Exercise 14: Network Analysis

In this exercise we provide a brief introduction to network analysis in ArcGIS Pro. First, you will convert tables of addresses to spatial coordinates using geocoding. You will then produce a network dataset from line vector features that are topologically integrated. Using the coordinates and network dataset, you will then solve some network problems including finding routes, defining service areas, finding closest facilities to individual locations, and finding the facility that is collectively closest to all facilities. You will work with problems associated with pizza deliveries in Morgantown, WV, which will involve solving network problems along a road network. However, these tools can be used to solve a variety of problems along different types of networks, such as stream networks.

Topics covered in this exercise include:

1. Geocode addresses
2. Create a network dataset
3. Solve routing problems using network analysis
4. Solve service area problems using network analysis
5. Solve closest facility problems using network analysis
6. Solve location-allocation problems using network analysis

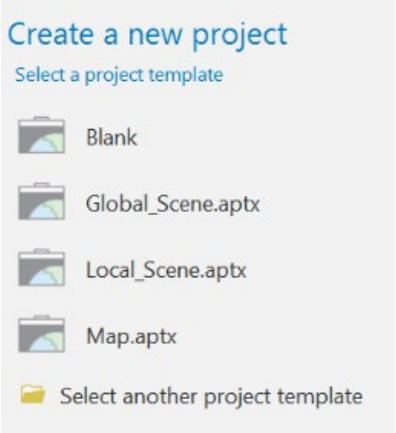
Step 1. Create and Prepare a New Project

Before you start, create a folder where you would like to save your work, name it Exercise_14.

- Download the **Exercise_14** data from https://www.wvview.org/. All lab materials are available on the course webpage and linked to the exercise. You will need to extract the compressed files and save it to the location of your choosing.

Now, you will need to create a new project in which to work.

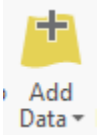
Open ArcGIS Pro. This can be done by navigating to All Apps followed by the ArcGIS Folder. Within the ArcGIS Folder, select ArcGIS Pro. Note that you can also use a Task Bar or Desktop shortcut if they are available on your machine.



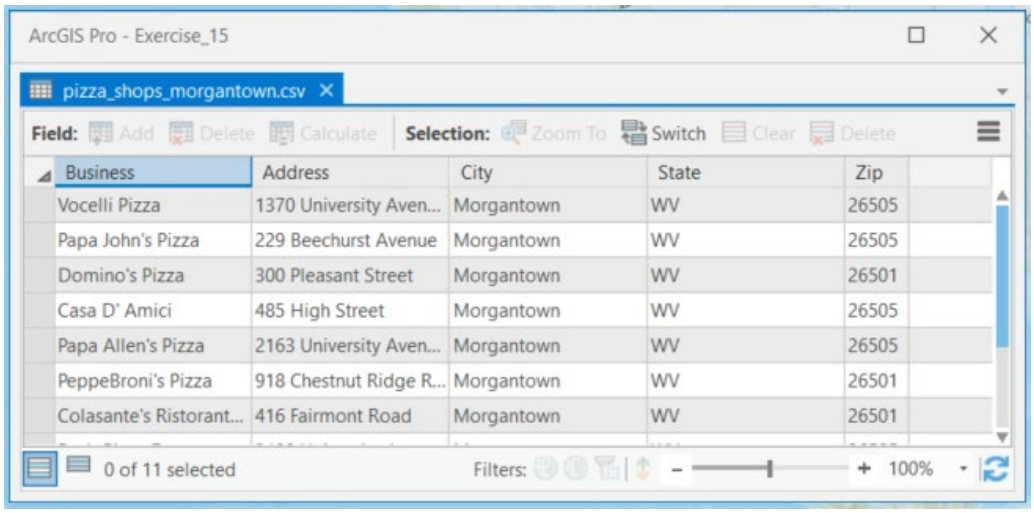
- Once ArcGIS Pro launches, select **Map.aptx** under Create a new project on the right side of the page.
- In the Create a New Project Dialog Box, name your new project **Exercise_14** and save it to the **Exercise_14** folder you created. You can leave "Create a new folder for this project" option selected.

You have now created a new project. Since you used the **Map.aptx** project template, a map has already been added, but it does not contain any data layers other than a basemap. So, you will need to add the required data.

- Using the Add Data button, add the following files from the **Exercise_14** folder you downloaded: **hotels_morgantown.csv** and **pizza_shops_morgantown.csv**.

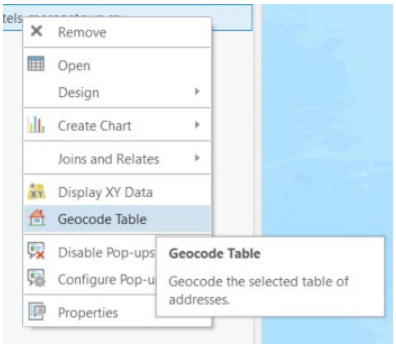


The **hotels_morgantown.csv** file provides addresses for some hotels in Morgantown, West Virginia while the **pizza_shops_morgantown.csv** file provides addresses for some pizza shops in the city. No geographic data were added to the map because these data layers are not spatial data. They are simply tables in CVS (comma-separated values) format that provide address locations. Below is the address locations for the pizza shops. You can view the table by right-clicking on the table in the Contents Pane then selecting Open.



Step 2. Geocode Addresses

You will now convert the table of addresses to spatial point features using geocoding and an address locator, which contains information including address attributes, indexes, and queries that allow you to geocode addresses. An address locator has been provided in the **Exercise_14** folder.



- Right-click on the **hotels_morgantown.csv** layer in the Contents Pane then select Geocode Table. This will open the **Geocode Addresses Tool**.

Note: ESRI offers geocoding services through the ESRI World Geocoder that can be accessed with a valid ArcGIS Online account. We will not make use of this service here.

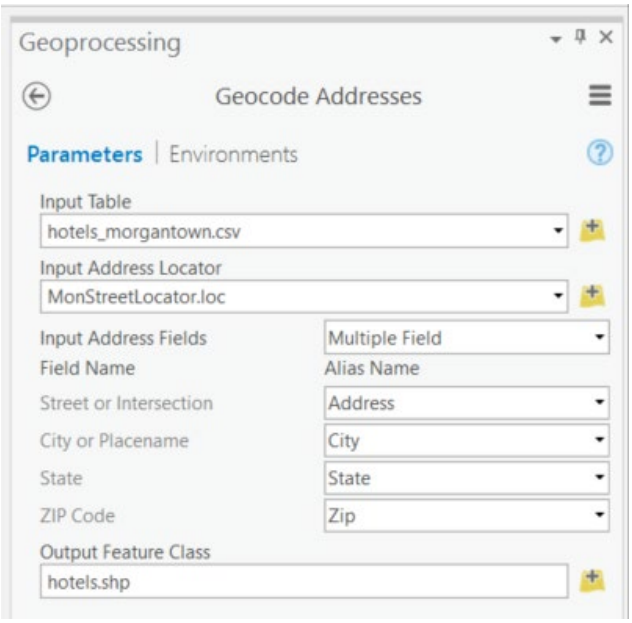
- In the **Geocode Addresses Tool**, make sure the Input Table is set to the **hotels_morgantown.csv** layer.
- Set the Input Address Locator to the **MonStreetLocator.loc** file located in the **Exercise_14** folder you downloaded.

Note: This is an address locator that works only for addresses within Monongalia County, West Virginia.

- The correct Input Address fields should populate automatically. However, just to confirm, make sure the settings are as follows:
  a. Input Address Fields = Multiple Field
  b. Street or Intersection = "Address"

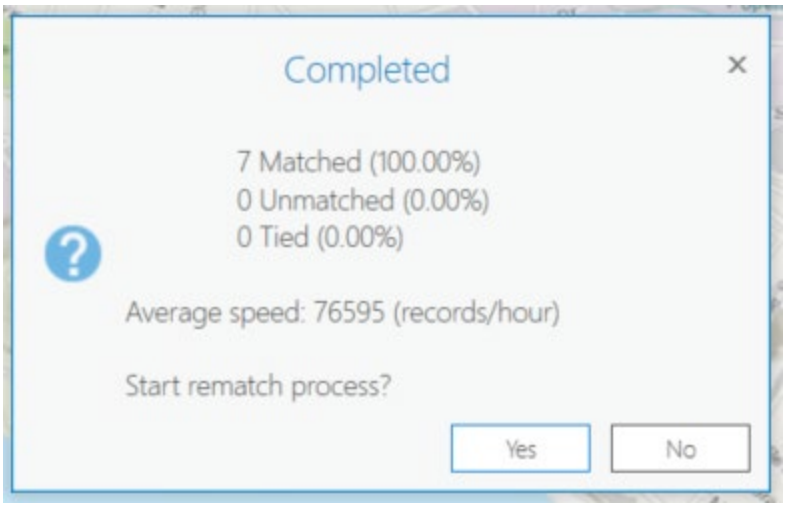
c. City or Placename = "City"
d. State = "State"
e. ZIP Code = "Zip"

- Name the output **hotels.shp** and save it to the **Exercise_14** folder you created.
- Click Run to execute the tool.

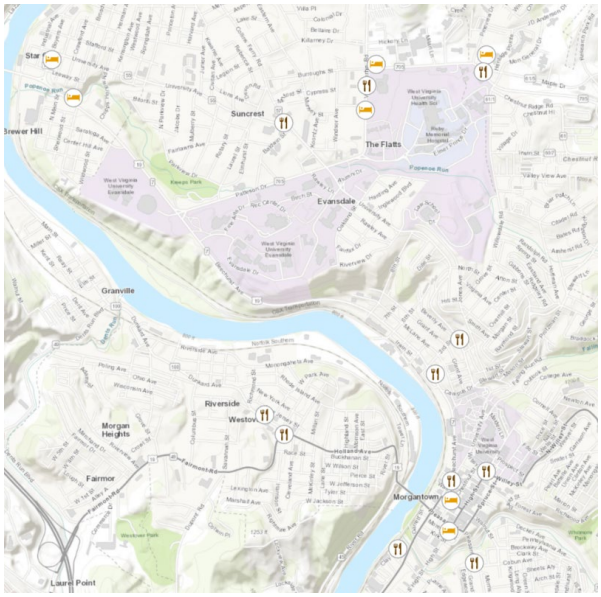


The tool should execute with 7 matched, 0 unmatched, and 0 tied addresses. The new shapefile should automatically be added to the Contents Pane. If some points were unmatched or tied, this means that the tool was not able to locate the address using the available address locator. This could happen for many reasons. For example, the address locator could be outdated or the address could be incomplete or incorrect. If you attempt to geocode addresses and are not able to locate all of them, we would suggest checking the table to make sure it is complete and that there are no errors. You can also attempt to geocode the addresses using a different address locator, such as the ESRI World Geocoder.

Note: You may get two possible matches for one of the hotels. If this happens, you can ignore it for this exercise and just use the first match.



- Repeat this process for the **pizza_shops_morgantown.csv** file. Name the output **pizza_shops.shp** and save it to the **Exercise_14** folder. You may get multiple matches for one of the shops. If so, just choose the first option for this exercise.
- Take some time to change the symbology of the point layers.



Step 3. Create a Network Dataset

If you do not have access to ArcCatalog, you will not be able to complete this section. We have provided the required network dataset in the provided transport_data_prepared.gdb. You can use that copy of the file and skip ahead to Step 4 if you do not have ArcCatalog.

Before you can perform network analysis, you need a network dataset. ESRI offers a network dataset that can be accessed through ArcGIS Online with a

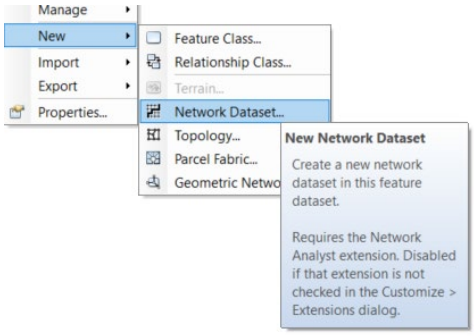
valid account. However, you will produce your own network here. This can be accomplished in ArcCatalog.

- Open ArcCatalog. This can be done by navigating to All Apps followed by the ArcGIS Folder. Within the ArcGIS folder, select ArcCatalog. The icon is a yellow file cabinet containing a globe. Note that you can also use a Task Bar or Desktop shortcut if they are available on your machine.

- Once ArcCatalog loads, navigate to your **Exercise_14** folder.
- Right-click in the folder space then choose New followed by File Geodatabase. Name the file geodatabase **transport_data.gdb**.
- Inside of the new geodatabase, create a feature dataset called **transportation** by right-clicking inside of the geodatabase then selecting New followed by New Feature Dataset.
- In the first screen, set the name to **transportation**. Click Next.
- Set the coordinate system to NAD 1983 UTM Zone 17N. This is available at the following location: Projected Coordinate Systems → UTM → NAD 1983. Click Next.
- You do not need to set a vertical coordinate system. Just click Next.
- You do not need to change the tolerance settings. Just click Finish.
- Enter the new feature dataset. Right-click then select Import followed by Feature Class (multiple). This will open the **Feature Class to Geodatabase (multiple) Tool**.
- For the Input Features, navigate to the **Exercise_14** folder and select the **morgantown_roads.shp** file. You do not need to change any additional settings here. Click OK to execute the tool.

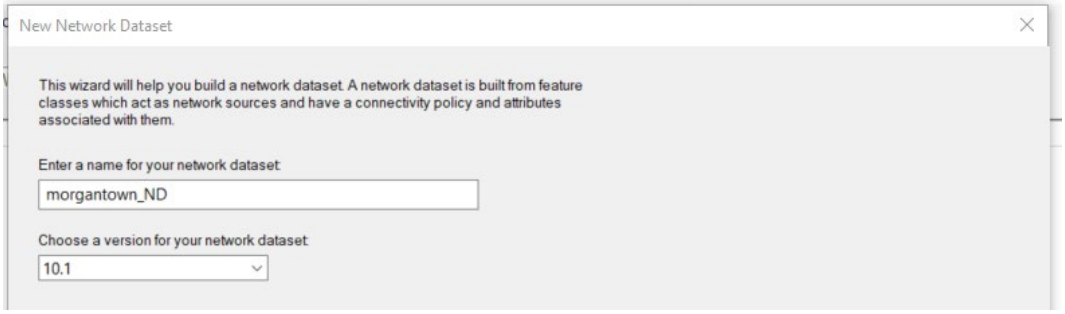
You are now ready to build a network dataset from the roads that were just added to the geodatabase.

- Inside of the feature dataset, right-click then select New followed by Network Dataset. This will open the New Network Dataset Wizard.

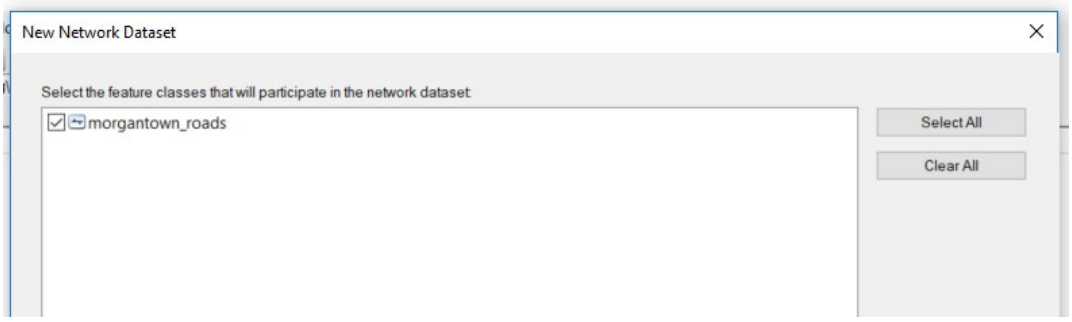


Note: If this option is not available you need to activate the Network Analyst Extension. Do so by going to Customize followed by Extensions. Make sure Network Analyst is checked.

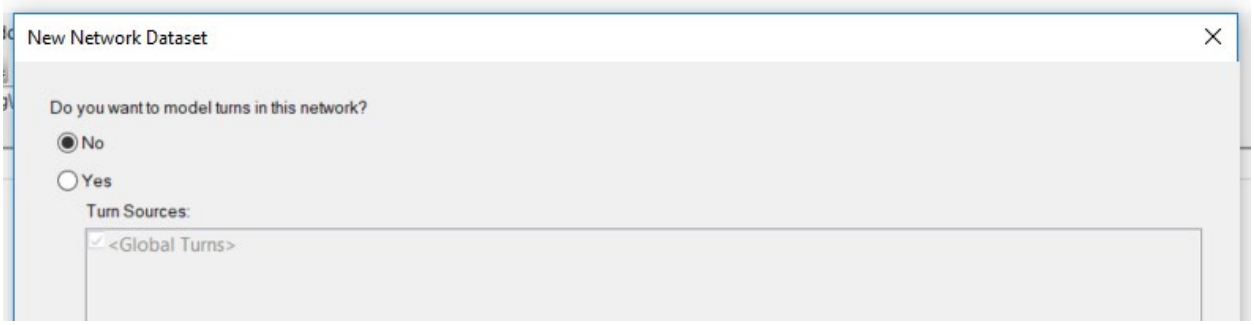
- Click next on the first screen. Name the network **Morgantown_ND**.



- On the next screen, make sure that **morgantown_roads** is checked. Click Next.

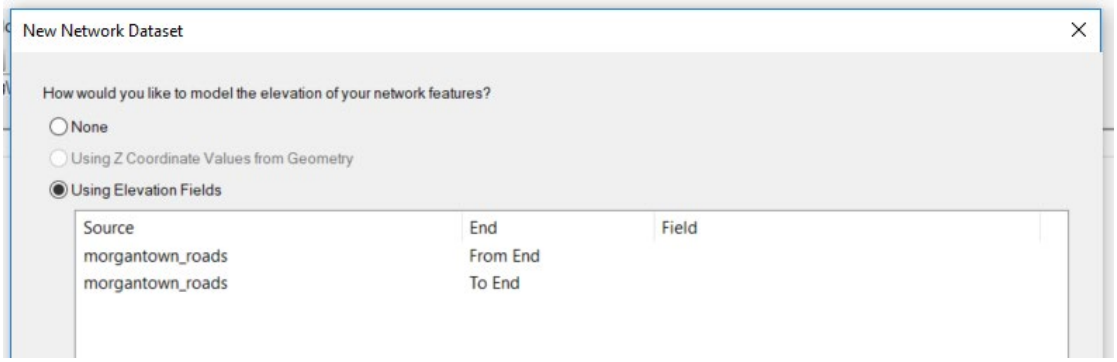


- Click No for "Do you want to model turns in this network?" You will not need this feature for the exercise.

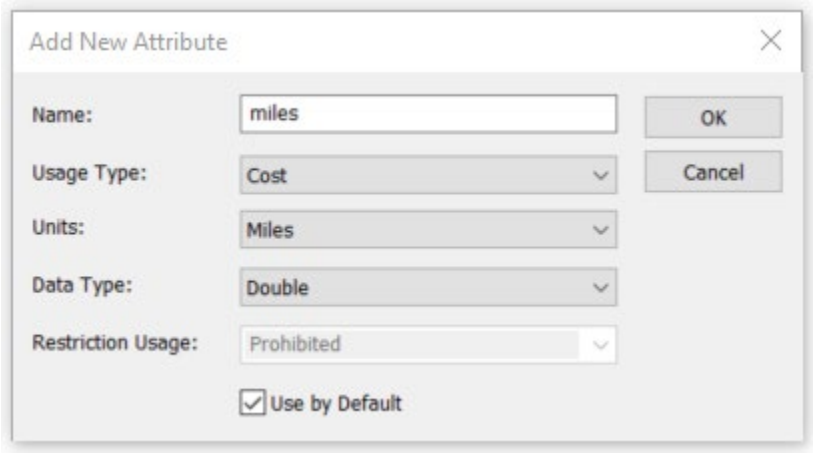


- Click Next on the next screen. You do not need to make any changes here.

- Click Next on the next screen. You do not need to make any changes here.

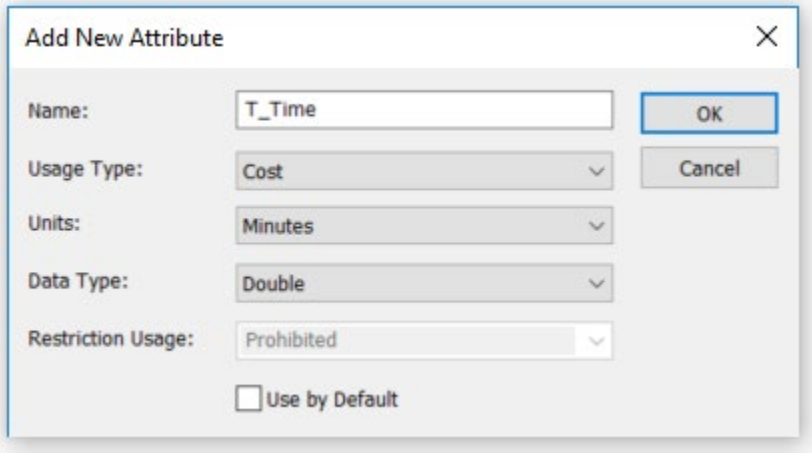


- On the next screen, click on the Miles attribute then select Remove to remove it.
- Click Add. In the Add New Attribute window, set the Name to miles, the Usage to Cost, the units to Miles, and the Data Type to Double. Make sure that Use by Default is selected. Click OK to save this new attribute.



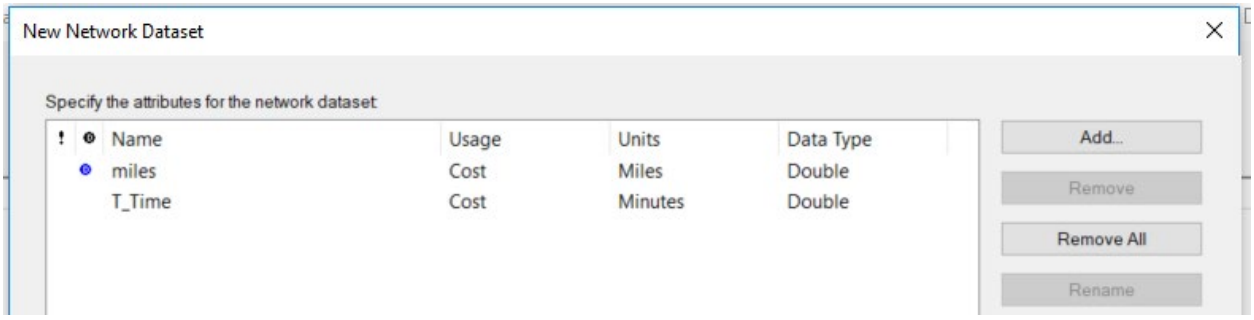
- Repeat this process to add another new attribute. Click Add. In the Add New Attribute window, set the Name to T_Time, the Usage to

Cost, the units to Minutes, and the Data Type to Double. Make sure that Use by Default is not selected. Click OK to save this new attribute.

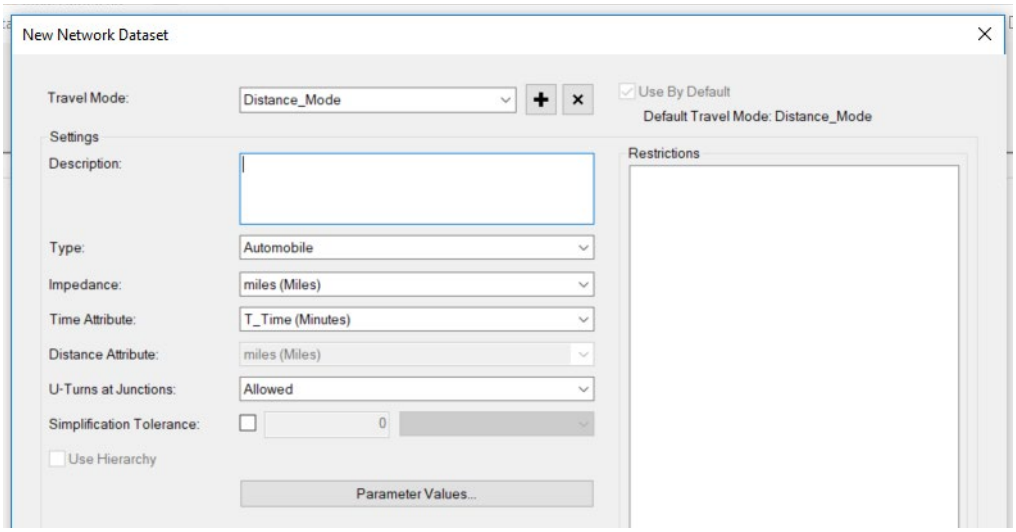


Note: In your network you would like to model both the travel distance and time. That is why you are defining these attributes. The miles attribute references a field in the attribute table of the roads layer named "miles" that provides the length of the specific road segment in miles. The "T_Time" field provides the travel time, which was derived by dividing the distance by the speed limit. So, these fields can be used to model travel cost in regards to distance and time.

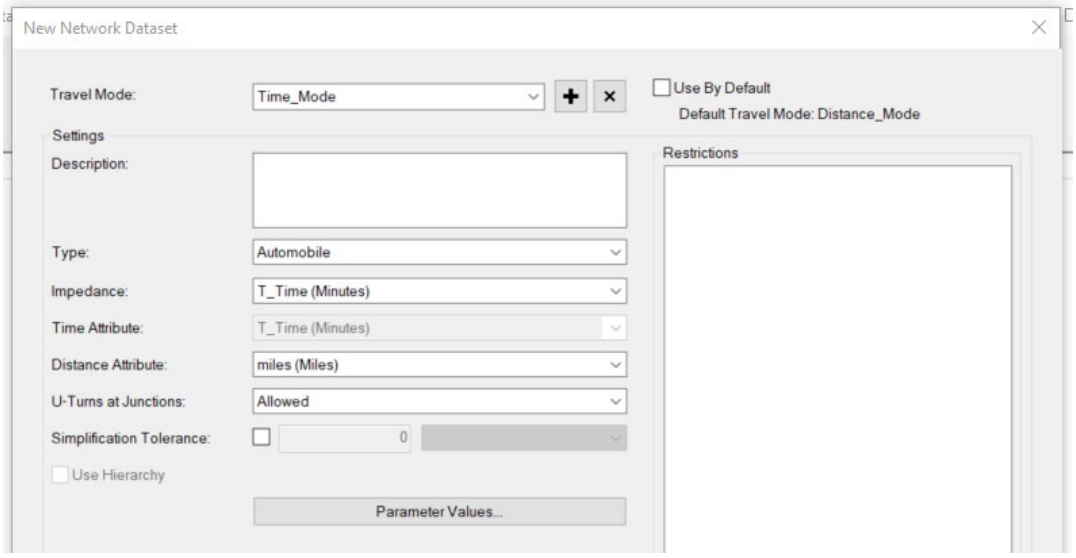
- Click Next to move on to the next screen.



- Name the first Travel Mode Distance_Mode. Set the Type to Automobile, the Impedance to miles (Miles), the Time Attribute to T_Time (Minutes), the Distance Attribute to miles (Miles), and make sure U-Turns at Junctions is set to Allowed. This should be the default Travel Mode.



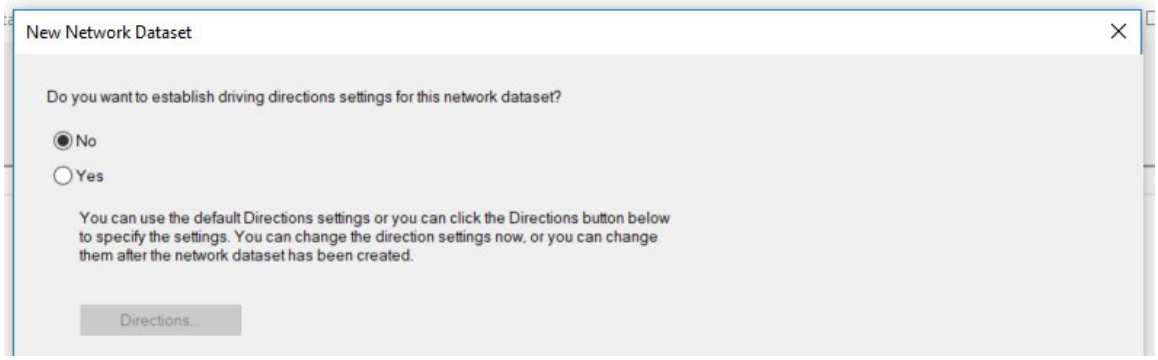
- Create a second travel mode. Click the Add button next to Travel Mode. Name the second Travel Mode Time_Mode. Set the Type to Automobile, the Impedance to T_Time (Minutes), the Time Attribute to T_Time (Minutes), the Distance Attribute to miles (Miles), and make sure U-Turns at Junctions is set to Allowed. This should not be the default Travel Mode.



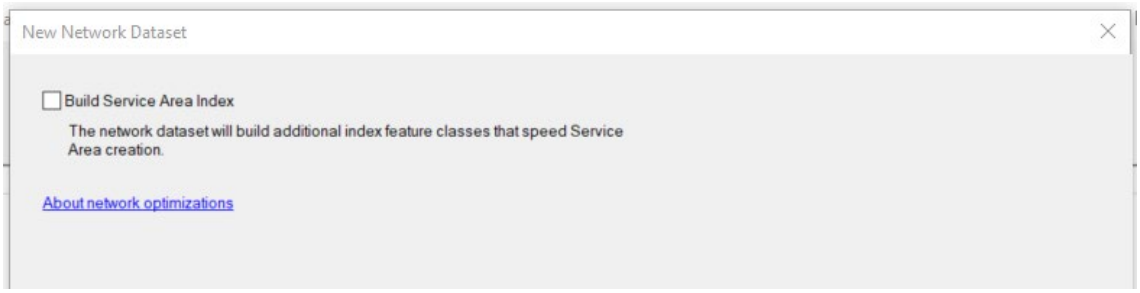
Note: Setting travel models will allow you to solve network problems based on different parameters on which to optimize based on impedance. Here you are setting up two modes, one for distance and one for time. So, you will later be able to solve problems using both distance and time.

- Click Next to move on to the next screen.

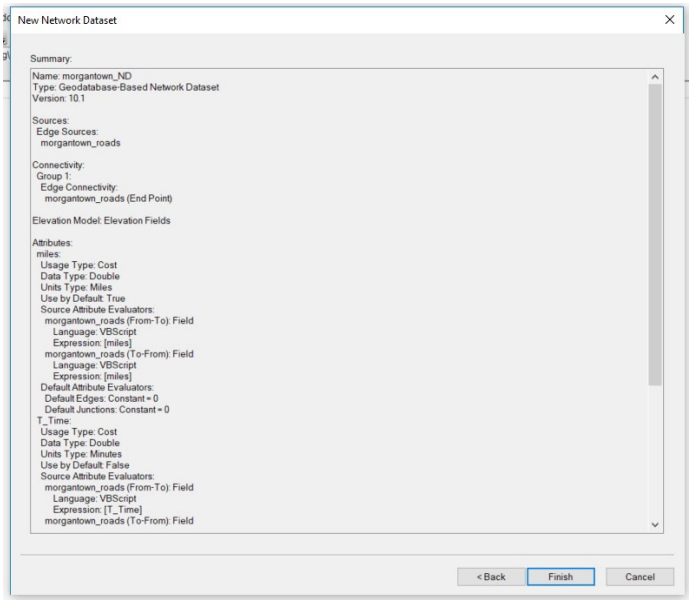
- On the next screen select No for "Do you want to establish directions settings for this network." You will not be able to generate directions from the road data provided.



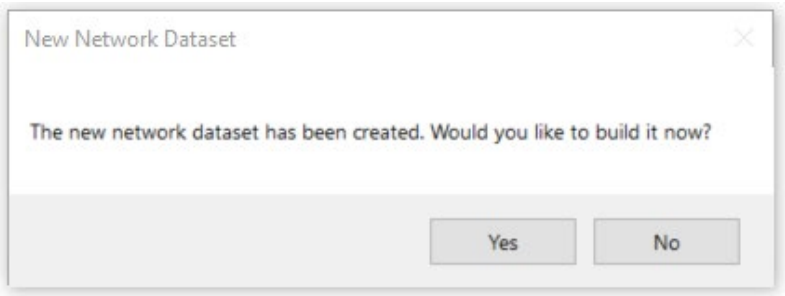
- Click Next to move on to the next screen.
- Do not select "Build Service Area Index." This is not necessary here. Click Next to move on to the next screen.



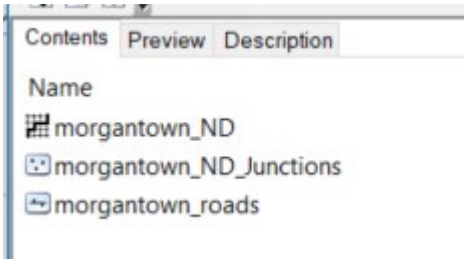
- The last screen provides a summary of your network settings. Click Finish to create the network.



- Click Yes on the pop-up that asks if you want to build the new network.



Once the network dataset is built, it will be added to the feature dataset in the geodatabase. A junctions point layer will also be generated.

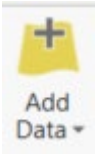


Note: The roads layer that was used here to generate the network dataset is made available through the 2011 United States Census as part of the TIGER (Topologically Integrated Geographic Encoding and Referencing) data. The road lines are topologically integrated, as the name implies. This dataset does not include speed limits for each road segment. We generated the data using the available road codes as an estimate, so they do not represent real speed limits. As a result, the travel time estimates you generate here will not represent real travel times. Also, you will not be able to model all of the complexities of the road network here, such as one-way streets and turning rules. However, these data will suffice for this introductory exercise.

Step 4. Analyzing Routes

Now that you have a network dataset, you can start using it to conduct network analysis. We will begin with route analysis.

- Return to ArcGIS Pro.
- Add the network dataset you just created (**Morgantown_ND**) using the Add Data button.

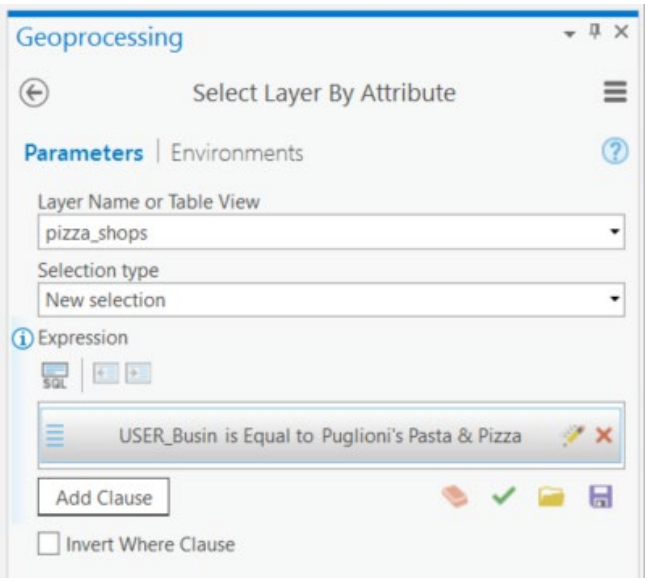


- You don't need to see the network to conduct the network analysis. So, we would suggest not making it visible on the map. Uncheck it in the Contents Pane.

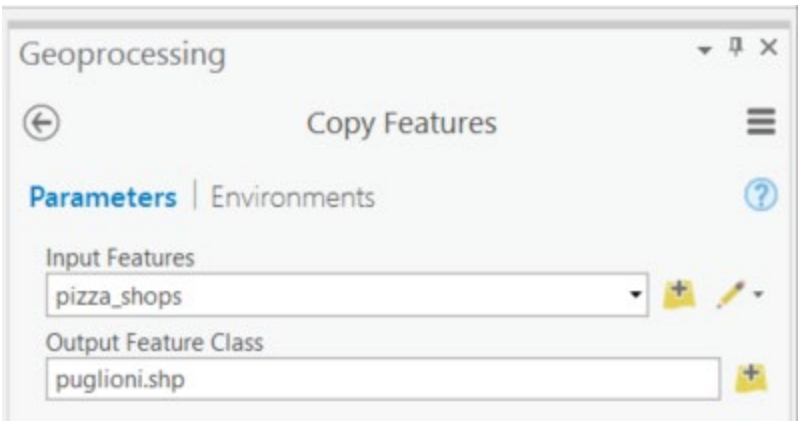
Problem 1: You are a pizza delivery person and need to make a delivery from Puglioni's Pasta & Pizza to the Hotel Morgan. Find the fastest route based on distance.

First you will need to select the restaurant and hotel of interest from the larger dataset. You can do this using the **Select by Attributes Tool**. Start by selecting the pizza shop.

- Click on the **Select by Attribute Tool** in the Selection area under the Map Tab. This will open the **Select by Attributes Tool**.
- Make sure the Layer Name or Table View is set to the **pizza_shops** layer.
- Make sure the Selection type is set to New selection.
- Create the following clause: "USER_Busin" is Equal to Puglioni's Pasta & Pizza.
- Add the clause.
- Click Run to execute the selection.



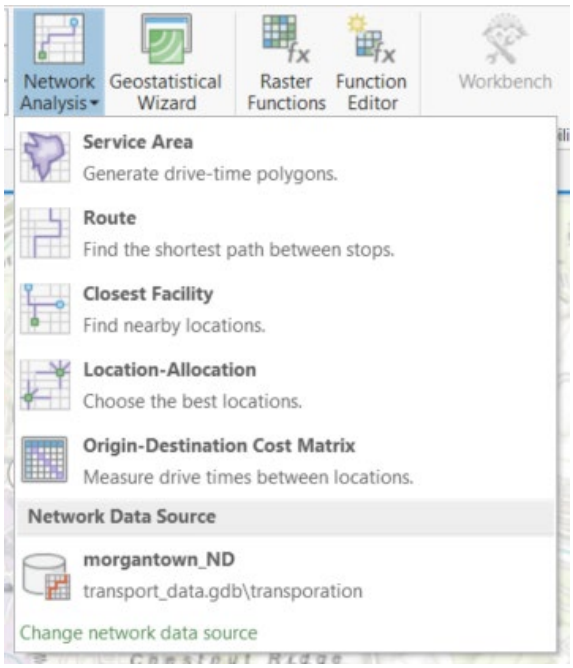
- Right-click on the **pizza_shops** layer in the Contents Pane. Right-click then select Export followed by Export Features. This will open the **Copy Features Tool**.
- Make sure the Input Features is set to **pizza_shops**.
- Name the Output Feature Class **puglioni.shp** and save it to the **Exercise_14** folder.
- Click Run to execute the tool. The result will automatically be added to your map.



- Repeat this process to extract the point representing the Hotel Morgan. The hotel names are in the "USER_Hotel" field. Name the output **hotel_morgan.shp**.

You now have the required locations. You can now begin setting up the route analysis.

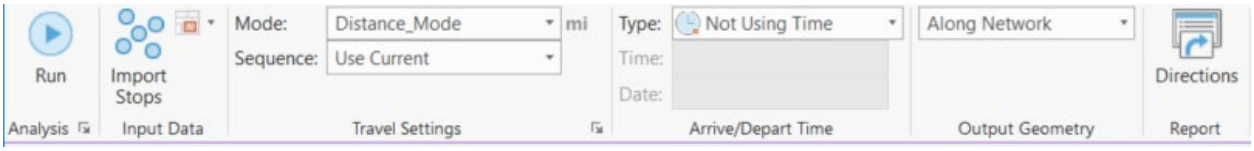
- Navigate to the Analysis Tab. Click on Network Analysis followed by Route. This will generate a new Route Layer.



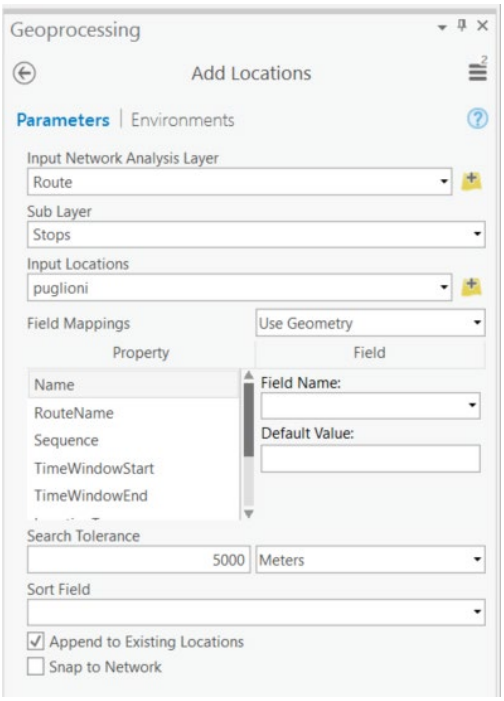
Note: Make sure that the Network Data Source is set to the **Morgantown_ND**. If it is set to a different dataset, you will need to change it to the **Morgantown_ND** network using the "Change network data source" option.

- Navigate to the Route Tab.

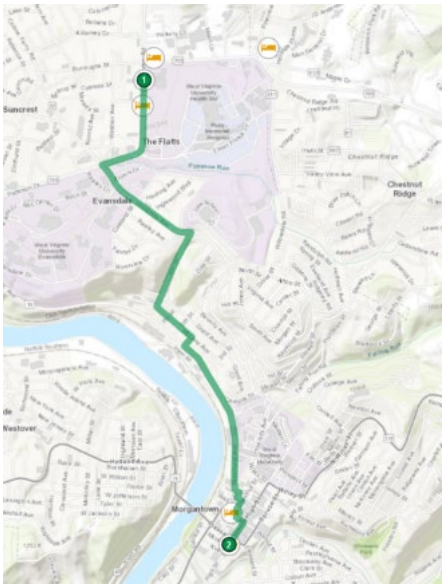
Note: The Routes Tab will only be available when the **Route** layer is selected in the Contents Pane.



- Click on the Import Stops button in the Input Data section of the **Route** Tab. This will open the **Add Locations Tool**.
- Make sure the Input Network Analysis Layer is set to the **Route** layer.
- Make sure the Sub Layer is set to **Stops**.
- Set the Input Locations to the **puglioni** layer.
- You do not need to change any additional settings.
- Click Run to execute the tool. This will add the restaurant as a stop.



- Repeat the process to add the **hotel_morgan** feature. Make sure that Append to Existing Locations is selected in the **Add Locations Tool**.
- Back in the Routes Tab, make sure the Mode is set to "Distance_Mode."
- Click Run in the Route Tab to perform the Analysis.



A route should be added to your map. This route is also added to the **Routes** sublayer in the **Route** layer. Right-click on this sublayer in the Contents Pane and open the attribute table to answer the following questions.

Question 1. What is the total distance for this route in miles (this is provided in the "Total_miles" field)? (2 Points)

Question 2. What is the total travel time for this route in minutes (this is provided in the "Total_T_Time" field)? (2 Points)

Problem 2: You are a pizza delivery person and need to make a delivery from Puglioni's Pasta & Pizza to the Hotel Morgan. Find the fastest route based on time.

- To obtain this answer, you simply need to run the routes analysis again. However, this time change the Mode in the Travel Settings area of the Routes Tab to "Time_Mode."

Use the result to answer the following questions.

Question 3. Did optimizing for time change the route? (2 Points)

Question 4. What is the total distance for this route in miles (this is provided in the "Total_miles" field)? (2 Points)

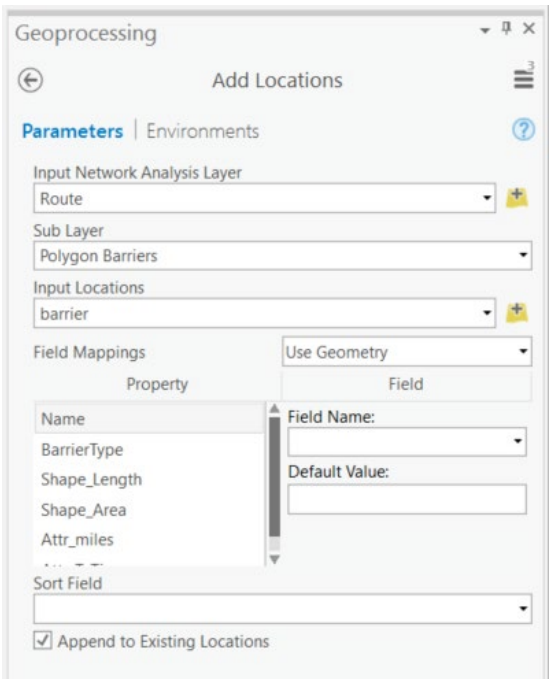
Question 5. What is the total travel time for this route in minutes (this is provided in the "Total_T_Time" field)? 2 Points)

It is also possible to input barrier features as lines or polygons to include in a network analysis. This could be useful for modeling detours or road closures. You will now conduct route analysis with barriers included.

Problem 3: You are a pizza delivery person and need to make a delivery from Puglioni's Pasta & Pizza to the Hotel Morgan. However, there is currently a parade in progress, so certain roads are closed. Find the best route based on distance that won't require you to travel on a closed road.

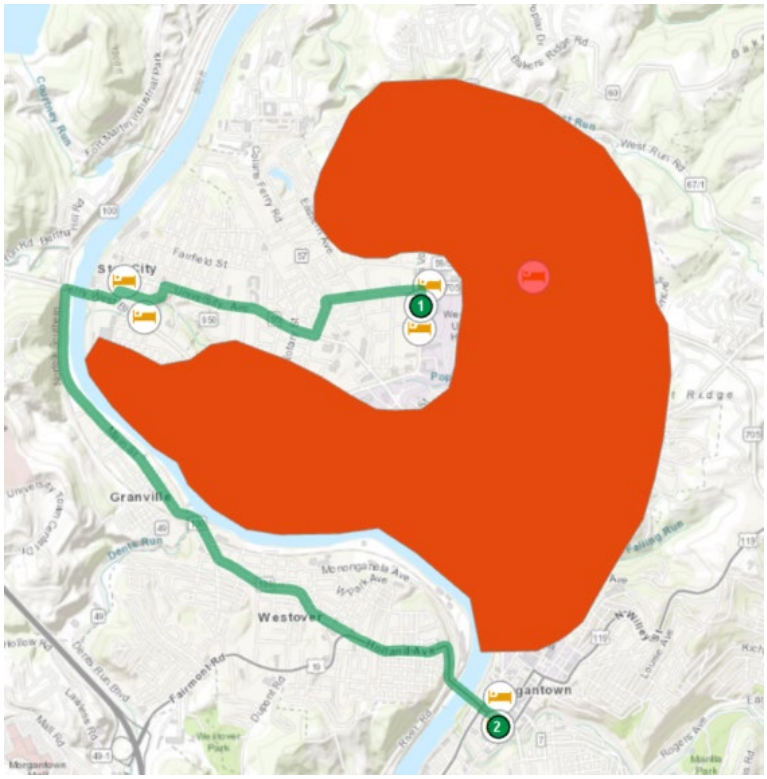
You can answer this question by adding to the analysis defined above. You simply need to add a barrier feature.

- Add the **barrier.shp** layer from the **Exercise_14** folder using the Add Data button from the Map Tab.
- Navigate back to the Routes Tab.
- Click the Import Stops button in the Input Data area.
- Make sure the Input Network Analysis Layer is set to the **Route** layer.
- Make sure the Sub Layer is set to **Polygon Barriers**.
- Set the Input Locations to the **barrier** layer.
- You do not need to change any other settings.
- Click run to add the barrier.



You are now ready to re-execute the tool.

- Change the Mode back to “Distance_Mode” in the Travel Settings area of the Routes Tab.
- Click Run in the Route Tab to execute the analysis.



Use the result to answer the following questions.

Question 6. What is the total distance for this route in miles? (2 Points)

Question 7. How much longer in miles is this route than the route optimized for distance that did not include the barrier? (2 Points)

Problem 4: You are a pizza delivery person and need to make a delivery from Puglioni's Pasta & Pizza to the Hotel Morgan. However, there is currently a parade in progress, so certain roads are closed. Find the fastest route based on travel time that won't require you to travel on a closed road.

- To obtain this answer, you simply need to run the routes analysis again. However, this time change the Mode in the Travel Settings area of the Routes Tab to "Time_Mode."

Use the result to answer the following questions.

Question 8. What is the total travel time for this route in minutes? (2 Points)

Question 9. How much longer will this route take in minutes in comparison to the route optimized for time that did not include the barrier? (2 Points)

You are now done with the route analysis. You can remove the **Route** layer.

- Remove the **Route** layer from the Contents Pane. You can also remove the **barrier** layer if you want. You won't need it again.

Step 5. Analyzing Service Areas

You will now explore service areas. You can define service areas based on distance or travel time. You will explore both options here.

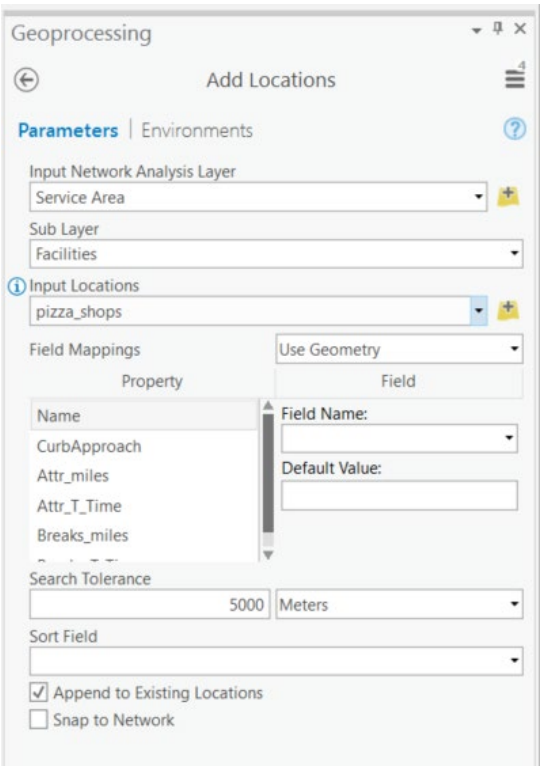
- Navigate to the Analysis Tab.
- Click on Network Analysis followed by Service Area. This will create a new Service Area Layer that will be added to the Contents Pane.
- Navigate to the Service Area Tab.

Note: The Service Area Tab will only be available when the **Service Area** layer is selected in the Contents Pane.

Problem 5: Find all of the areas that are within 0.25 miles of a pizza shop and determine how many hotels are outside of this travel distance.

- In the Input Data area of the Service Area tab, click on the Import Facilities button. This will open the **Add Locations Tool**.

- Make sure the Input Network Analysis Layer is set to the **Service Area** layer.
- Make sure the Sub Layer is set to **Facilities**.
- Set the Input Locations to the **pizza_shops** layer.
- You do not need to change any additional settings.
- Click Run to execute the Tool.

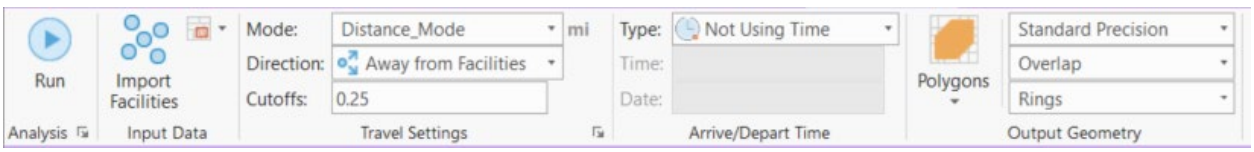


All of the pizza shops have now been added as facilities.

- In the Travel Settings of the Service Area Tab, make sure the Mode is set to "Distance_Mode." Make sure the Direction is set to Away from Facilities. Change the Cutoffs to 0.25.

Note: It is possible to specify multiple distances or times as a list for Cutoff. Also, it is possible to define a direction as either away or toward the facilities.

- You do not need to change any additional settings. Click the Run button in the Service Tab to run the analysis.



Use the result to answer the following question.

Question 10. How many of the mapped hotels were not within 0.25 miles along the road network to one of the mapped pizza shops? (2 Points)

Problem 6: Find all of the areas that are within 2 minutes travel time of a pizza shop and determine how many hotels are outside of this travel time.

- Re-execute the Service Area analysis. All you need to do is change the Mode to "Time_Mode."

Use the result to answer the following question.

Question 11. How many of the mapped hotels were not within 2 minutes travel time along the road network to one of the mapped pizza shops? (2 Points)

You are now done with the service area analysis. You can remove the **Service Area** layer.

- Remove the **Service Area** layer from the Contents Pane.

Step 6. Analyzing Service Areas

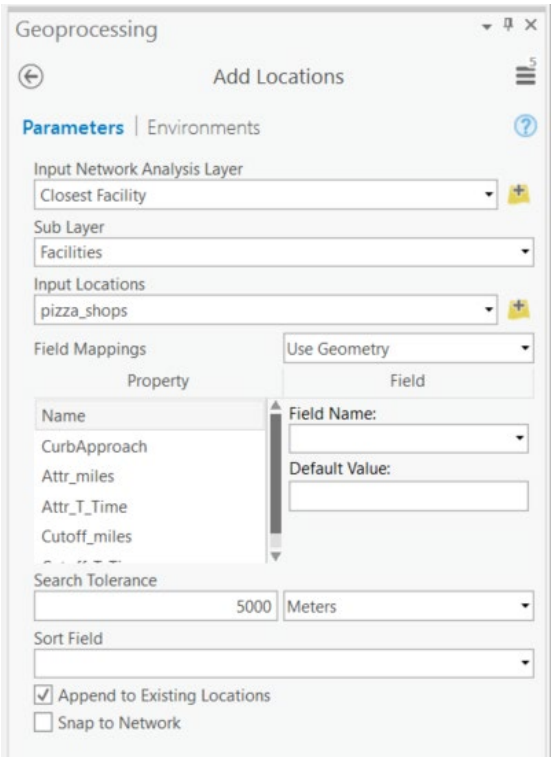
You will now explore the closet facility analysis to determine what pizza shop is closest to each hotel.

Problem 7: Determine which pizza shop is closest to each hotel based on travel distance.

- Navigate to the Analysis Tab.
- Click on Network Analysis followed by Closest Facility. This will create a new Closest Facility Layer that will be added to the Contents Pane.
- Navigate to the Service Tab.

Note: The Closest Facility Tab will only be available when the **Closest Facility** layer is selected in the Contents Pane.

- Navigate to the Closest Facilities Tab.
- Click on the Import Facilities button in the Input Data area. This will open the **Add Locations Tool**.
- Make sure the Input Network Analysis Layer is set to the **Closest Facility** Layer.
- Make sure the Sub Layer is set to **Facilities**.
- Set the Input Locations to the **pizza_shops** layer.
- You do not need to change any other settings.
- Click Run to execute the tool.



You now need to import the incidences, in this case the hotels.

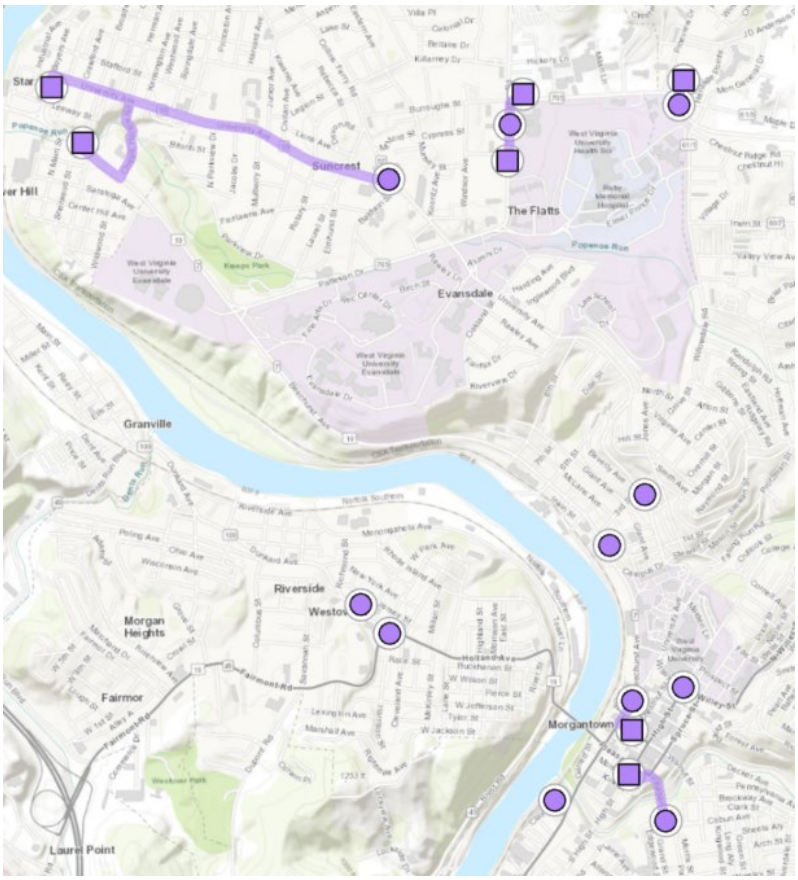
- Navigate to the Closest Facilities Tab.
- Click on the Import Incidences button in the Input Data area. This will open the **Add Locations Tool**.
- Make sure the Input Network Analysis Layer is set to the **Closest Facility** Layer.
- Make sure the Sub Layer is set to **Incidences**.
- Set the Input Locations to the **hotels** layer.
- You do not need to change any other settings.
- Click Run to execute the tool.

You will run this tool optimized for distance.

- In the Closest Facility Tab and in the Travel Settings, make sure that the Mode is set to "Distance_Mode."

You are now ready to execute the analysis.

- Click Run in the Closest Facility tab to execute closest facility analysis.



Use the result to answer the following question.

Question 12. Which pizza shop is closest to the Hotel Morgan? (2 Points)

Question 13. Which pizza shop is closest to the Best Western Mountaineer Inn? (2 Points)

Question 14. Is Casa D' Amici closest to any hotel in comparison to the other pizza shops? (2 Points)

Question 15. How many hotels are closer to Puglioni's Pasta & Pizza than any other pizza shop? (2 Points)

You are now done with the Closest Facility analysis. You can remove the **Closest Facility** layer.

- Remove the **Closest Facility** layer from the Contents Pane.

Step 7. Location-Allocation Analysis

Lastly, you will conduct a location-allocation analysis to determine which pizza shop is collectively nearest to all of the hotels based on travel distance and travel time.

Problem 8: Determine which pizza shop is collectively nearest to all hotels based on travel distance.

- Navigate to the Analysis Tab.
- Click on Network Analysis followed by Location-Allocation. This will create a new Location-Allocation Layer that will be added to the Contents Pane.
- Navigate to the Location-Allocation Tab.

Note: The Location-Allocation Tab will only be available when the **Location-Allocation** layer is selected in the Contents Pane.

You will begin by importing the pizza shops as the facilities.

- Navigate to the Location-Allocation Tab.
- Click on the Import Facilities button in the Input Data area. This will open the **Add Locations Tool**.
- Make sure the Input Network Analysis Layer is set to the **Location-Allocation** layer.
- Make sure the Sub Layer is set to **Facilities**.
- Set the Input Locations to the **pizza_shops** layer.
- You do not need to change any other settings.
- Click Run to execute the tool.

Next, you will need to import the hotels as the demand points.

- Navigate to the Location-Allocation Tab.
- Click on the Import Demand Points button in the Input Data area. This will open the **Add Locations Tool**.
- Make sure the Input Network Analysis Layer is set to the **Location-Allocation** layer.
- Make sure the Sub Layer is set to **Demand Points**.
- Set the Input Locations to the **hotels** layer.
- You do not need to change any other settings.
- Click Run to execute the tool.

Note: It is possible to apply a weight for the demand points. For example, an occupancy field could be used to weight each hotel by the number of customers or rooms. However, you will not do so here since these data are not available.

Next, you need to set the remaining tool settings.

- In the Travel Settings area of the Location-Allocation Tab, make sure the Mode is set to "Distance_Mode." Make sure the Direction is set to

Away from Facilities. Do not define a Cutoff. Make sure Facilities is set to 1.

- Use the default setting in the Problem Type area. These settings can have a large impact on the output. The default type is minimized weighted impedance.
- Click Run in the Location-Allocation Tab to execute the analysis.

Use the result to answer the following question.

Question 16. Which pizza shop is collectively nearest to all hotels based on travel distance and the defined settings? (2 Points)

Problem 9: Determine which pizza shop is collectively nearest to all hotels based on travel time.

- Re-execute the analysis, but change the Mode to "Time_Mode."

Use the result to answer the following question.

Question 17. Which pizza shop is collectively nearest to all hotels based on travel time and the defined settings? (2 Points)

Final Remarks

This exercise provided an introduction to network analysis in ArcGIS Pro. It should be noted that there are many more networks problems that can be solved. Also, these problems can become rather complex.

Also, it should be noted that we provided the input locations as files here. It is also possible to input features, such as barriers or facilities, by directly editing and drawing in ArcGIS Pro using the tools available under the Edit Tab.

Please answer the final questions to complete this exercise.

Question 18. Explain what junctions are in a network model. (5 Points)

Question 19. Explain what edges are in a network model. (5 Points)

Question 20. List and explain three complexities in road networks that would need to be modeled to obtain accurate directions and analysis results. (5 Points)

END OF EXERCISE