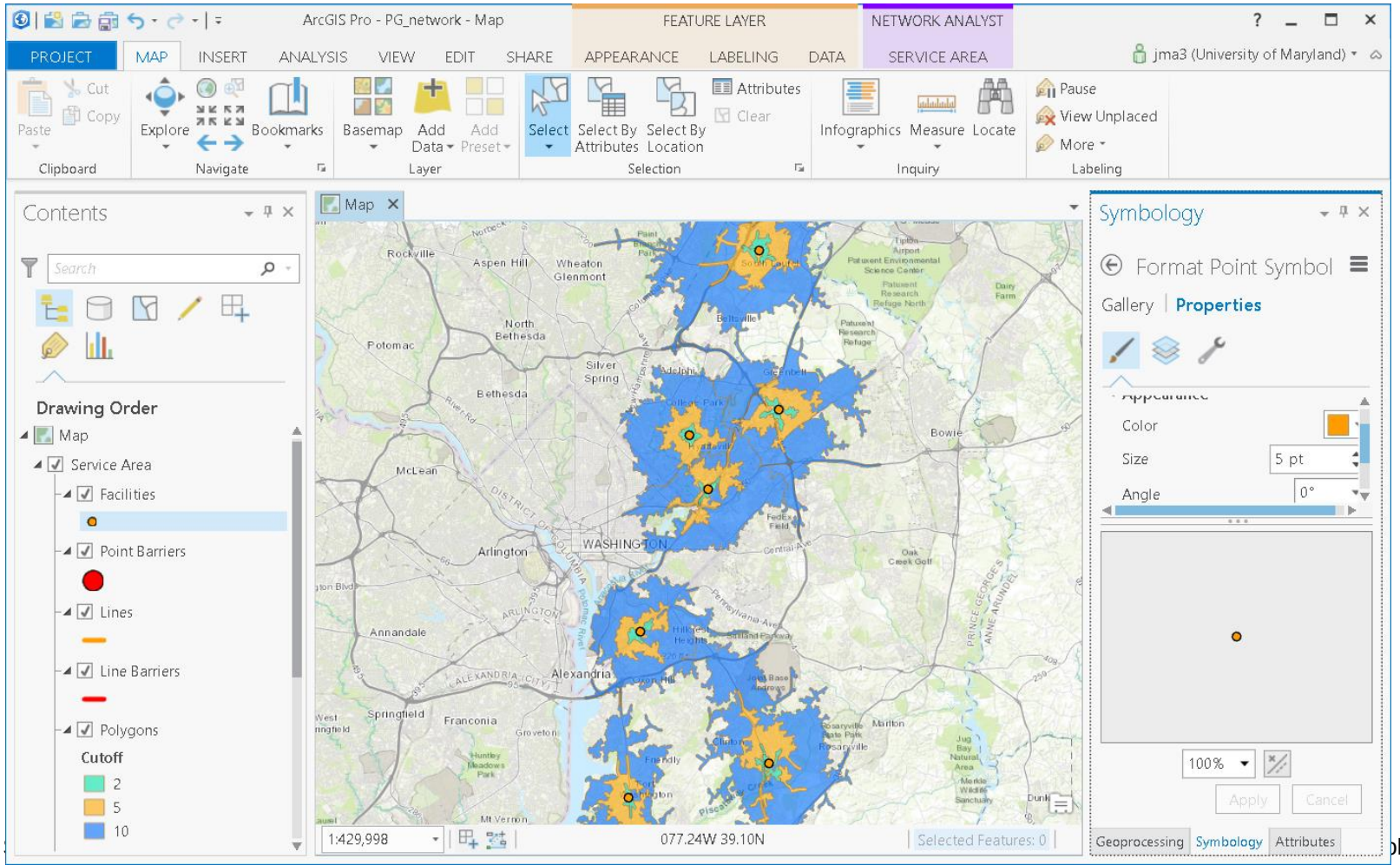
Network Analysis

- Service Area
  - Service area based on network
    - With barriers



Network Analysis

- Service Area
  - Example in ArcGIS Pro



THE END