Lab Assignment 4 – Network Analysis

Due Date: 10**/09/2020**

Overview

This assignment is designed to help you practice various analytical methods using various platforms including ArcMap, ArcGIS Pro, and ArcGIS Online. The topics covered in the lectures include: creating network dataset based on shapefiles or geodatabase, finding the best route (i.e. shortest path), generating the service areas surrounding a facility, and identifying the closest facility/facilities from an incident or multiple incident, and OD cost matrix, and Location-Allocation analysis.

Objectives

The objectives of this lab assignment are to help you:

- Become familiar with network dataset.
- Practice network analysis methods and learn how to use them.
- Learn how to do network analysis using different platforms which provide different features and functions.
- More importantly, understand the potential, limitations, and differences of various tools.

Part I – Creating Network Dataset

When you have a set of data which has information about every single street in a study area, it can not be readily used for network analysis because regular line features (such as roads or streets) are not aware of one another. The software doesn't understand or recognize the spatial context of such raw data, for example, which streets are connected or disconnected. Only when the data has this topology information, can it be used by GIS software. This leads to network dataset which is a collection of topologically connected network elements (edges, junctions, and optionally turns). It stores the connectivity of features and defines how different segments are linked together and how these segments are related to each other.

So, the first step is to use the raw data to create network dataset. In this exercise, you will practice to use both ArcMap and ArcGIS Pro to create the network dataset.

1. Creating Network Dataset in ArcMap

Download and unzip the data.

Add the data – "PG_Streets".

Note:

- You need to study the data first before using them. For example, what is the coordinate system of the data? Although not a requirement, it is preferred to use projected data for network analysis. (I provided the data in this "raw" format on purpose because I want you

to practice more about how to cleanup or prepare data for analysis. In real world, you almost always need to clean-up and process the data before using it.)

- In general, whenever distance is involved in a spatial analysis, it is the best practice to use projected data in planar space.
- Also, in general, whenever the study area is small enough, it is the best practice to use projected data in planar space.

In this case, you may want to use this coordinate system to define the PG County data – "NAD_1983_StatePlane_Maryland_FIPS_1900".

After you have prepared the data, add this new data. Now you can create the network dataset based on "PG_Streets".

You can create the network dataset based on shapefiles or geodatabse. (In the case of using geodatabase, it gives you extra option to create a multimodel network.)

First, try to create a network dataset using shapefile in ArcMap.

Make sure you turn on the Network Analyst extension. Click **Tools → Extensions** and check the small box in front of **Network Analyst**.

Right-click on the projected PG_Streets shapefile and choose **New Network Dataset**. The name of the network dataset is set to PG_Streets_ND by default.

Follow the instructions until the tool is finished and the network dataset is built. There will be many steps and for now you can keep all of the default settings.

Now that the network dataset has been created, you can add it to ArcMap and explore it.

Make a screenshot of ArcMap at this point.

[1] Include the screenshot in your report.

Now, you may want to spend some time to explore the data you just created, especially "PG_Streets.ND.nd" and "PG_Streets_ND_Junctions.shp". You can use the Identify tool -  to click some junctions or edges to have a better understanding of the network dataset.

Edges and junctions form the basic structure of any network. Connectivity in a network deals with connecting edges and junctions to each other. These elements must be interconnected to allow navigation over the network.

Now, you can also try to create the network dataset using a geodatabase. Below are a few steps to follow:

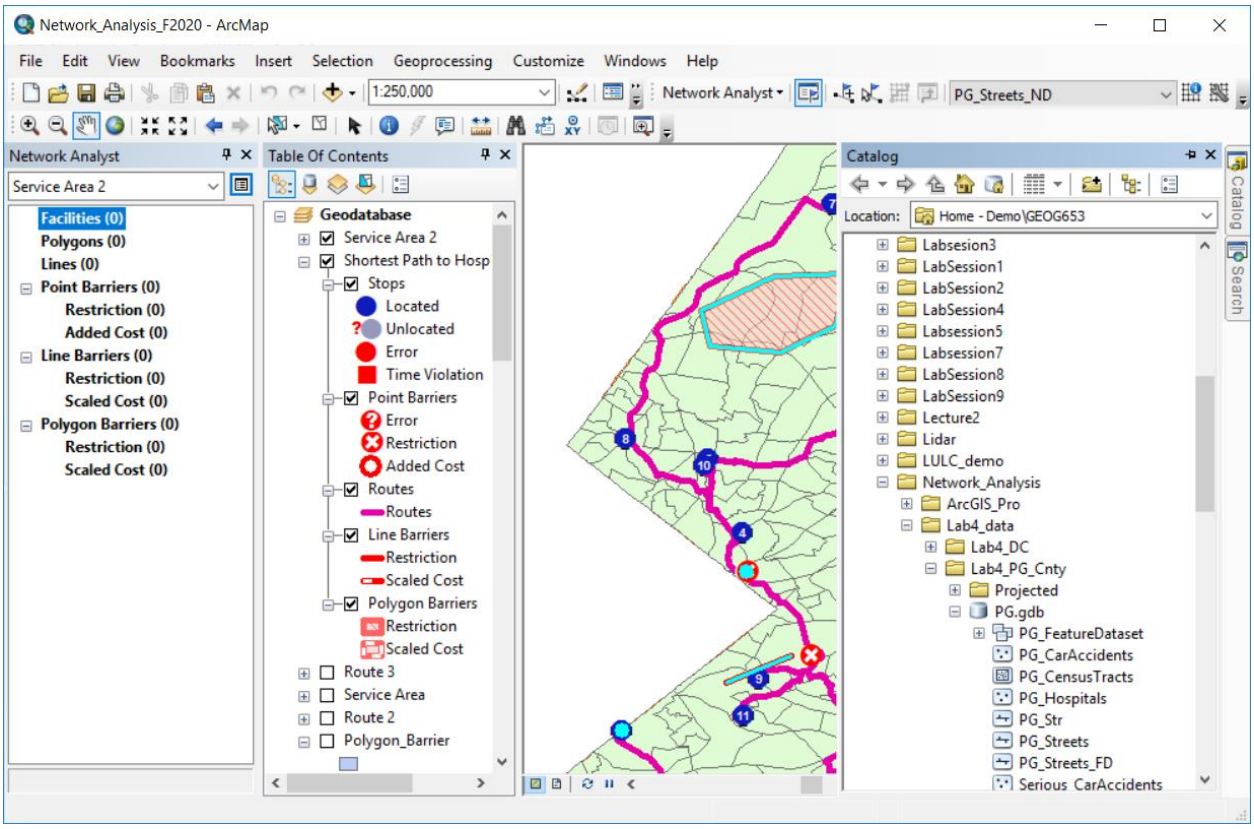
1. Create a new File geodatabase or Personal geodatabase in your workspace folder.
2. Right-click on the geodatabase and New and then create a Feature Dataset.
3. Import the feature classes, especially the source feature classes into this feature dataset.

- The source feature class – "PG_Streets" must be added.
- If you want to create a multimodel network dataset, you will also need to add other related source feature classes such as "PG_PublicSchools" and "PG_Hospitals". (**Optional**)

4. Create the network dataset from the feature dataset.
    - Right-click the feature dataset and then select New > Network Dataset

After you complete, make a screenshot of Catalog showing the result. It should be similar to the one below.

[2] Include the screenshot in your report.

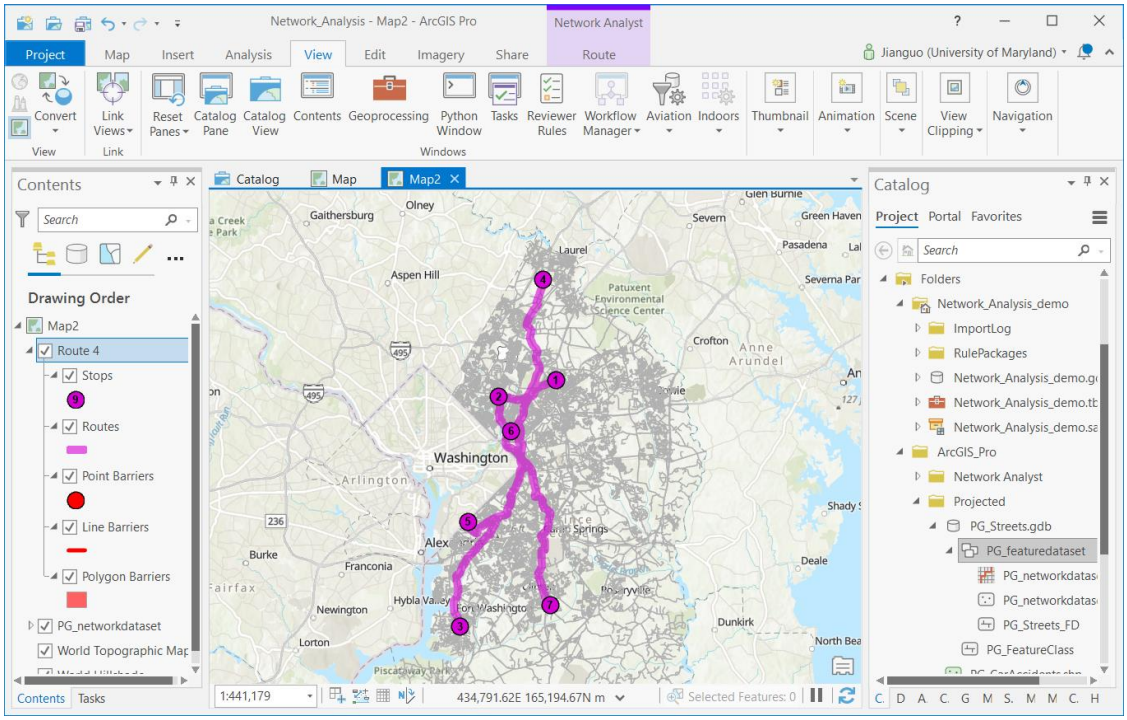


2. Creating Network Dataset in ArcGIS Pro

The steps for creating a network dataset in ArcGIS Pro are very different from those in ArcMap.

The major steps in creating a network dataset in ArcGIS Pro:

- Prepare the feature dataset and sources
- Create a geodatabase
- Create a feature dataset
- Create a network dataset
- Build the network dataset



Create your network dataset.

Make sure you build the network dataset after it is created. This is a common mistake that people make.

Note:

- If you are not clear on the specific details, you can refer to the video archive of a demo at the end of lecture on Tuesday.

Make a screen shot similar to the one above to show your work.

[3] Include the screenshot in your report.

Part II – Route Analysis

Route analysis can help users find the best way to get from one location to another or the best way to visit several locations. The best route can be defined as the route that has the lowest impedance. It can be the shortest path (based on distance) or the quickest path (based on time).

1. Shortest Path without Barriers

First, try to use this tool in ArcMap. (Later you will use ArcGIS Pro to compare so that you can recognize the new features.)

Click on Network Analyst tool bar and select “New Route” from the drop-down list.

Highlight or select "Stops (0)" in the Network Analyst Window on the left.

Now, create five "Stops". Make sure these points/locations are or very close to the network because all the network analysis can only be possible when the points/locations are on the edges.

Solve it.

Now, you should get the result which shows the shortest path from the first location you created to the other stops created in sequence.

Make a screen of the results (the graphic on the map).

[4] Include the screenshot in your report.

Open the "Directions (Route)" window and then make a screenshot. It shows the turn-by-turn directions of the selected (shortest) route.

[5] Include the screenshot in your report.

Now, you can change the sequence of stops by dragging and moving a location in the Network Analyst Window. Then, you can run the analysis again. The best route will quickly update.

Note:

- When adding data or generating new data layers, be creative about how to display them so that the map is easy to read. Because there are usually multiple layers including the result layer displayed on the map, you need to pay attention to the details such as symbology selection, color contrast, sequence of data in the Table of Content, display transparency, etc. All these efforts will make a difference on the quality of your results.
- This practice should be applied to all of the following exercises.

2. Shortest Path with Barriers

You just created the shortest path for those locations you defined. Now, what if there is a car accident or construction going on somewhere on the route? Such locations are called barriers.

Create two barriers (points) on the route. You can decide where to put them as long as they are on the route (shortest path from the previous exercise).

Solve it.

Now you will see the route has changed by avoiding the barrier points. An alternative route was found.

Make a screenshot of the result.

[6] Include the screenshot in your report.

3. Define the Stops with Point Feature Data

So far, the locations/stops were created interactively on the map. You can also define stops based on a point feature data.

Delete the three locations/stops you created in previous session.

Right-click on "Stops (0)" in the Network Analyst Window and then select "Load Locations". A window pops up.

Browse and find the "PG_Hospitals" file to load from. Leave the rest of settings as default.

Solve it.

Now, you should get the result which shows the shortest path from the first hospital to the 7th hospital passing through all other hospitals.

Make a screenshot of the shortest path map.

[7] Include a copy of the screenshot in your report.

Note:

- The default sequence of these hospitals is defined by the rank of their FIDs in the attribute table. However, you can change the sequence of these stops by dragging and moving a specific hospital to any order in the Network Analyst Window.
- So, it is very important that you know your data well before conducting the analysis. Sometimes, it is necessary that you modify the sequence in order to find out the optimal route. You may want to do some tests should you have time and interest.

Turn off the route layer to make better visualization for future sessions.

Now, switch to ArcGIS Pro.

Create a new map.

On the **Analysis** tab, in the **Tools** group, click **Network Analysis > Change Network Data Source**.

On the **Analysis** tab, in the **Tools** group, click **Network Analysis > Route**

First, make sure you are using the network dataset that you had created earlier.

Next, define the stops using "PG_Hospitals".

For Mode, it is automatically set as “Driving Distance” because the original street data does not have any information (e.g. speed limit) about time.

Use other default settings for now.

Run the analysis.

Make a screen shot of ArcGIS Pro showing the result on the map.

[8] Include the screenshot in your report.

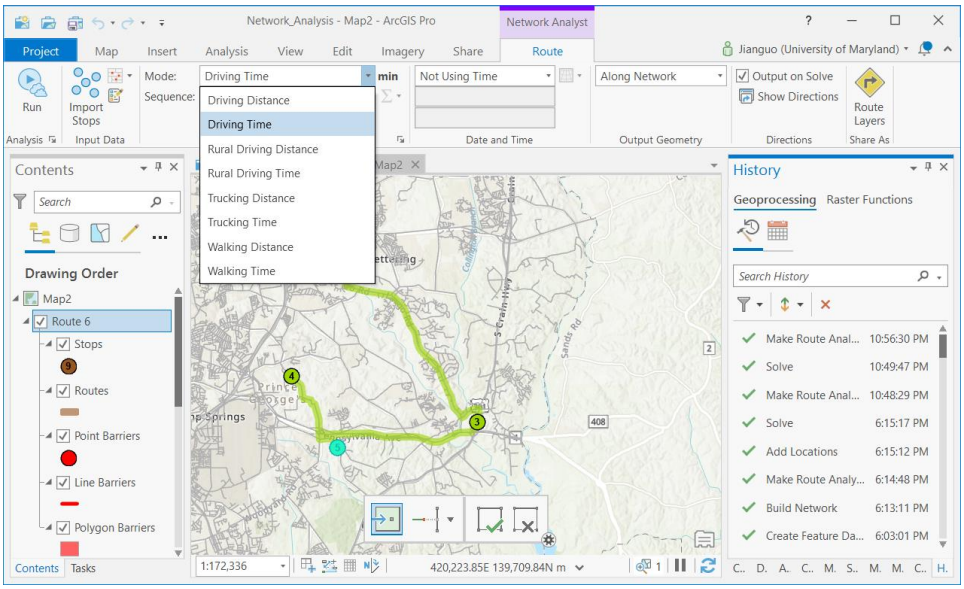
Now, you will change the data source.

On the **Analysis** tab, in the **Tools** group, click **Network Analysis > Change Network Data Source**. Choose **https://www.arcgis.com/**

Create a new Route analysis.

Next, define the stops using “PG_Hospitals”.

For Mode, choose “Driving Distance” so that you can compare the result to the previous one.



Run the analysis.

Make a screen shot of ArcGIS Pro showing the result on the map. It should show slight difference from the one generated with local data because the reference data is no longer limited to PG County boundary.

[9] Include the screenshot in your report.

Note:

- The network dataset from Esri server is the most complete because it covers the whole nation and also includes every street. In addition, it is frequently updated. Therefore, this data is the best of quality.
- Because the data from the Esri server has more details such as speed limits of all streets, it becomes possible to conduct analysis based on time.

Part III – Service Area Analysis

A network service area is a region that encompasses all accessible streets, that is, streets that lie within a specified impedance.

From now on, use ArcGIS Pro only. And you will continue to use the ArcGIS Online data source.

1. Service Area of a Single Facility

Make sure you turn on "PG_Hospitals" layer.

Now, create a new layer that contains only one specific hospital – **Prince George's Hospital Center**.

Add this new layer.

Let's assume that we want to find out the 10-minute service area of this specific hospital.

Create a new Service Area analysis.

Click on Import Facilities. For Input Location, find and select the new point layer you just created.

Run. This will add/define this hospital as the Facility.

On the Service Area Analysis Settings tab, we will set the Cutoffs as "10".

Solve it. (Click the Run button at the top left corner of the window.)

You should get the result which shows the 10-minute service area from Prince George's Hospital Center. The result (a polygon) is displayed at 50% transparency.

Zoom in and show the entire service area and then make a screenshot of the result.

[10] Include the screenshot in your report.

2. Service Areas of Multiple Facilities

In previous exercise, you created a service area for a single facility. And you can create service areas for multiple facilities at same time.

This time, define "PG_Hospitals" as the Input Locations.

On the Service Area Analysis Settings tab, we will set the Cutoffs as "10".

Solve it.

Now, you should get the result which shows the 10-minute service areas for all seven hospitals.

Make a screenshot of the result.

[11] Include the screenshot in your report.

Now, add the data layer – "PG_CarAccidents".

Your task is to find out how many car accidents are located within the 10-minute service areas of those hospitals.

Create a table to display the results and then make a screenshot.

[12] Include the screenshot in your report. How many car accidents are located within the 5-mi service area of these hospitals?

Turn off the service area layer to make better visualization for future sessions.

3. Multiple Ring Service Areas

So far, the service areas you have created are defined by the same service area size. It is possible to create service areas of different sizes around every facility.

Let's assume that we want to determine the service areas of each hospital within 5- minute, 10-minute, and 20-minute radius respectively.

Create a new Service Area analysis.

Use "PG_Hospitals" as the Input Locations.

For the Cutoff, enter "5, 10, 20".

Solve it.

Make a screenshot of the result, which shows a map of the multiple ring service areas.

[13] Include a copy of the screenshot in your report.

Turn off the service area layer to make better visualization for future sessions.

Part IV – Closest Facility Analysis

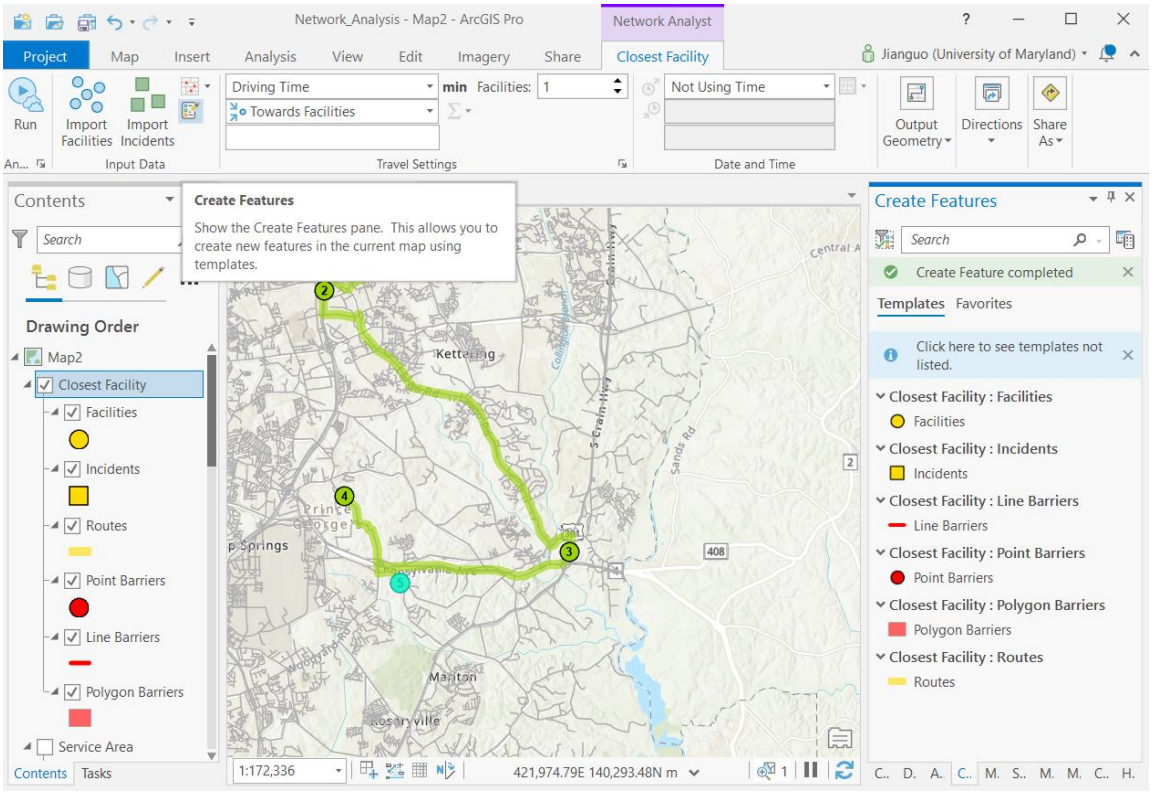
1. Closest Facility to a Single Incident

Let's assume that you want to find out the closest hospital (one and only one) to your home or any location (point).

Create a **Closest Facility** analysis.

Define the Facilities using "PG_Hospitals".

Now, create a point to represent an "Incident". You can create this incident anywhere on a street which you are interested in or familiar with.



Note:

- This point/location has to be on (or very close to) a road. This is because all the network analysis can only be possible when the points/locations are on the edges.

Solve it.

You should get the result which shows the closest hospital to the location (Incident) that you just defined.

Zoom in to show the result. Make a screenshot of the result.

[14] Include a copy of the screenshot in your report.

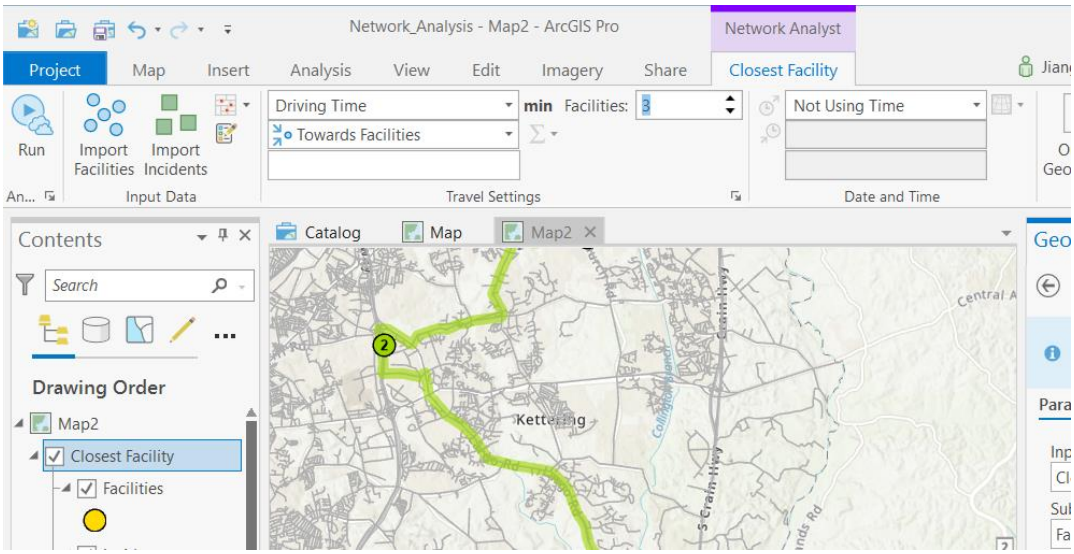
Turn off the Closest Facility layer to make better visualization for future sessions.

2. Closest Facilities to a Single Incident

Now, let's assume that you want to find the top three closest facilities to a location (point).

Use the same Facilities and Incident point you created earlier.

Type "3" in the box for "Facilities". This will allow the Network Analyst to find the top three closest facilities.



Note:

- This option can be very useful if you need to identify a certain number of top candidates. It is often used in the business world such as marketing for applications like optimization. It can also been used in resource management or land suitability.

Get the result which shows the top three closest hospitals to the location that you defined.

Zoom in to show the result. Make a screenshot of the result.

[15] Include the screenshot in your report.

3. Closest Facilities to Multiple Incidents

Let's assume that you want to find out the closest facilities to a few locations (points). And there is one and only one closest facility to each location.

Create a new **Closest Facility** analysis.

The Facilities are still "PG_Hospitals".

Then, define the Incidents with "Serious_CarAccidents".

Type "1" in the box for "Facilities".

You should get the result which shows the closest hospitals to the serious car accident sites. Only one hospital (the closest) is identified for each location.

Zoom in to show the result. Make a screenshot of the result.

[16] Include a copy of the screenshot in your report.

You can further redesign the question: What are the top 2 closest facilities to each of those locations?

Use the same Facilities and Incidents.

Type "2" in the box for "Facilities".

Zoom in to show the result. Make a screenshot of the result.

[17] Include a copy of the screenshot in your report.

Turn off the Closest Facility layer to make better visualization for future sessions.

Now, create a polygon barrier that intersects with the route. You can decide where to put this polygon as long as it intersects with the route. There are different options to create the polygon barrier: (1) creating a polygon feature from scratch, similar to the demo during the lab session. (2) Exact a polygon from an existing polygon feature dataset. It is up to you to create the polygon feature which will serve as the barrier.

Run the solver.

Zoom in to show the result. Make a screenshot of the result.

[18] Include the screenshot in your report.

Part V – OD Cost Matrix Analysis

The Closest Facility tool can help users find the route and driving directions among locations. The OD (Origin-Destination) cost matrix can do something similar. It can help find and measure the least-cost paths along the network from multiple origins to multiple destinations.

An OD cost matrix is a table that contains the network impedance from each origin to each destination. Additionally, it ranks the destinations that each origin connects to in ascending order based on the minimum network impedance required to travel from that origin to each destination.

The origin locations can be the same as the destinations. They can also be different.

Create a new **OD Cost Matrix.**

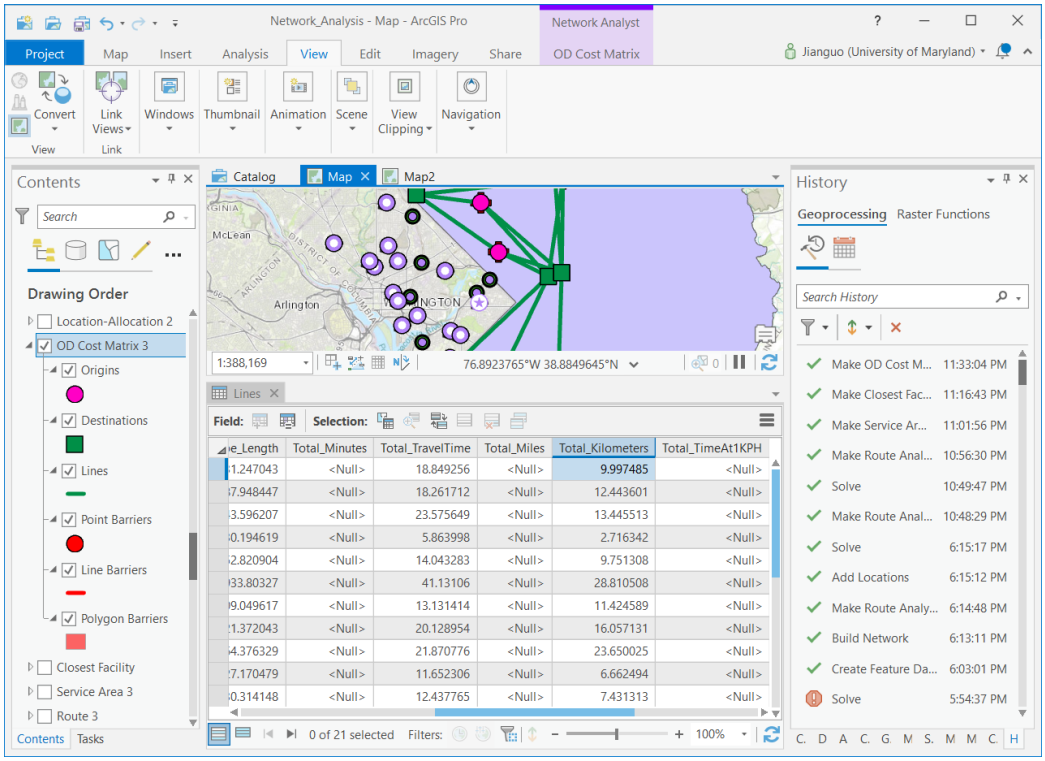
Now, define both Origins and Destinations with "PG_Hospitals".

Solve it.

The graphic shows the results of this OD cost matrix. Note that the lines appear to be straight.

Now, open the attribute table of the **Lines** listed in the folder OD Cost Matrix.

Make a screenshot of the results (both the map and the table). Similar to the example below.



[19] Include the screenshot in your report.

Note:

- Even though the graphic output lines seem to be straight and does not follow the network (for performance reasons), the distances stored in the attribute table actually reflect the travel distances along the network.
- The straight lines can be symbolized in various ways, such as by color, representing which point they originate from, or by thickness, etc. So, be creative.

Now, redesign the question: What are the distances between every hospital to every serious car accident site?

Create a new **OD Cost Matrix.**

Now, define Origins with "PG_Hospitals".

Then, define Destinations with "Serious_CarAccidents". (These accidents involved injuries and the vehicles were impounded.)

Solve the OD cost matric again.

Open the attribute table of the **Lines** listed within the folder – OD Cost Matrix.

Make a screenshot of the results.

[20] Include the screenshot in your report.

Note:

- The Closest Facility and OD Cost Matrix solvers perform very similar analyses.
- The main difference is in the output and the computation speed. OD Cost Matrix generates results more quickly but cannot return the true shapes of routes or their driving directions. It is designed to quickly solve large M x N problems and, as a result, does not internally contain the information required to generate route shapes and driving directions. Alternatively, the Closest Facility solver returns routes and directions but performs the analysis more slowly than the OD Cost Matrix solver.
- If you need driving directions or true shapes of routes, use the Closest Facility solver; otherwise, use the OD Cost Matrix solver to reduce the computation time.

Optional:

Assume you are the Director of Emergency Response for PG County. Briefly describe, in your own words, a particular application or problem that this OD Cost Matrix could be used for.

Part VI –Location-Allocation Analysis

Location-Allocation analysis is a process of finding the best locations for one or more facilities that will service a given set of points and then assigning those points to the facilities, taking into account factors such as the number of facilities available, their cost, and the maximum impedance from a facility to a point.

This analysis can help locate the facilities in a way that supplies the demand points most efficiently. It can solve the twofold location-allocation problem that simultaneously locates facilities and allocates demand points to the facilities.

There are seven different problem types which correspond to a variety of questions that you can investigate. The seven problem types are the following:

1. Minimize Weighted Impedance
    - Facilities are located such that the sum of all weighted costs between demand points and solution facilities is minimized.
2. Maximize Coverage
    - Maximize Coverage chooses facilities such that as much demand as possible is covered by the impedance cutoff of facilities.
3. Maximize Capacitated Coverage
    - Maximize Capacitated Coverage chooses facilities such that all or the greatest amount of demand can be served without exceeding the capacity of any facility.
4. Maximize Coverage and Minimize facilities

- Minimize Facilities chooses facilities such that as many demand points as possible are within the impedance cutoff of facilities. Additionally, the number of facilities required to cover all demand points is minimized.

5. Maximize Attendance
    - Maximize Attendance chooses facilities such that as much demand weight as possible is allocated to facilities while assuming the demand weight decreases with distance.
6. Maximize Market Share
    - Maximize Market Share chooses facilities such that the largest amount of allocated demand is captured in the presence of competitors. You specify the number of facilities you want it to choose.
7. Target Market Share
    - Target Market Share chooses the minimum number of facilities necessary to capture a specific percentage of the total market share in the presence of competitors. The total market share is the sum of all demand weight for valid demand points. You set the percent of the market share you want to reach and let the solver choose the fewest number of facilities necessary to meet that threshold.

In this exercise, we will test three of these problem types.

I. Minimize Weighted Impedance

Application scenario: Let's say you want to identify those hospitals in PG County so that the sum of all distances between demand points (public schools) and solution facilities (hospitals) is minimized.

Create a new **Location-Allocation** analysis.

Now, import the data – PG_Hospitals for "Facilities" and then import PG_PublicSchools for "Demand Points".

Note: You may want to reduce the symbol size of the schools so that the points don't appear too crowded on the map. The size "2" seems to be good in this case.

Select "Driving Time" for Travel Mode.

For the "Facilities To Choose", use the default "1".

For the "Problem Type", choose "Minimize Weighted Impedance".

For the Impedance Cutoff, use 30-minutes, because this will be enough to cover most part of the county in the search.

Solve it.

Make a screenshot of the result.

[21] Include the screenshot in your report.

Note: You should notice that some demand points are left out matching with any of those facilities (i.e. hospitals). This is because that those demand points fall outside of Impedance Cutoff search radius.

Now, you can change the number of Facilities to "3".

Run this analysis again.

How does this result look different from the previous one? Why?

Make a screenshot of the results.

[22] Include the screenshot in your report.

Now, you can change the Cutoff to "15" (minutes).

Still set the number of Facilities to "3".

Run this analysis again.

Note: You should notice that more demand points are left out because of smaller Impedance Cutoff (i.e. search radius).

Make a screenshot of the results.

[23] Include the screenshot in your report.

II. Maximize Coverage

Application scenario: Let's say you want to identify those hospitals in PG County so that all or the greatest amount of demand points is within a specified impedance cutoff (i.e. 10-mile).

Start a new Location-Allocation Analysis.

Use the same facilities and demand points.

For Travel Mode, choose "Driving Time".

For the "Problem Type", choose "Maximize Coverage".

For the "Facilities To Choose", enter "3", i.e. we are trying to identify only three facilities to cover the most demand points.

For the Impedance Cutoff, use 15.

Solve it.

Note: You should see only three hospitals are selected to cover the demand points. This coverage is maximized based on these three specific facilities, given the 15-minutes Impedance Cutoff. In another words, if any combinations of three facilities are chosen, the number of demand points covered will always be less.

Make a screenshot of the results.

[24] Include the screenshot in your report.

III. Maximize Coverage and Minimize Facilities

Application scenario: Let's say you want to identify the minimum number of hospitals needed to cover all or the greatest amount of demand points within a specified impedance cutoff (i.e. 15-minute). At the same time, the key is that the number of facilities required to cover all demand points is minimized.

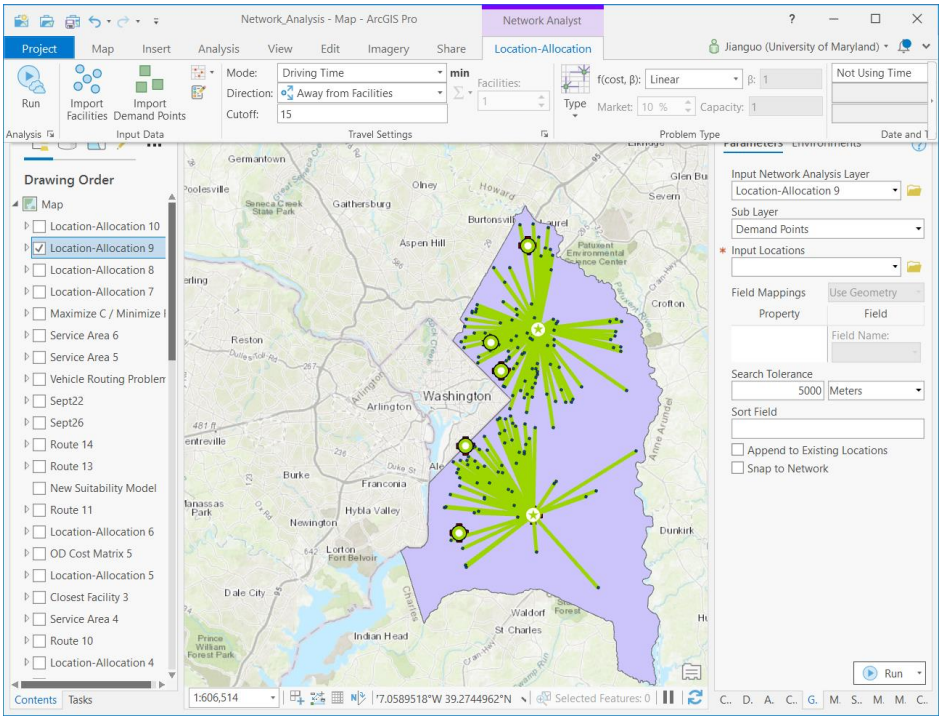
Start a new Location-Allocation Analysis.

Use the same facilities and demand points.
For Travel Mode, choose "Driving Time".

For the "Problem Type", choose "Maximize Coverage and Minimize Facilities".

You will notice that the "Facilities" is not available to enter a value. This makes sense because it is the question and you are trying to find out the minimal number of facilities.

For the Impedance Cutoff, use 15.



Solve it.

You should see that totally seven hospitals are selected to cover the demand points. So, seven is the minimum number of facilities needed to cover all or the greatest amount of demand points within the specified impedance cutoff (15-minute).

Make a screenshot of the results.

[25] Include the screenshot in your report.

Now, change the Cutoff value to 30 (minutes).

Solve it again.
This time you should notice that only two hospitals are selected to cover the demand points. So, two is the minimum number of facilities needed to cover all or the greatest amount of demand points within the specified impedance cutoff (30-minute).

Part VII – Network Analysis with ArcGIS Online

(Optional)
In this exercise, you need to create a table of at least ten addresses. These addresses can be from anywhere in the DC/MD/VA area and represent anything of your interest, for example, your favorite restaurants.

To save your time, I have already prepared a table of eleven addresses representing some of Walmart and Target stores in Maryland.

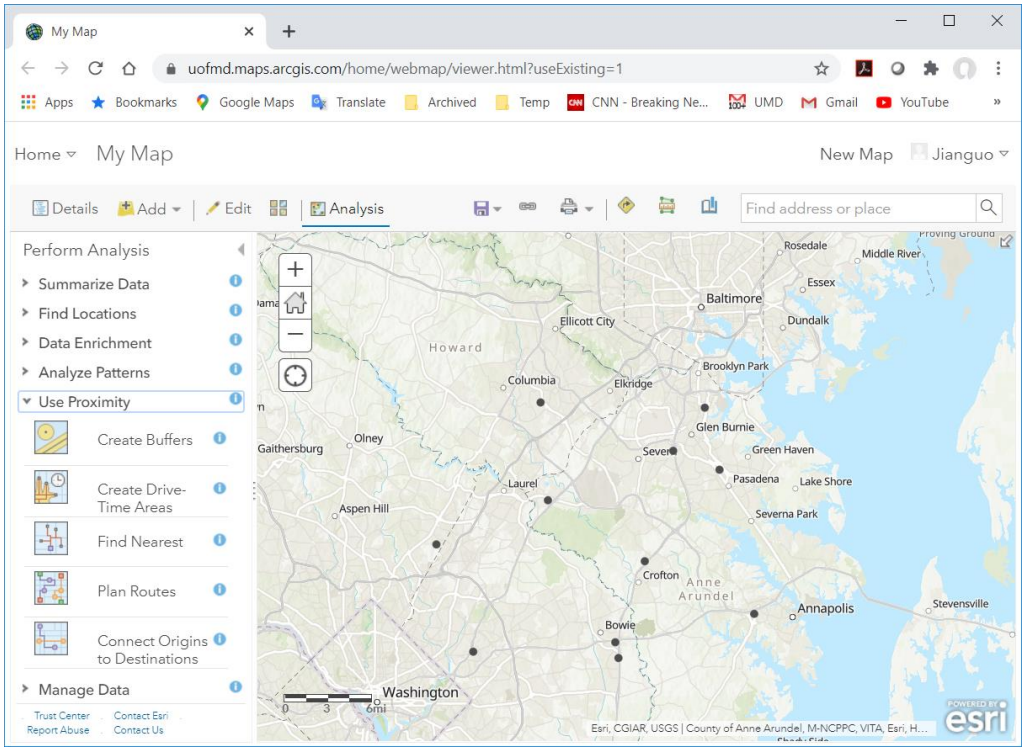
Your tasks:

1. Geocode these addresses using ArcGIS Online
2. Conduct a Route Plan analysis

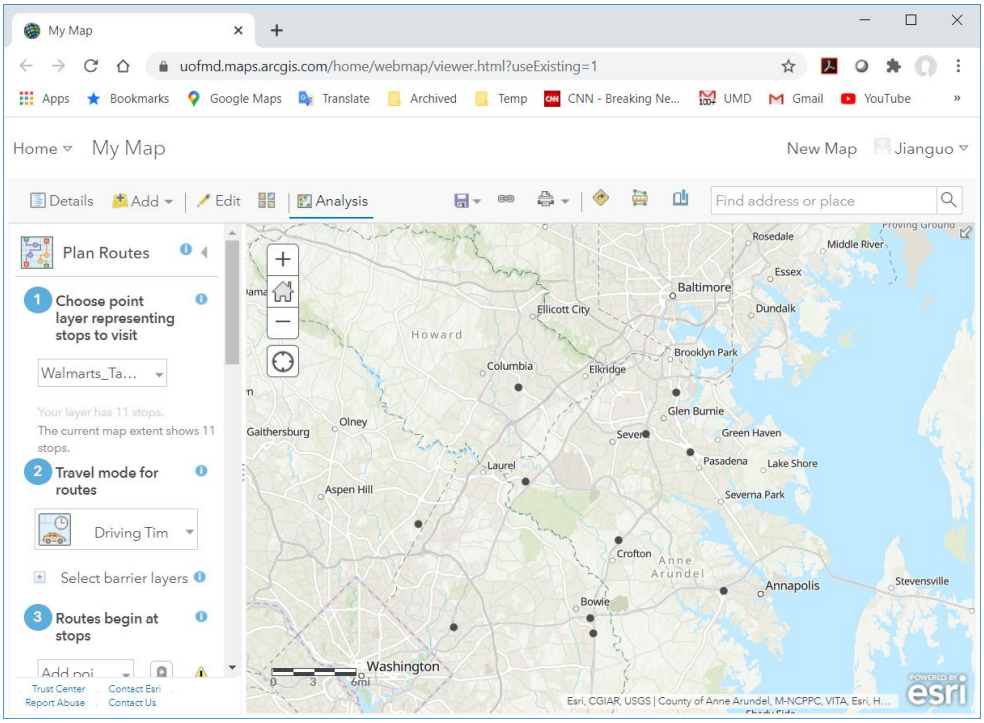
Log into ArcGIS Online – http://www.arcgis.com , follow the instructions as I demonstrated in the lab session and geocode this table of addresses.

Zoom to the geocoding results.

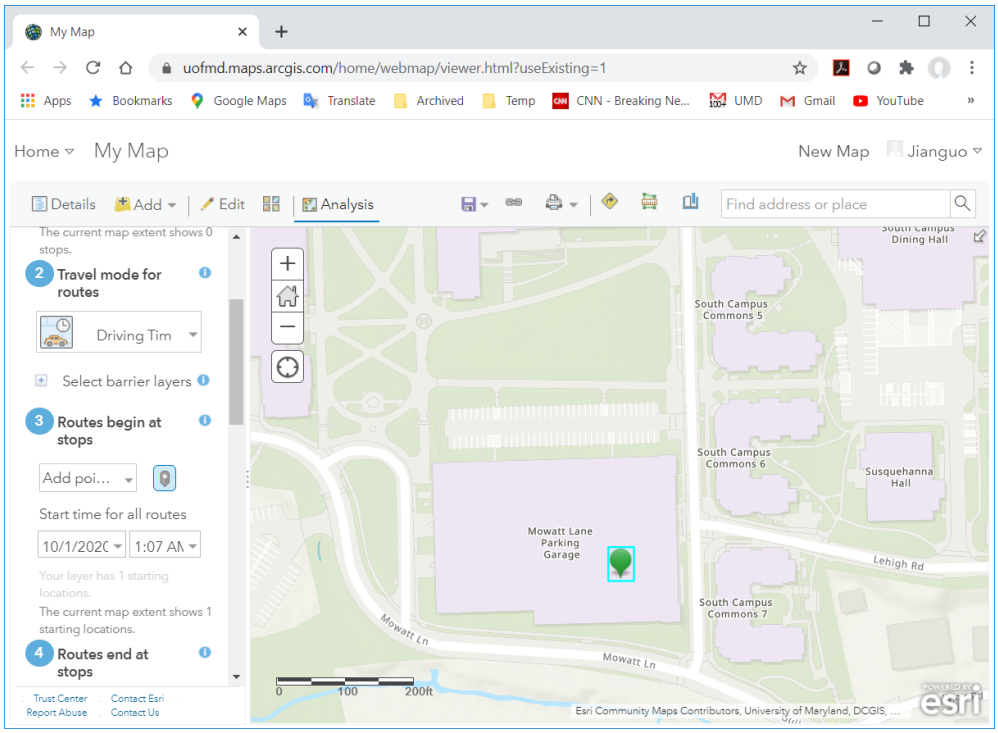
Click Analysis < Use Proximity < Plan Routes.



For Travel Mode, choose “Driving Time”.



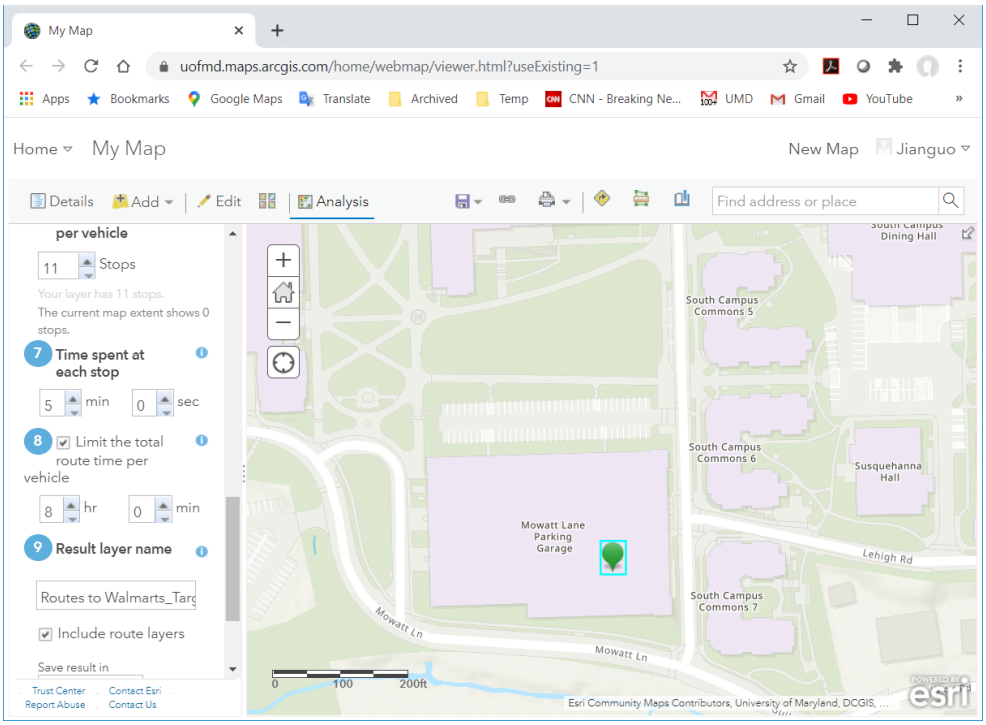
For the beginning stop, create a point that is somewhere on UMD campus, for example, Mowatt Lane Garage as shown in the screenshot below.



For Maximum number of vehicles to route, choose “1”.

For Maximum number of stops per vehicle, choose "11" (which is the total number of stores).

Make sure you uncheck the small box in front of "Use current map extent".



Make a screenshot of the results.

[26] Include the screenshot in your report.

Open the attribute table of Routes to "Walmart Target Stores in MD – Assigned Stops". Inspect the attributes in the table carefully so that you have a good understanding about what kind of information being generated in this analysis.

Save the amp.

Also, practice sharing it in ArcGIS Online community.

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