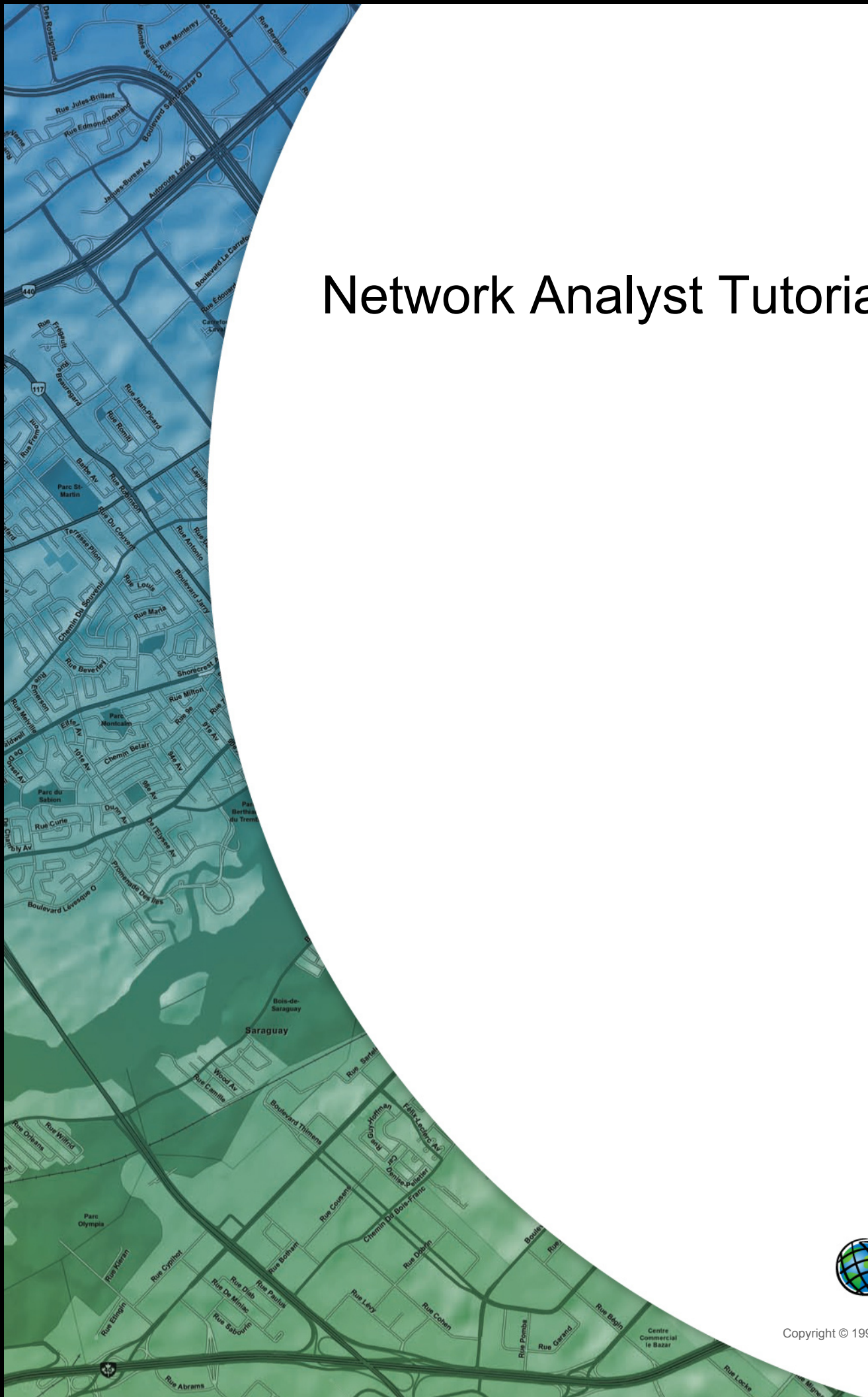

Network Analyst Tutorial

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Table of Contents

About the ArcGIS Network Analyst tutorial

The ArcGIS Network Analyst extension allows you to build a network dataset and perform analyses on a network dataset. The best way to learn Network Analyst is to use it. In the exercises in this tutorial, you will do the following:

- Use ArcCatalog to create and build a network dataset from feature classes stored within a geodatabase.
- Define connectivity rules and network attributes for the network dataset.
- Perform various network analyses in ArcMap using the Network Analyst toolbar.
- Learn how to use the Network Analyst geoprocessing tools to create models that automate analyses.

To use this tutorial, you need to have ArcGIS installed with the Network Analyst extension and have the tutorial data installed on a local or shared network drive on your system.

Tutorial data

Ask your system administrator for the correct path to the tutorial data if you do not find it at the default installation path (C:\ArcGIS\ArcTutor\Network Analyst\Tutorial).

In this tutorial

Exercise 1: Creating a network dataset

In this exercise, you will create a network dataset in a geodatabase using San Francisco street and turn features. You will also include historical traffic data so you can solve time-dependent routes.

Complexity:
Beginner

Data Requirement:
ArcGIS Tutorial Data Setup

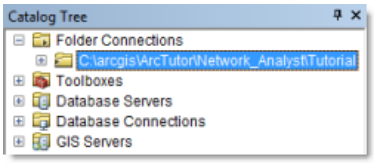
Data Path:
C:\ArcGIS\ArcTutor\Network Analyst\Tutorial\Exercise01

Goal:
To create a network dataset from a streets feature class in a geodatabase

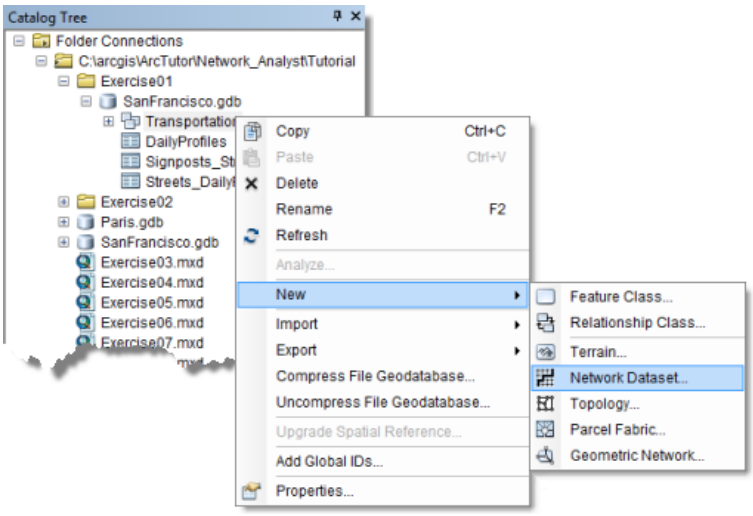
Creating a network dataset

Steps:

1. Start ArcCatalog by clicking **Start** > **All Programs** > **ArcGIS** > **ArcCatalog 10.**
2. Enable the Network Analyst extension.
   a. Click **Customize** > **Extensions.**
      The ***Extensions*** dialog box opens.
   b. Check **Network Analyst**.
   c. Click **Close**.
3. On the ***Standard*** toolbar, click the **Connect To Folder** button .
   The ***Connect to Folder*** dialog box opens.
4. Navigate to the folder with the ArcGIS Network Analyst tutorial data.
   The default location for the tutorial data is C:\ArcGIS\ArcTutor\Network Analyst\Tutorial
5. Click **OK**.
   A shortcut to the folder is added to the ***Catalog Tree*** under **Folder Connections**.



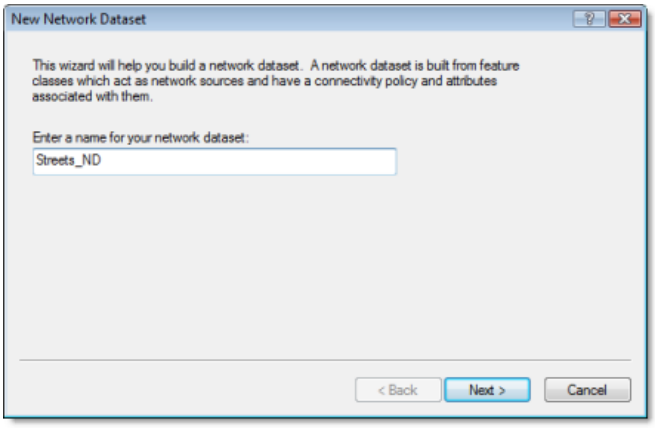
6. In the ***Catalog Tree***, expand **...\ArcTutor\Network Analyst\Tutorial** > **Exercise01** > **SanFrancisco.gdb**.
7. Click the **Transportation** feature dataset.
   The feature classes the feature dataset contains are listed on the **Contents** tab of ArcCatalog.
8. Right-click the **Transportation** feature dataset and click **New** > **Network Dataset**.



The ***New Network Dataset*** wizard opens.

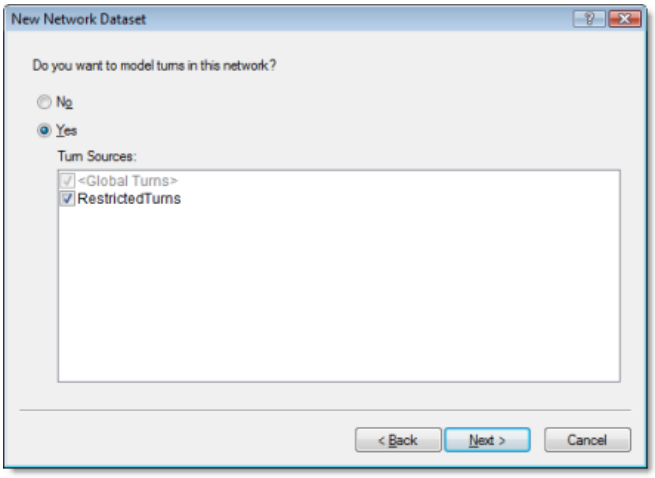
Note: To open the ***New Network Dataset*** wizard in a geodatabase, you right-click the feature dataset that contains the source feature classes (Streets, for example) and choose **New** > **Network Dataset**. For a shapefile-based network dataset, you right-click the Streets shapefile itself—not the workspace that contains the shapefile—and choose **New** > **Network Dataset.**
The reason for the difference is that geodatabase networks allow you to use multiple sources that are stored in the feature dataset to create a multimodal network, while shapefile-based network datasets are only capable of handling a single source feature class.

9. Type `Streets_ND` for the name of the network dataset.



10. Click **Next**.
11. Check the **Streets** feature class to use it as a source for the network dataset.

12. Click **Next**.
13. Click **Yes** to model turns in the network.
14. Check **<Global Turns>**, which enables you to add default turn penalties, and check **RestrictedTurns** to select it as a turn feature source.

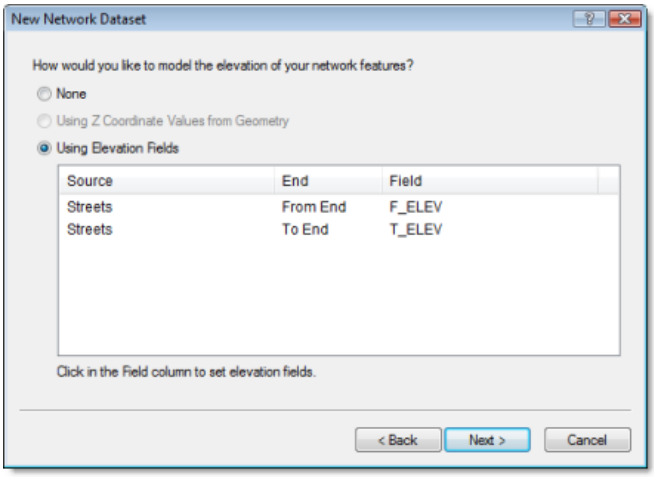


15. Click **Next**.
16. Click **Connectivity**.
    The Connectivity dialog box opens. Here you can set up the connectivity model for the network.

    For this Streets feature class, all streets connect to each other at endpoints.
17. Make sure that the connectivity policy of **Streets** is set to **End Point**.
18. Click **OK** to return to the ***New Network Dataset*** wizard.
19. Click **Next**.
20. This dataset has elevation fields, so make sure that the **Using Elevation Fields** option is chosen.
    Elevation settings in a network dataset further defines connectivity. To understand why, assume two edges have coincident endpoints in X and Y space but have different elevations (one endpoint is higher than the other). Furthermore, assume their connectivity policy is set to **Endpoint**. If elevation is ignored, the edges connect. However, if elevation is considered, they won't connect.

    There are two ways to model elevations: using true elevation values from geometry or using logical elevation values from elevation fields.

    The Streets feature class has logical elevation values stored as integers in the F_ELEV and T_ELEV fields. If two coincident endpoints have field elevation values of 1, for example, the edges will connect. However, if one endpoint has a value of 1, and the other coincident endpoint has a value of 0 (zero), the edges won't connect. ArcGIS Network Analyst recognizes the field names in this dataset and automatically maps them, as shown in the graphic below. (Only integer fields can serve as elevation fields.)

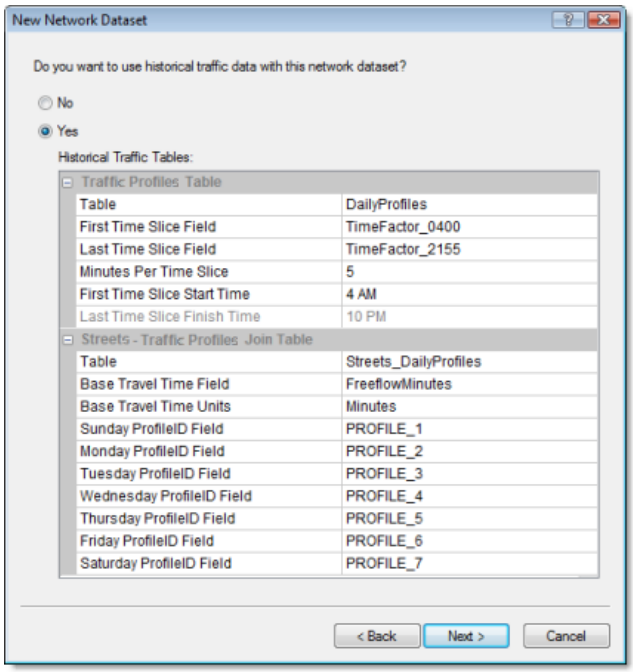


21. Click **Next**.

You can configure historical traffic data with this page of the wizard. Traffic data enables you to find the quickest routes based on time and day of the week. For example, the quickest route from point A to point B at 8:30 a.m. on Wednesday (during rush hour) could be different than the quickest route between the same points at 1:00 p.m. on Sunday. Even if the path of the route is the same, the time it takes to reach the destination could vary.

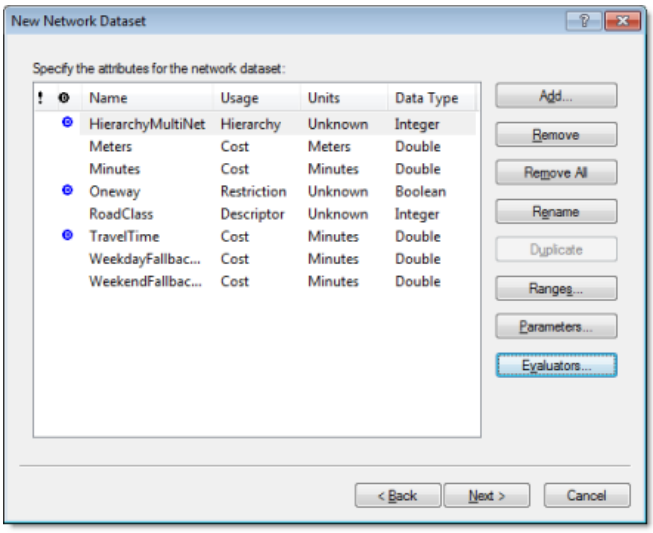
Learn more about historical traffic data

The SanFrancisco geodatabase contains two tables that store historical traffic data: DailyProfiles and Streets_DailyProfiles. The schemata of the tables were designed in such a way that Network Analyst could recognize the role of each table and configure historical traffic automatically.



22. Click **Next**.

The page for setting network attributes is displayed.

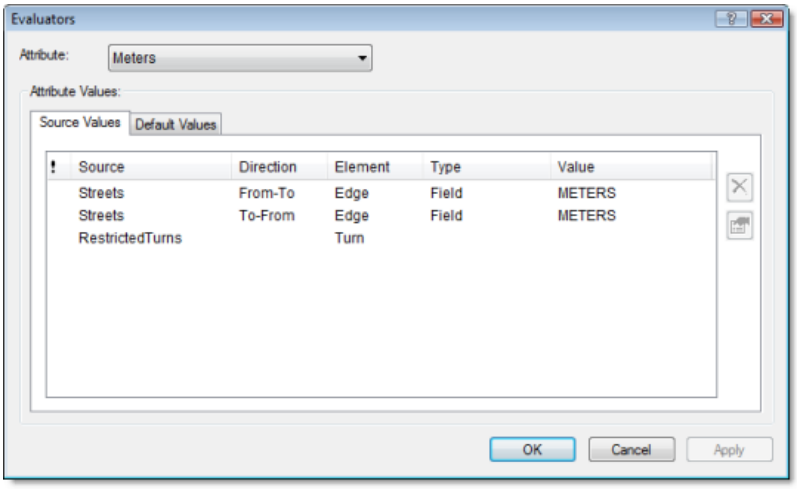


Network attributes are properties of the network that control navigation. Common examples are cost attributes that function as impedances over the network and restriction attributes that prohibit traversal in both directions or one direction, like one-way roads.

ArcGIS Network Analyst analyzes the source feature class (or classes) and looks for common fields like Meters, Minutes (FT_Minutes and TF_Minutes, one for each direction), and Oneway. If it finds these fields, it automatically creates the corresponding network attributes and assigns the respective fields to them. (This can be viewed by clicking **Evaluators**.)

Network Analyst automatically sets up eight attributes for this San Francisco data: HierarchyMultiNet, Meters, Minutes, Oneway, RoadClass, TravelTime, WeekdayFallbackTravelTime, and WeekendFallbackTravelTime. It also assigns evaluators to the attributes.

23. Click the **Meters** row to select it, then click **Evaluators** to examine how the values of network attributes are determined.
    The ***Evaluators*** dialog box opens.



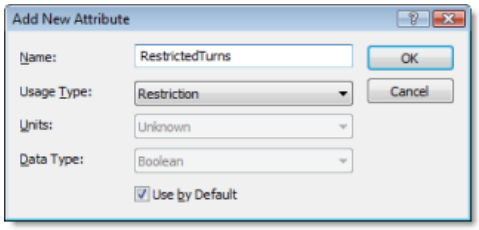
The table on the **Source Values** tab lists the source feature classes. Linear source feature classes, which become edge elements in the network dataset, are listed twice; once for the from–to direction and once for the to–from direction. (The directions are in relation to the digitized direction of the source line feature.) The **Type** column shows the type of evaluator used to calculate the network attribute values. The ***Value*** column holds information the evaluator needs to calculate attribute values.

24. From the **Attribute** drop-down list, click each type of attribute, one at a time, and inspect the evaluator types and values for the source feature classes.
25. Click **OK** to return to the ***New Network Dataset*** wizard.

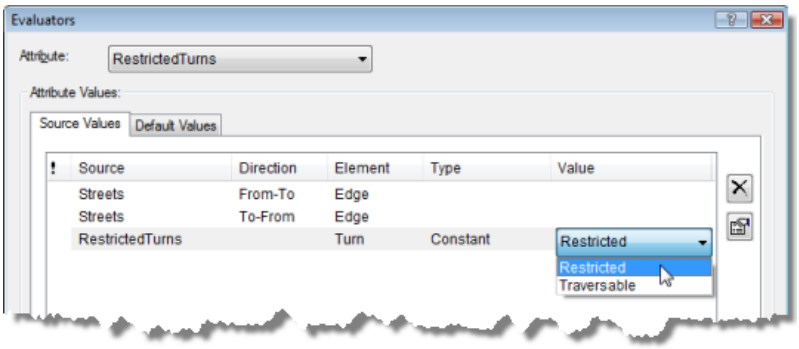
In the next steps, you will add a new attribute to restrict movement over the turn elements created from the RestrictedTurns feature class.

26. Click **Add**.
    The ***Add New Attribute*** dialog box opens.
27. Type `RestrictedTurns` in the **Name** field.
28. For **Usage Type**, choose **Restriction**.

Note that **Use by Default** is checked. This restriction will be used by default when a new network analysis layer is created. If you want to ignore the restriction when performing an analysis, you can disable it in the settings of the analysis.

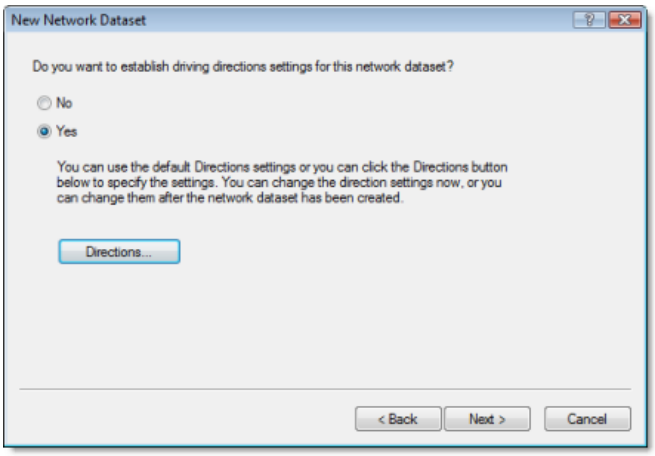


29. Click **OK**.
    The new attribute, RestrictedTurns, is added to the list of attributes. The blue circle with the D in the middle indicates the attribute is enabled by default in new analyses.
30. Click **Evaluators** to assign values by source to the new attribute.
31. Follow these substeps to set the type of evaluator for RestrictedTurns to Constant with a value of Restricted.
    a. Click the **Attribute** drop-down list and choose **RestrictedTurns**.
    b. For the **RestrictedTurns** row, click under the **Type** column and choose **Constant** from the drop-down list.
    c. Click the **Value** column and choose **Restricted**.
       The result should look like the following graphic:



The evaluators for the street sources are empty, so they will remain traversable when this restriction is used.

32. Click **OK** to return to the ***New Network Dataset*** wizard.
33. Right-click the HierarchyMultiNet row and choose **Use By Default**.
    The blue symbol is removed from the attribute. This means the hierarchy won't be used by default when an analysis layer is created with this network dataset.
34. Click **Next**.
35. Click **Yes** to set up directions.

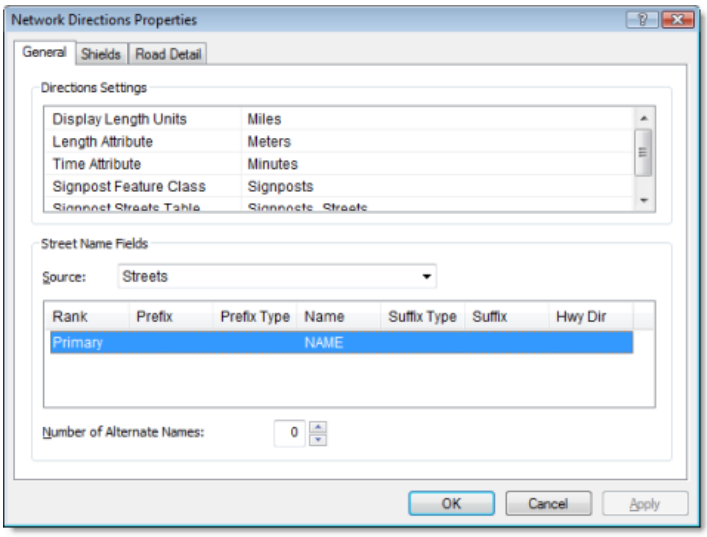


36. Click **Directions**.
    The ***Network Directions Properties*** dialog box opens.

Now you will specify the fields used to report directions for network analysis results.

37. On the **General** tab, make sure that the **Name** field for the **Primary** row automatically mapped to **NAME**.
    The NAME field contains the San Francisco street names, which are needed to help generate driving directions.

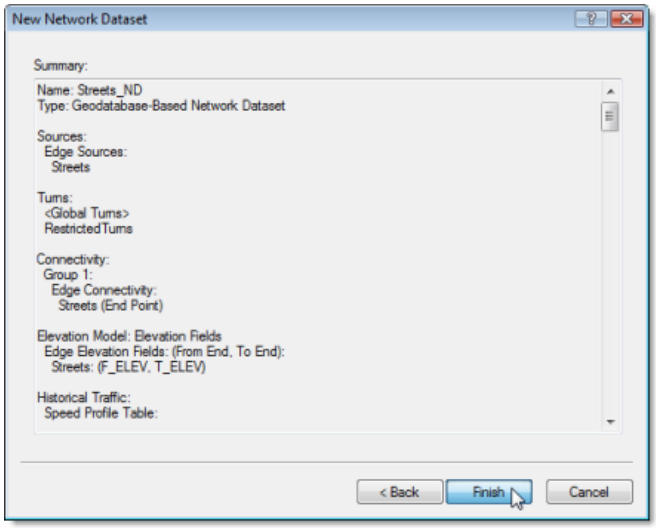
    The result should look like the following graphic:



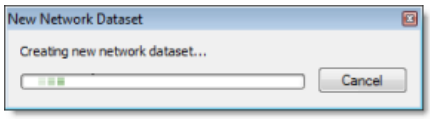
38. Click **OK** to return to the ***New Network Dataset*** wizard.

39. Click **Next**.
    A summary of all the settings is displayed for your review.

40. Click **Finish**.

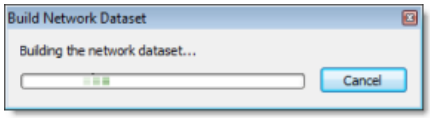


A progress bar opens showing you that Network Analyst is creating the network dataset.



Once the network is created, the system asks if you want to build it. The build process determines which network elements are connected and populates the attributes of the network dataset. You must build the network before you can perform any network analysis on it.

41. Click **Yes**.
    The Build Network Dataset progress bar opens; it will disappear when the build process is finished.



The new network dataset, Streets_ND, is added to ArcCatalog along with the system junctions feature class, Streets_ND_Junctions.

42. Preview the network dataset by clicking its name and clicking the **Preview** tab.
43. Close ArcCatalog.

Now you can add the network dataset to ArcMap and use it to create network analysis layers.

Exercise 2: Creating a multimodal network dataset

Exercise 1 shows how to create a network for a single mode of transportation; however, travelers and commuters frequently use several modes of transportation, such as walking on sidewalks, driving on road networks, and riding on trains. Goods also travel on many modes of transportation like trains, ships, trucks, and airplanes. In this exercise, you create a multimodal network dataset from multiple feature classes within a feature dataset.

Complexity:
Beginner

Data Requirement:
ArcGIS Tutorial Data Setup

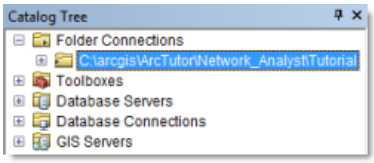
Data Path:
C:\ArcGIS\ArcTutor\Network Analyst\Tutorial\Exercise02

Goal:
Create a multimodal network dataset

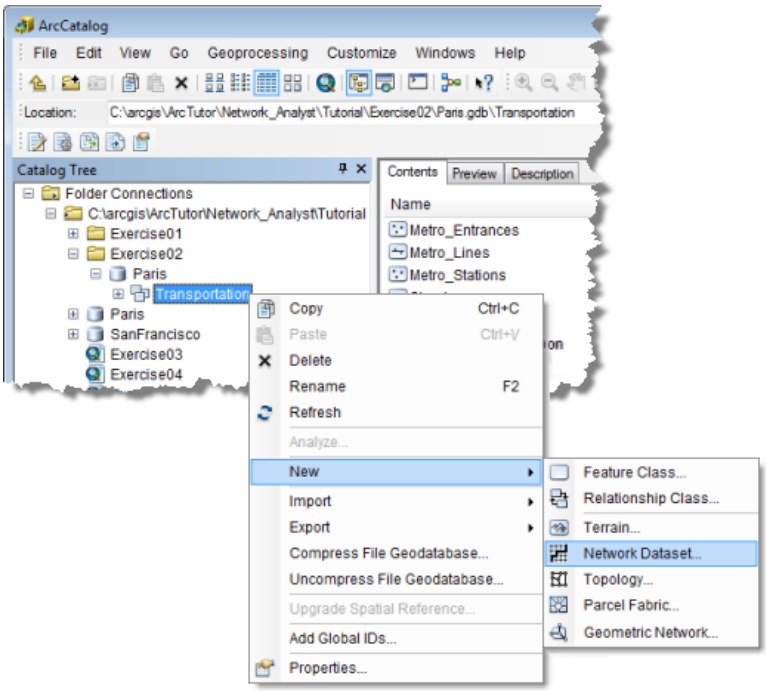
Starting the New Network Dataset wizard

Steps:

1. Start ArcCatalog by clicking **Start** > **All Programs** > **ArcGIS** > **ArcCatalog 10.**
2. Enable the Network Analyst extension.
   a. Click **Customize** > **Extensions.**
      The ***Extensions*** dialog box opens.
   b. Check **Network Analyst**.
   c. Click **Close**.
3. If you don't already have a connection to the Network Analyst Tutorial folder, you need to create one by following the substeps below.
   a. On the ***Standard*** toolbar, click the **Connect To Folder** button .
      The ***Connect to Folder*** dialog box opens.
   b. Navigate to the folder with the ArcGIS Network Analyst tutorial data.
      The default location for the tutorial data is C:\ArcGIS\ArcTutor\Network Analyst\Tutorial
   c. Click **OK**.
      A shortcut to the folder is added to the ***Catalog Tree*** under **Folder Connections**.



4. In the ***Catalog Tree***, expand **...\ArcTutor\Network Analyst\Tutorial** > **Exercise02** > **Paris.gdb.**
5. Click the **Transportation** feature dataset.
   The feature classes it contains are listed on the **Contents** tab of ArcCatalog.
6. Right-click the **Transportation** feature dataset and click **New** > **Network Dataset.**

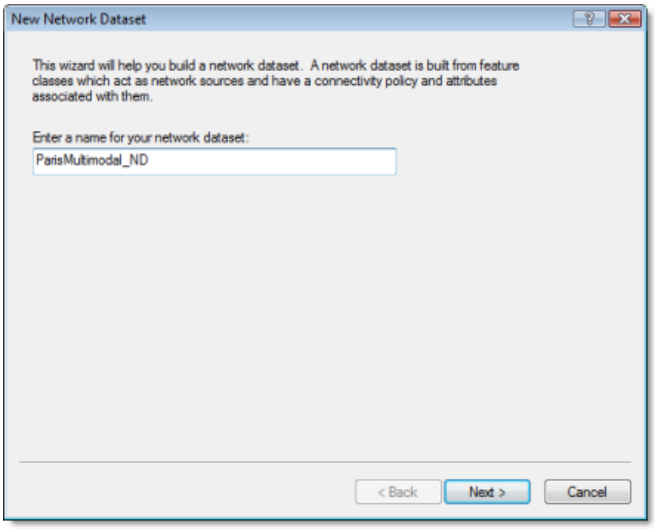


The ***New Network Dataset*** wizard opens.

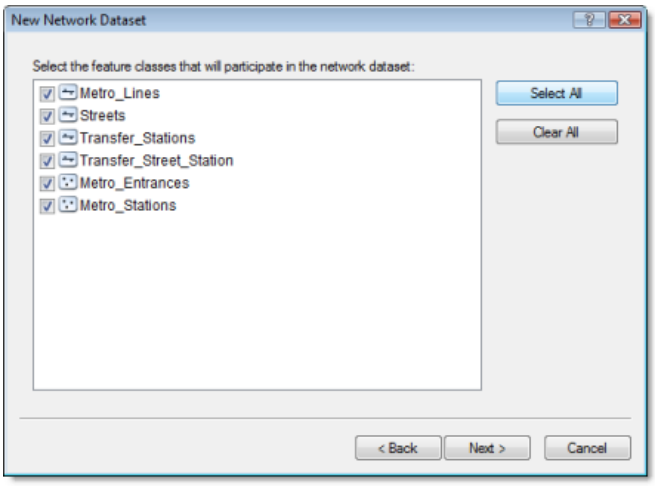
Naming the network and selecting source feature classes

Steps:

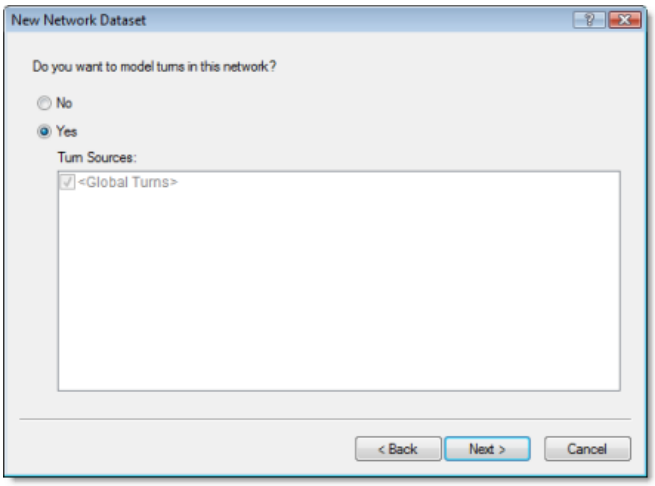
1. Type `ParisMultimodal_ND` as the name of your network dataset.



2. Click **Next**.
   The wizard page for choosing the feature classes that participate in the network dataset is displayed.
3. Click **Select All** to select all the feature classes to participate as sources in the network.



4. Click **Next**.
5. Click **Yes** to model turns in the network.
   Although there are not any turn feature classes for this network, selecting **Yes** allows the network dataset to support global turns and gives you the option of adding turn features anytime after the network is created.



6. Click **Next**.
   The page for setting connectivity is displayed.

Setting the connectivity and elevation policies

Connectivity in ArcGIS Network Analyst begins with the definition of connectivity groups. Each edge source is assigned to exactly one connectivity group, and each junction source can be assigned to one or more connectivity groups. A connectivity group can contain any number of sources. How network elements connect depends on which connectivity groups the elements are in. For example, two edges created from two distinct source feature classes can connect if they are in the same connectivity group. If they are in separate connectivity groups, the edges won't connect unless they are joined by a junction that participates in both connectivity groups.

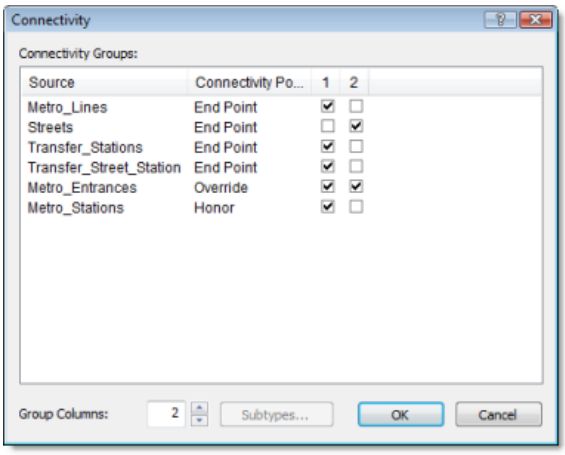
You will create connectivity groups in the following steps.

Steps:

1. Click **Connectivity** to set up the connectivity model for the network.
   The ***Connectivity*** dialog box opens.
2. Click the **Group Columns** up-arrow once to increase the number of connectivity groups to **2**.
   A column for the second connectivity group is created in the **Connectivity Groups** table.

   Connectivity group 1 represents the metro system, and group 2 represents the street network.
3. Click the **Streets** row and check the check box under the column labeled **2** to move the Streets source to connectivity group 2.
4. Click the **Metro_Entrances** row and check the check box under the column labeled **2** to include the source feature class in groups 1 and 2.
   Metro entrances are points of transfer between the streets and the walkways that lead to the metro stations.

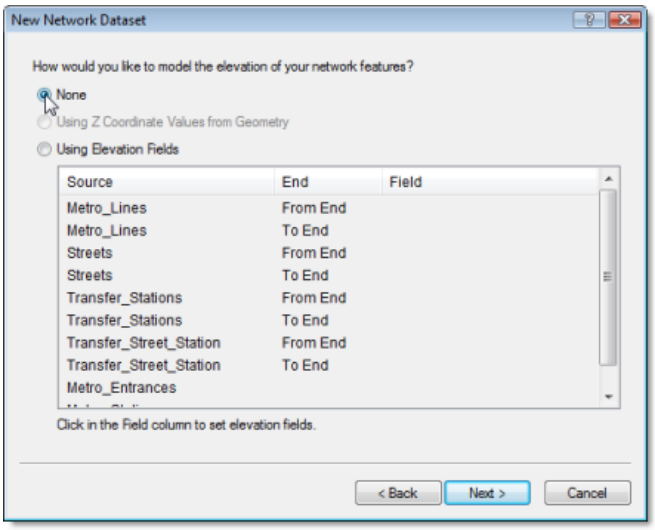
   Each feature of Metro_Entrances is coincident with a vertex of the streets feature class. However, the streets feature class has a policy of endpoint connectivity. Since the metro entrances need to be connected to the streets at the coincident vertex, you must set Metro_Entrances to override the default endpoint connectivity of the streets.
5. Change the **Connectivity Policy** of the **Metro_Entrances** row from **Honor** to **Override**.



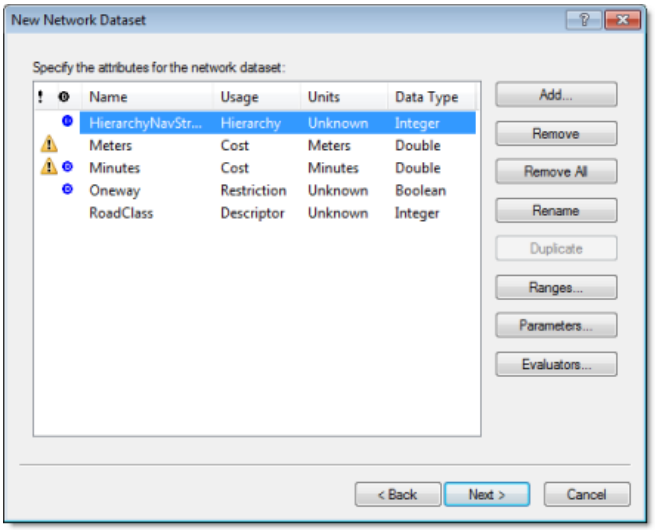
6. Click **OK** to return to the ***New Network Dataset*** wizard.
7. Click **Next**.

   Elevation settings in a network dataset further defines connectivity. To understand why, assume two edges have coincident endpoints in X and Y space but have different elevations (one endpoint is higher than the other). Furthermore, assume their connectivity policy is set to **Endpoint**. If elevation is ignored, the edges connect. However, if elevation is considered, they won't connect.

   There are two ways to model elevations: using true elevation values from geometry or using logical elevation values from elevation fields.
8. No elevation data exists for this dataset; therefore, click **None**.



9. Click **Next**.
   The wizard displays the attributes of the network dataset.



Removing an attribute

Network attributes are properties of the network that control navigation. Common examples are cost attributes that function as impedances over the network and restriction attributes that prohibit traversal in both directions or one direction, like one-way roads.

ArcGIS Network Analyst analyzes the source feature class (or classes) and looks for common fields like Meters, Minutes (FT_Minutes and TF_Minutes, one for each direction), and Oneway. If it finds these fields, it automatically creates the corresponding network attributes and assigns the respective fields to them. (This can be viewed by clicking **Evaluators**.)

Network Analyst automatically configures five attributes for the Paris streets data: HierarchyNavStreets, Meters, Minutes, Oneway, and Road Class.

Although you could leave the hierarchy attribute on the network dataset, this short set of steps demonstrates how to remove a network attribute by removing HierarchyNavStreets.

Steps:

1. Click **HierarchyNavStreets**.
2. Click **Remove**.
   Now the network is left with four attributes.

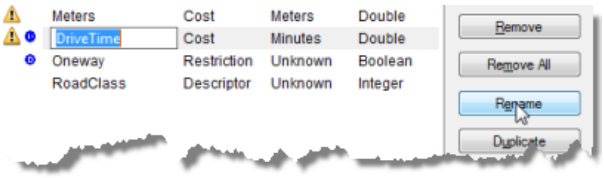
Verifying and creating network attributes

One goal for this network dataset is to model both pedestrian times and drive times. When performing analyses on the network, this allows you to choose between the two time costs. For example, you can choose to answer a question like, What's the quickest route from point A to point B for a pedestrian who can walk along streets and ride the metro? or What's the quickest route for someone who's driving a car? To accomplish this, you must set up two time-cost attributes: PedestrianTime and DriveTime.

Steps:

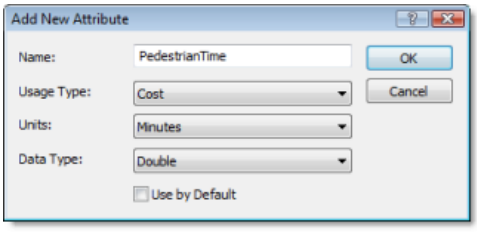
The Minutes attribute that Network Analyst automatically detected in the source data represents drive times, so you can change the name to something more appropriate.

1. Select the **Minutes** row, click **Rename**, type `DriveTime`, and press ENTER.



Next, you will create the PedestrianTime attribute.

2. Click **Add**.
   The ***Add New Attribute*** dialog box opens.
3. Type `PedestrianTime` in the **Name** text box.
4. Set the **Usage Type** to **Cost**.
5. Change **Units** to **Minutes**.
6. Set the **Data Type** to **Double**.



7. Click **OK**.
   The ***Add New Attribute*** dialog box closes, and PedestrianTime is added to the list of attributes.

The three cost attributes—Meters, DriveTime, and PedestrianTime—have yellow warning symbols that alert you to potential problems with the evaluators, which specify how the values of network attributes are calculated.

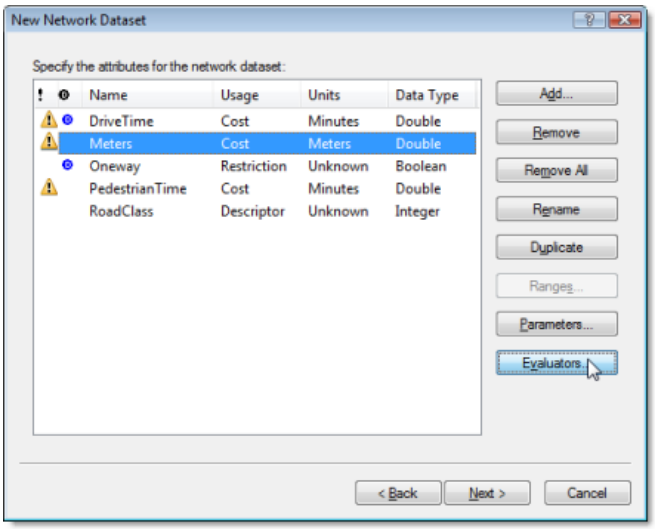
In the next three sections, you will configure the evaluators.

Configuring the Meters evaluator

You will set up various evaluators in this section and the following sections. The Meters evaluator calculates the distance cost for edges in the network.

Steps:

1. Select **Meters** and click **Evaluators**.

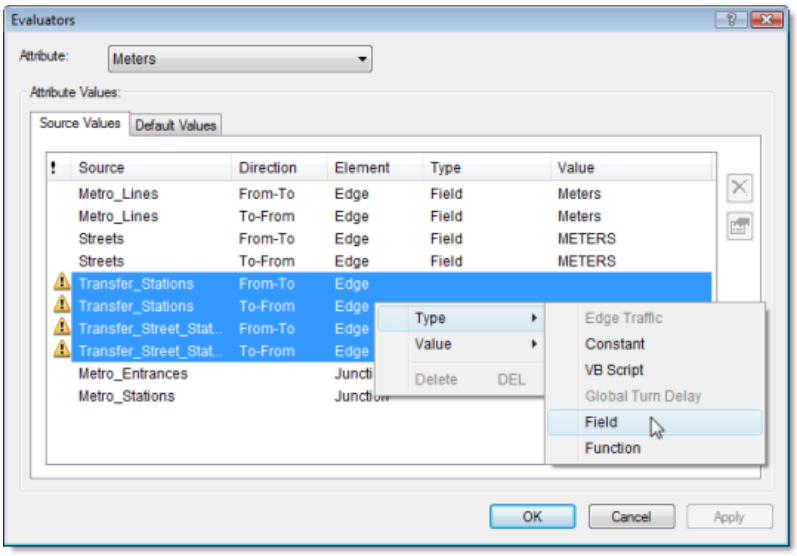


The ***Evaluators*** dialog box opens. Here you can view and edit the evaluator type and its value for each source in the network. You can see that junction and turn sources always have one associated evaluator, but edge sources have two: one for each direction of travel (the from-to and to-from directions).

ArcGIS Network Analyst inspects all source feature classes and tries to automatically assign evaluators for the Meters attribute. In this case, it discovered that the Metro_Lines and Streets sources had a field named Meters, so it set up evaluators to pull values from those fields. The same length values are assigned to the from-to and to-from directions of the edge sources.

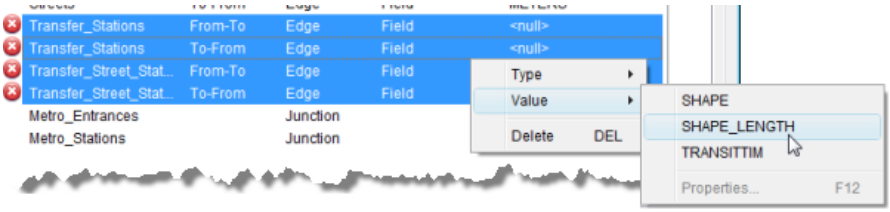
Network Analyst was unable to find fields for meters in the Transfer_Stations and Transfer_Street_Station sources. Hence, a warning symbol is present to indicate there is a potential problem.

2. While holding the SHIFT key, click the **Transfer_Stations From-To** row and click the **Transfer_Street_Station To-From** row.
   The four rows with the warning symbols are selected.
3. Right-click any of the selected rows and click **Type** > **Field.**



The warning symbols change to red error symbols, which indicate an incomplete assignment of values for the field evaluator.

4. With the four rows still selected, right-click any one of them and click **Value** > **SHAPE_LENGTH.**



This assigns values from the SHAPE_LENGTH field in the selected source feature classes to the Meters attribute for their associated network edge elements.

5. Click **Apply**.
The Meters network attribute is configured to get length values. For the network elements created from Metro_Lines, Streets, Transfer_Stations, and Transfer_Street_Station sources, the attribute values are respectively pulled from their Meters, METERS, Shape_Length, and SHAPE_LENGTH fields.

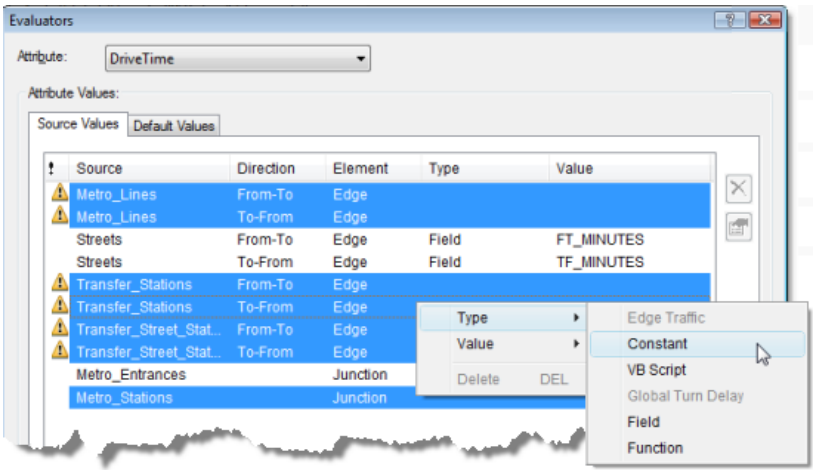
Configuring the DriveTime and Oneway evaluators

Since automobiles only travel on streets, the evaluators for the various sources should be set up accordingly.

Steps:

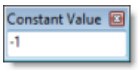
1. From the **Attribute** drop-down list, choose **DriveTime**.
The DriveTime values for the Streets source have been populated automatically by Network Analyst; however, the other edge sources display warning symbols because they don't have values assigned. These sources need to be marked as restricted. Also, metro stations need to be restricted so that new network analysis objects can be prevented from locating there.

2. Make sure that all the rows with a warning symbol (Metro_Lines, Transfer_Stations, and Transfer_Street_Station) are selected.
   If they aren't selected, select them by clicking one row and holding the CTRL key while clicking the other rows.
3. Hold the CTRL key and click **Metro_Stations** to add it to the selection.
4. Right-click any one of the selected rows and click **Type** > **Constant.**

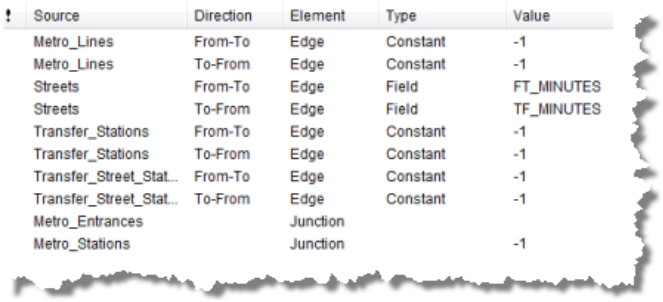


The same rows remain selected, and their evaluator type changes to **Constant**.

5. Again, right-click one of the selected rows, but this time click **Value** > **Properties.**
   The **Constant Value** input box appears.
6. Type `-1` and press ENTER.



The values for all the selected rows change to -1. Network Analyst treats any elements that have a cost value of -1 as restricted. So whenever the DriveTime attribute is used as impedance in network analyses, these sources are not traversable.



Source	Direction	Element	Type	Value
Metro_Lines	From-To	Edge	Constant	-1
Metro_Lines	To-From	Edge	Constant	-1
Streets	From-To	Edge	Field	FT_MINUTES
Streets	To-From	Edge	Field	TF_MINUTES
Transfer_Stations	From-To	Edge	Constant	-1
Transfer_Stations	To-From	Edge	Constant	-1
Transfer_Street_Stat...	From-To	Edge	Constant	-1
Transfer_Street_Stat...	To-From	Edge	Constant	-1
Metro_Entrances		Junction		
Metro_Stations		Junction		-1

7. Click **Apply**.

The Oneway attribute is loosely associated with the DriveTime attribute because it models the one-way traffic restrictions that drivers are required to follow. Later, when you perform an analysis using DriveTime as the cost, you should enable the Oneway restriction so the resulting

routes respect one-way streets. Alternatively, when modeling the movement of a pedestrian, you shouldn't use the Oneway restriction, since pedestrians are free to walk in the direction they choose.

8. From the **Attribute** drop-down list at the top of the ***Evaluators*** dialog box, choose **Oneway**. The **Attribute Values** frame now displays the evaluators for the Oneway network attribute, which has automatically been assigned values for the Streets source.

   The sources related to the metro system don't need one-way restrictions.

9. Click either one of the **Streets** rows and click the **Evaluator Properties** button .
   You can see the expression used to determine whether a street is one-way.

10. Click **Cancel** to return to the ***Evaluators*** dialog box.

Configuring the PedestrianTime evaluator

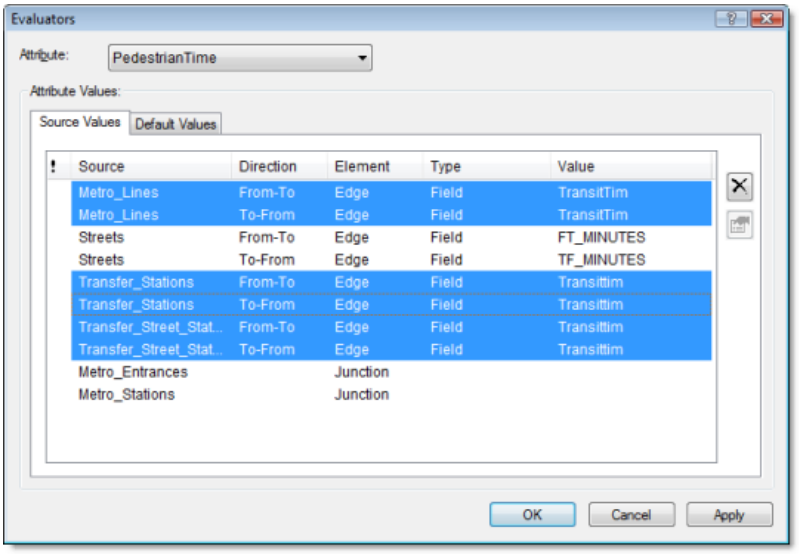
The PedestrianTime network attribute represents the time it takes a pedestrian to travel on the network. In this set of steps, you will assign appropriate travel times for a pedestrian who can ride the metro system or walk along streets.

Steps:

1. From the **Attribute** drop-down list at the top of the ***Evaluators*** dialog box, choose **PedestrianTime**.
   The rows for the following sources should already be selected: Metro_Lines, Transfer_Stations, and Transfer_Street_Station.

2. Right-click one of the selected rows and click **Type** > **Field.**

3. Again, right-click one of the selected rows, but this time click **Value** > **TRANSITTIM.**
   The TRANSITTIM fields store the time costs for a pedestrian to use the transit system. The streets also need pedestrian time values, but you calculate them differently.



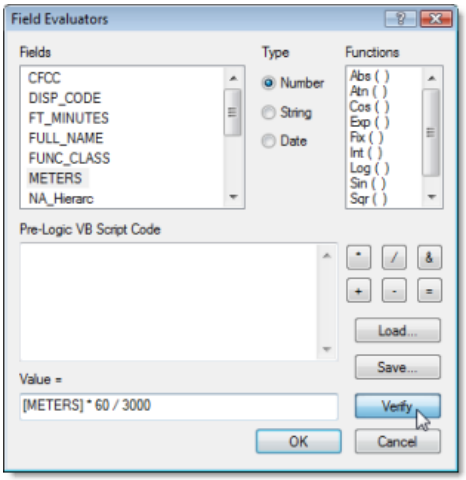
4. Click the **Streets From-To** row to select it. Hold the CTRL key and click the **Streets To-From** row to select both rows.

5. Right-click one of the selected rows and click **Value** > **Properties.**
   The ***Field Evaluators*** dialog box opens.

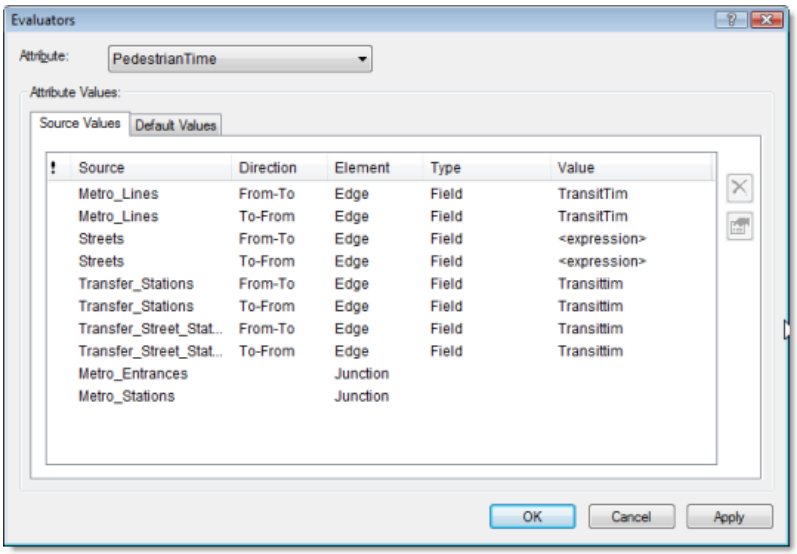
   For the Streets source, the value of PedestrianTime is the walk time. Assuming a pedestrian can walk at 3 km/hour, walk time in minutes would be [Meters] * 60 / 3000 where [Meters] is the attribute containing the length of the edge in meters.

6. Double-click the field **METERS** to move it into the **Value =** text box and finish typing the expression as [METERS] `* 60 / 3000` in the ***Field Evaluators*** dialog box, as shown below.

7. Click **Verify** to ensure that the expression is correct and fix it if necessary.



8. Click **OK** to return to the ***Evaluators*** dialog box.



9. Click **OK** to return to the ***New Network Dataset*** wizard.
10. Click **Next**.

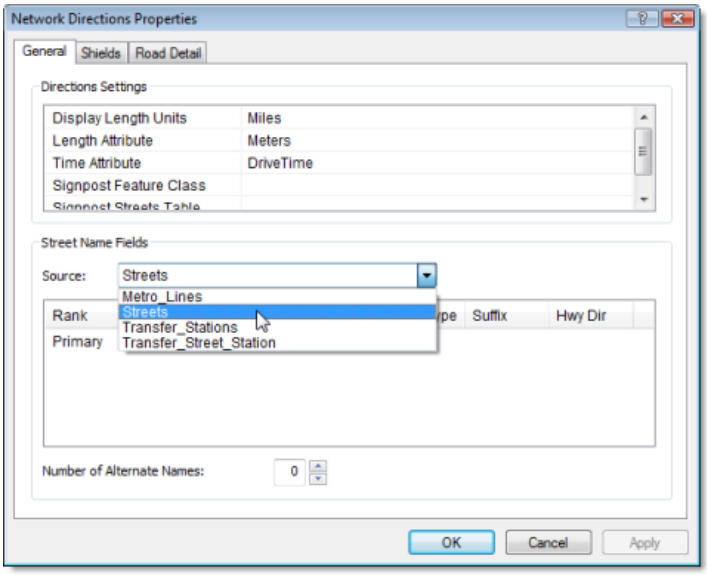
Configuring directions

When routes are calculated on your network dataset, you have the ability to produce driving directions to accompany the results. A network dataset is required to have at least one edge source with a text attribute (for street name information) and a distance attribute to show how far it will be before the next relevant maneuver is required.

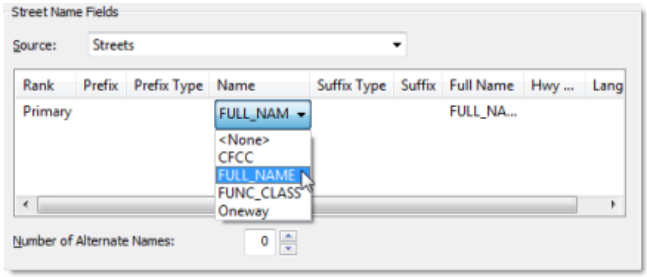
Steps:

1. Click **Yes** to set up directions.
2. Click **Directions**.
   The ***Network Directions Properties*** dialog box opens.

   Now you will specify the fields used to report directions for network analysis results.
3. On the **General** tab, click the **Source** drop-down list and choose **Streets**.



4. In the **Street Name Fields** list, click **Primary** to select it.
5. Click in the **Name** column and choose **FULL NAME**.



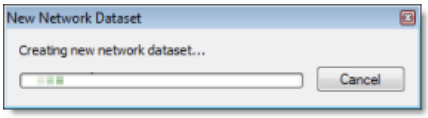
6. Click **OK** to return to the ***New Network Dataset*** wizard.
7. Click **Next**.
   A summary of all the settings is displayed for your review.

Creating and building the network dataset

After setting up how you want the network dataset to function, you need to create and build it. The creation process is quick and essentially creates a container for the logical network.

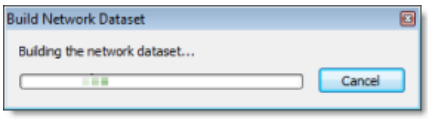
Steps:

1. Click **Finish**.
   A progress bar opens showing you that Network Analyst is creating the network dataset.



   Once the network is created, the system asks if you want to build it. The build process determines which network elements are connected and populates the attributes of the network dataset. You must build the network before you can perform any network analysis on it.

2. Click **Yes**.
   The Build Network Dataset progress bar opens; it will disappear when the build process is finished.



   The new network dataset, ParisMultimodal_ND, is added to ArcCatalog along with the system junctions feature class, ParisMultimodal_ND_Junctions.

3. Preview the network dataset by clicking its name and clicking the **Preview** tab.
4. Close ArcCatalog.

Exercise 3: Finding the best route using a network dataset

In this exercise, you will find the quickest route to visit a set of stops in a predetermined order.

Complexity:
Beginner

Data Requirement:
ArcGIS Tutorial Data Setup

Data Path:
C:\ArcGIS\ArcTutor\Network Analyst\Tutorial

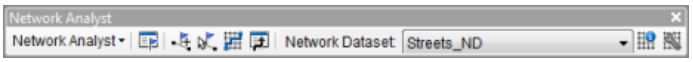
Goal:
Find the quickest route (shortest path) between stops.

Preparing your display

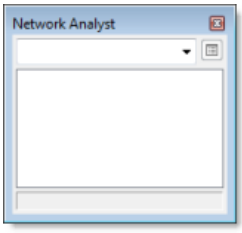
Steps:

1. If you have Exercise03.mxd open in ArcMap, skip to step 6.
2. Start ArcMap by clicking **Start** > **All Programs** > **ArcGIS** > **ArcMap 10.**
3. On the ***ArcMap - Getting Started*** dialog box, click **Existing Maps** > **Browse for more.**
   The ***Open ArcMap Document*** dialog box appears.
4. Browse to C:\ArcGIS\ArcTutor\Network Analyst\Tutorial.
   This is the default installation location for the tutorial data.
5. Double-click **Exercise03.mxd**.
   The map document opens in ArcMap.
6. Enable the Network Analyst extension.
   a. Click **Customize** > **Extensions**.
      The ***Extensions*** dialog box opens.
   b. Check **Network Analyst**.
   c. Click **Close**.

   If the ***Network Analyst*** toolbar is not displayed, you need to add it.
7. Click **Customize** > **Toolbars** > **Network Analyst.**
   The ***Network Analyst*** toolbar is added to ArcMap.



   If the ***Network Analyst*** window is not displayed, you need to add it.
8. On the ***Network Analyst*** toolbar, click the **Show/Hide Network Analyst Window** button.
   The dockable ***Network Analyst*** window opens.

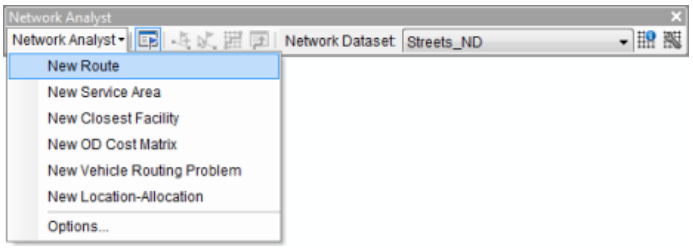


   You can dock or undock the ***Network Analyst*** window. In this exercise, it is docked below the ***Table Of Contents*** window.

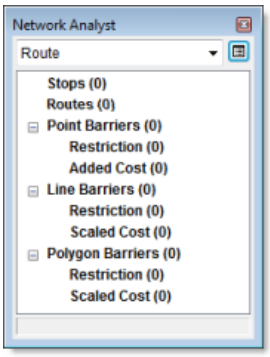
Creating a route analysis layer

Steps:

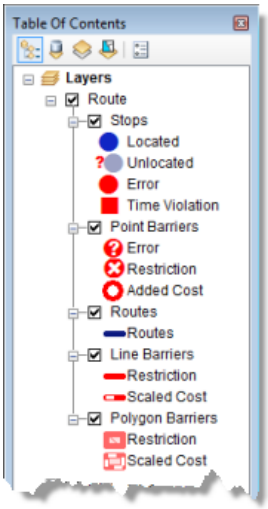
1. Click **Network Analyst** on the ***Network Analyst*** toolbar and click **New Route**.



The route analysis layer is added to the ***Network Analyst*** window. The network analysis classes (Stops, Routes, Point Barriers, Line Barriers, and Polygon Barriers) are empty.



The analysis layer is also added to the ***Table Of Contents*** window.

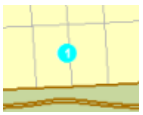


Adding a stop

Next, you will add the stops to be visited by a route.

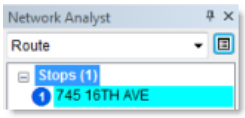
Steps:

1. In the ***Network Analyst*** window, click **Stops (0)**.
   Stops is selected, which means it is the active network analysis class.
2. On the ***Network Analyst*** toolbar, click the **Create Network Location Tool** .
   By clicking on the map with the **Create Network Location Tool**, you can add network analysis objects to the active network analysis class.
3. Click anywhere on the street network to define a new stop location.

   ArcGIS Network Analyst calculates the nearest network location and symbolizes the stop with the Located symbol. The stop remains selected until another stop is placed or you clear the selection.

   The located stop also displays the number 1. All stops have a unique number, which represents the order in which the stop will be visited by the route. Also notice that the **Stops** class in the ***Network Analyst*** window now lists one stop.

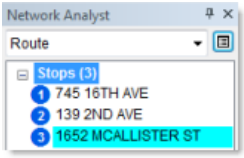
   

4. Add two more stops anywhere on or near the streets.

   The new stops are numbered 2 and 3.

   The first stop is treated as the origin, and the last as the destination.

   The sequence of the stops can be changed by clicking a stop in the ***Network Analyst*** window and dragging it to another position in the list.

   If a stop is not located on the network, it appears with an unlocated symbol. (However, using the default settings, you would need to place a stop more than 5 kilometers from the nearest street segment for it to not locate.)

You can move an unlocated stop closer to the network to locate it. If a stop is located on the network but in the wrong location, you can move the stop to the correct position.

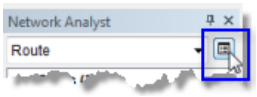
5. To move a stop, follow these substeps:
    a. Click the **Select/Move Network Locations Tool** on the ***Network Analyst*** toolbar.
    b. Click a stop to select it.
    c. Click the stop again and drag it to a new location.

Setting up the parameters for the analysis

Next, you will specify that your route will be calculated based on travel time (minutes), that U-turns are allowed anywhere, and that one-way and turn restrictions must be followed.

Steps:

1. Click the **Analysis Layer Properties** button on the ***Network Analyst*** window.



The ***Layer Properties*** dialog box opens.

2. Click the **Analysis Settings** tab.
3. Make sure that **Impedance** is set to **TravelTime (Minutes)**.

This network dataset has historical traffic data associated with the TravelTime (Minutes) attribute. If you choose to enter a start time by checking **Use Start Time** and filling out the three fields below it, Network Analyst will find the quickest route based on that time of day and historical traffic speeds. Alternatively, it will find the quickest route based on a function of street lengths and speed limits.

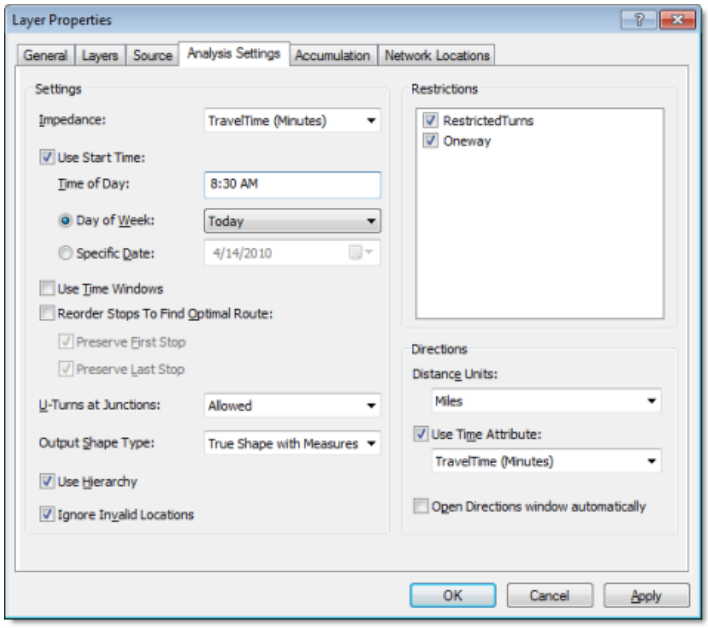
4. Check **Use Start Time**, enter a specific time and date or day of the week.
    a. For **Time of Day**, enter the time you want to leave the first stop.
    b. Click either **Day of Week** or **Specific Date**.
    If you choose **Day of Week**, specify any day between Sunday and Saturday; optionally, choose **Today** to use your system's current day setting.

    If you choose **Specific Date**, either type a date in the text box or click the down-arrow to open a calendar that allows you to choose a date.
5. Leave **Use Time Windows** unchecked.
    You can specify time windows for stops and have ArcGIS Network Analyst try to find a route that honors those time ranges in which a stop should be visited.
6. Leave **Reorder Stops To Find Optimal Route** unchecked.

By leaving this property unchecked, Network Analyst discovers the best route given the stop sequence you specify. This is commonly known as the traveling salesman problem (TSP). If checked, it finds the best route and best sequence to visit the stops.

7. Click the **U-Turns at Junctions** drop-down arrow and choose **Allowed**.
8. Click the **Output Shape Type** drop-down arrow and choose **True Shape with Measures**.
9. Make sure that the **Use Hierarchy** and **Ignore Invalid Locations** boxes are checked.
10. In the **Restrictions** frame, make sure that **RestrictedTurns** and **Oneway** are checked.
11. In the **Directions** frame, make sure that **Distance Units** is set to **Miles**, **Use Time Attribute** is checked, and the time attribute is set to **TravelTime (Minutes)**.

The **Analysis Settings** tab should look like the following graphic; however, your **Use Start Time** properties may be different:



12. Click **OK**.

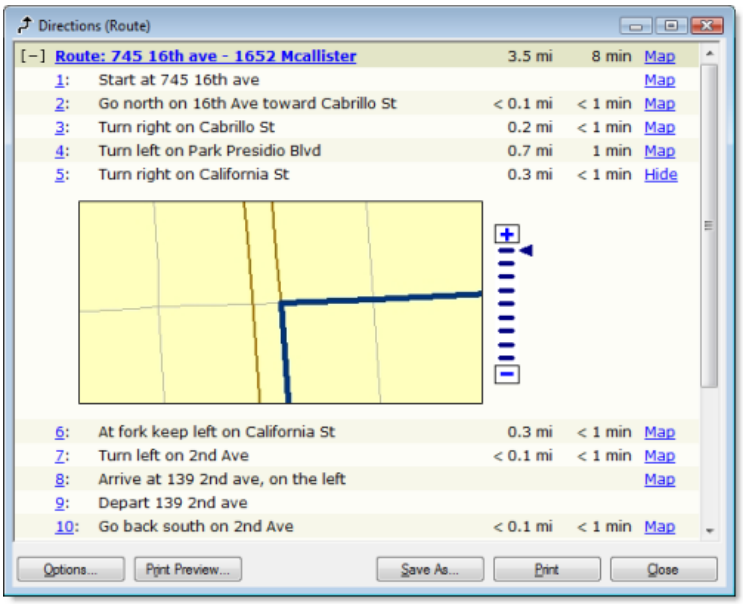
Computing the best route

Steps:

1. Click the **Solve** button on the ***Network Analyst*** toolbar.
   A route feature appears in the map display and in the ***Network Analyst*** window under the **Routes** class.

If a warning message appears, a stop may be located on a restricted edge. Try moving one or more stops using the **Select/Move Network Locations Tool**, which is on the ***Network Analyst*** toolbar.

2. Click the **Directions Window** button on the ***Network Analyst*** toolbar.
   The ***Directions*** dialog box opens.
3. On the rightmost column of the ***Directions*** dialog box, click one of the links named **Map**.
   An inset map of the maneuver is displayed.



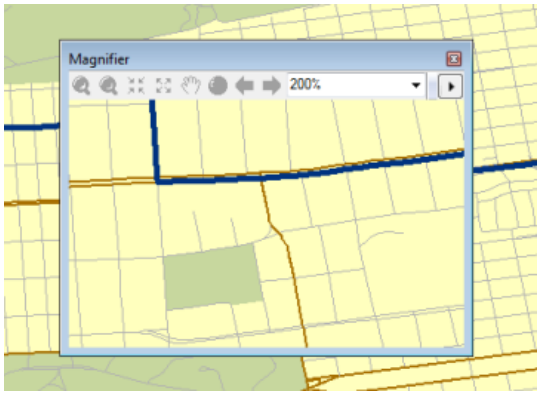
4. Click **Close**.

Adding a barrier

In this section, you will add a barrier on the route to represent a roadblock, and you will find an alternate route to your destination.

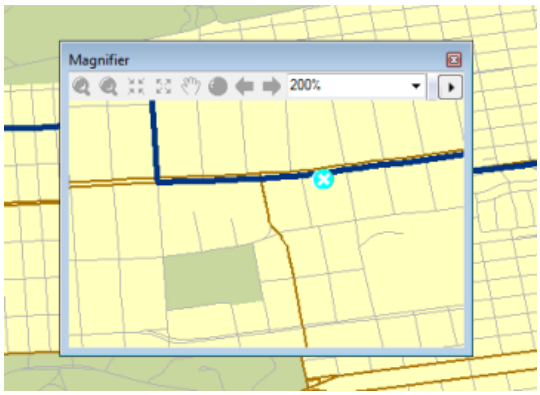
Steps:

1. Click **Windows** > **Magnifier.**
   The ***Magnifier*** window opens.
2. Click the title bar of the ***Magnifier*** window and drag the window to reposition it over the route.

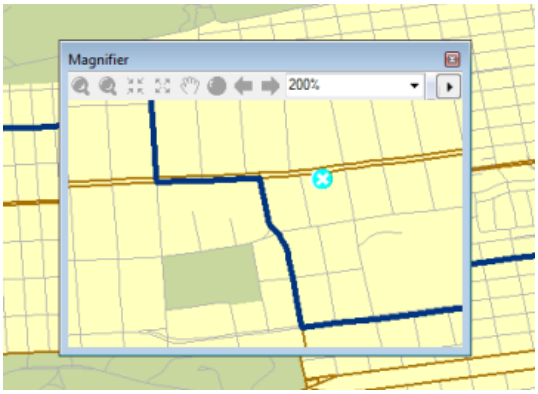


3. In the ***Network Analyst*** window under **Point Barriers (0)**, click **Restriction (0)** .
4. Click the **Create Network Location Tool** on the ***Network Analyst*** toolbar.
5. In the ***Magnifier*** window, click anywhere on the route to place one or more barriers.

Tip: To see where a barrier will be placed, hold down the 1 key before clicking on the map with the Create Network Location Tool.



6. Click the **Solve** button on the ***Network Analyst*** toolbar.
   A new, alternative route is computed that avoids the barrier.



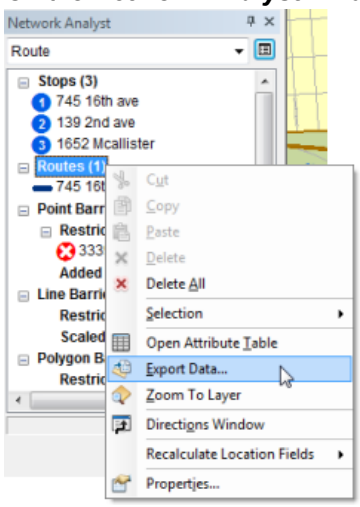
7. Close the ***Magnifier*** window.

Saving the route

The route analysis layer is currently stored in memory, so if you exit ArcMap without saving, the analysis is lost. However, if you save the map document, the analysis layer is saved with it. You can also export data. One option is to export the entire analysis layer to an LYR file. The analysis properties and objects are stored within the LYR file. Another option is to save the sublayers of the analysis as feature classes using the **Export Data** command. The next set of steps show how to export the Routes sublayer to a feature class.

Steps:

1. On the ***Network Analyst*** window, right-click **Routes (1)** and click **Export Data**.



   The ***Export Data*** dialog box opens.

2. In the **Output feature class** text box, type or browse to a location to save the results in, such as `C:\ArcGIS\ArcTutor\Network Analyst\Tutorial\SanFrancisco.gdb\Exercise3_Route`.
3. Click **OK**.
   The route's feature is saved to the specified workspace.
4. Click **No** when prompted to add the exported data to the map as a layer.
5. If you don't plan to work on any other exercise, exit ArcMap. Click **No** to discard any changes.
6. If you plan to work on another exercise, follow the substeps below.
   a. Click **File** > **New.**
      The ***New Document*** dialog box opens.
   b. Click **OK**.
   c. Click **No** when prompted to save changes.

Exercise 4: Finding the closest fire stations

In this exercise, you will find the four fire stations that can provide the quickest response to a fire at a given address. You will also generate routes and driving directions for the firefighters to follow.

Complexity:
Beginner

Data Requirement:
ArcGIS Tutorial Data Setup

Data Path:
C:\ArcGIS\ArcTutor\Network Analyst\Tutorial

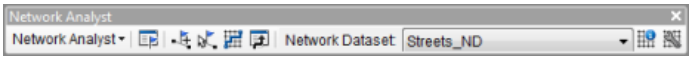
Goal:
Create, set up, and solve a closest facility analysis.

Preparing your display

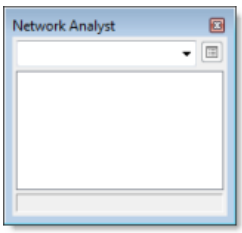
Steps:

1. If you have Exercise04.mxd open in ArcMap, skip to step 6.
2. Start ArcMap by clicking **Start** > **All Programs** > **ArcGIS** > **ArcMap 10.**
3. On the ***ArcMap - Getting Started*** dialog box, click **Existing Maps** > **Browse for more.**
4. Browse to C:\ArcGIS\ArcTutor\Network Analyst\Tutorial.
   This is the default installation location for the tutorial data.
5. Double-click **Exercise04.mxd**.
   The map document opens in ArcMap.
6. Enable the Network Analyst extension.
   a. Click **Customize** > **Extensions.**
      The ***Extensions*** dialog box opens.
   b. Check **Network Analyst**.
   c. Click **Close**.

   If the ***Network Analyst*** toolbar is not displayed, you need to add it.
7. Click **Customize** > **Toolbars** > **Network Analyst.**
   The ***Network Analyst*** toolbar is added to ArcMap.



   If the ***Network Analyst*** window is not displayed, you need to add it.
8. On the ***Network Analyst*** toolbar, click the **Show/Hide Network Analyst Window** button .
   The dockable ***Network Analyst*** window opens.

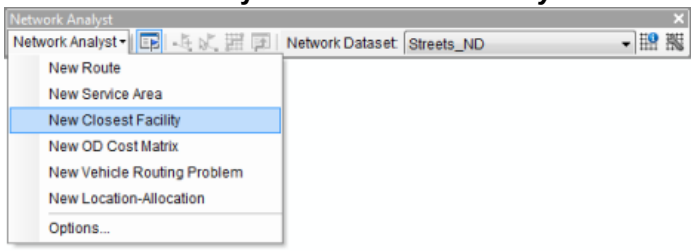


   You can dock or undock the ***Network Analyst*** window. In this exercise, it is docked below the ***Table Of Contents*** window.

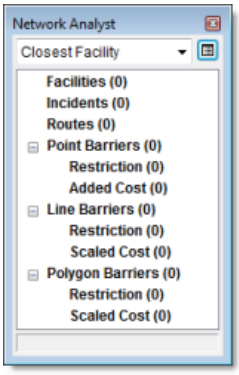
Creating the closest facility analysis layer

Steps:

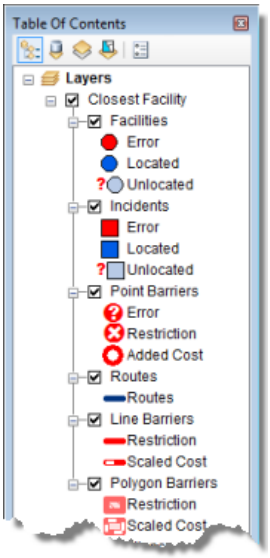
1. Click **Network Analyst** on the ***Network Analyst*** toolbar and click **New Closest Facility**.



The closest facility analysis layer is added to the ***Network Analyst*** window. The network analysis classes (Facilities, Incidents, Routes, Point Barriers, Line Barriers, and Polygon Barriers) are empty.



The analysis layer is also added to the ***Table Of Contents*** window.

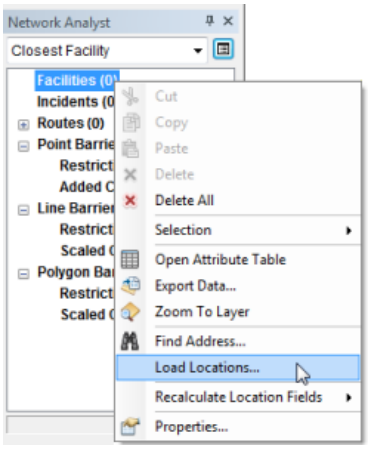


Adding facilities

Next, you will load facilities from a point feature layer that represents fire stations.

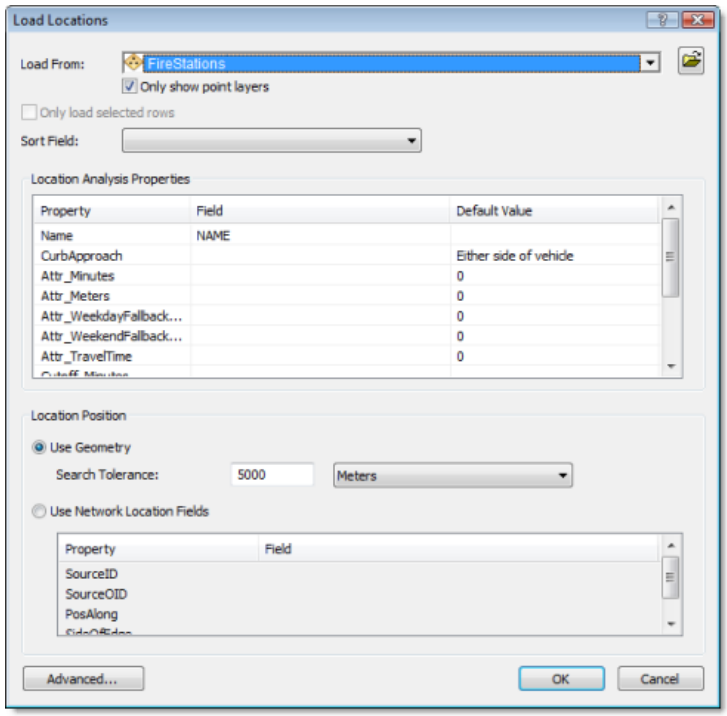
Steps:

1. In the ***Network Analyst*** window, right-click **Facilities (0)** and click **Load Locations**.

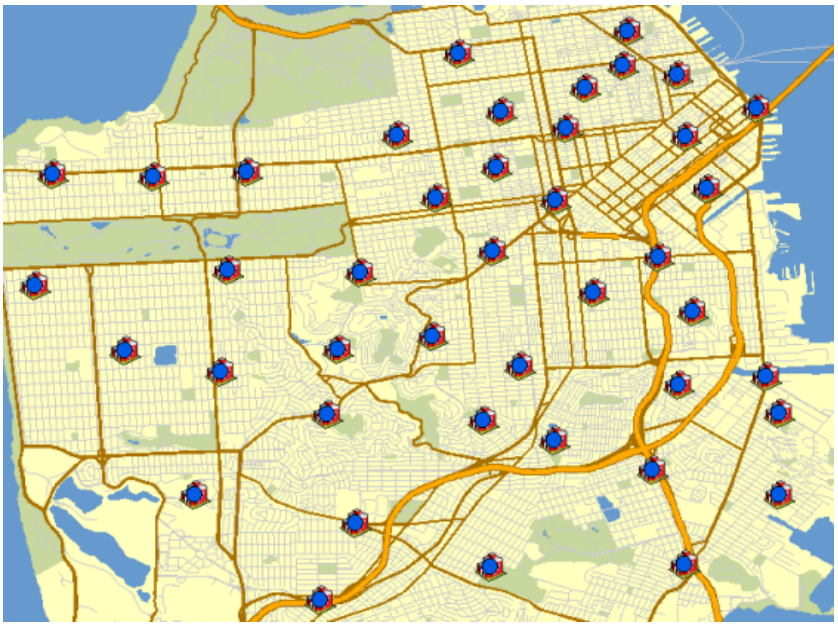


   The ***Load Locations*** dialog box opens.

2. Choose **FireStations** from the **Load From** drop-down list.



3. Click **OK**.
   Forty-three fire stations are displayed in the map as facilities and listed in the ***Network Analyst*** window.

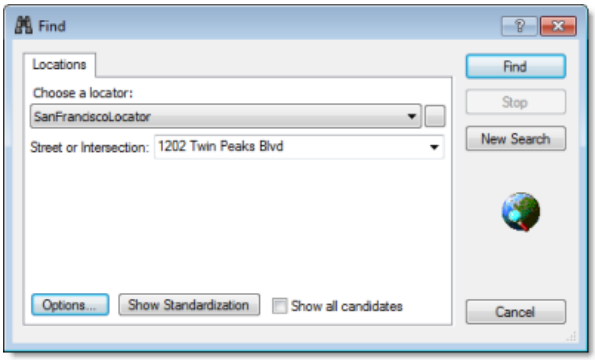


Adding an incident

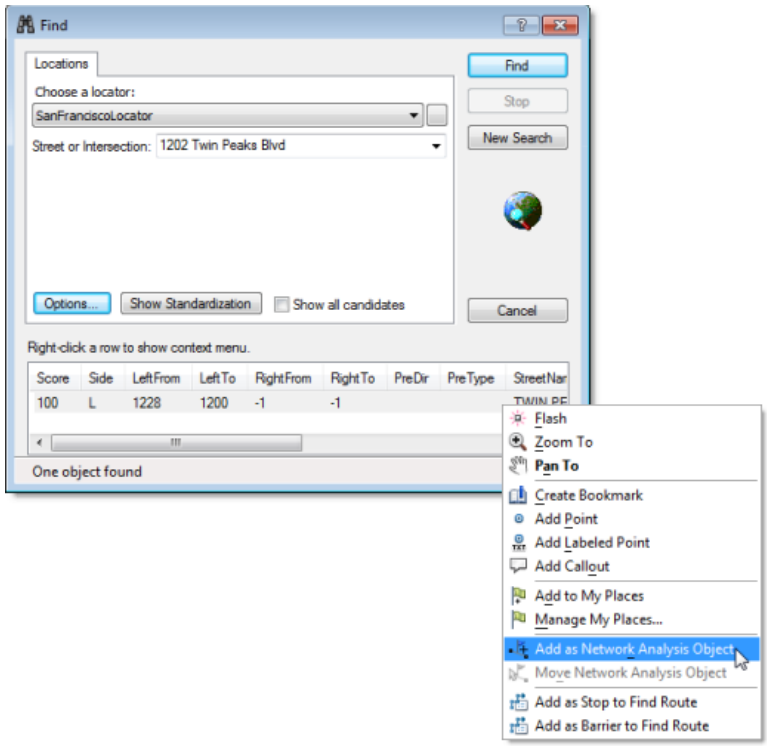
Next, you will add an incident by geocoding an address received from an emergency call.

Steps:

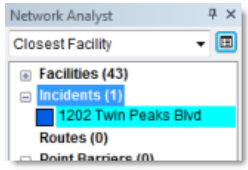
1. In the ***Network Analyst*** window, right-click **Incidents (0)** and choose **Find Address**.
   The ***Find*** dialog box opens.
2. Make sure that **SanFranciscoLocator** is chosen in the **Choose a locator** drop-down list.
3. In the **Street or Intersection** text box, enter `1202 Twin Peaks Blvd`.



4. Click **Find**.
   One location is found with that street address and is listed as a row in the table at the bottom of the ***Find*** dialog box.
5. Right-click the row and choose **Add as Network Analysis Object**.



This adds the located address as an incident, which you can see on the map and in the ***Network Analyst*** window.



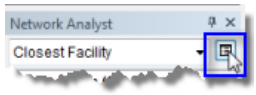
6. Close the ***Find*** dialog box.

Setting up parameters for the analysis

Next, you will specify the parameters for your closest facility analysis.

Steps:

1. Click the **Analysis Layer Properties** button on the ***Network Analyst*** window.



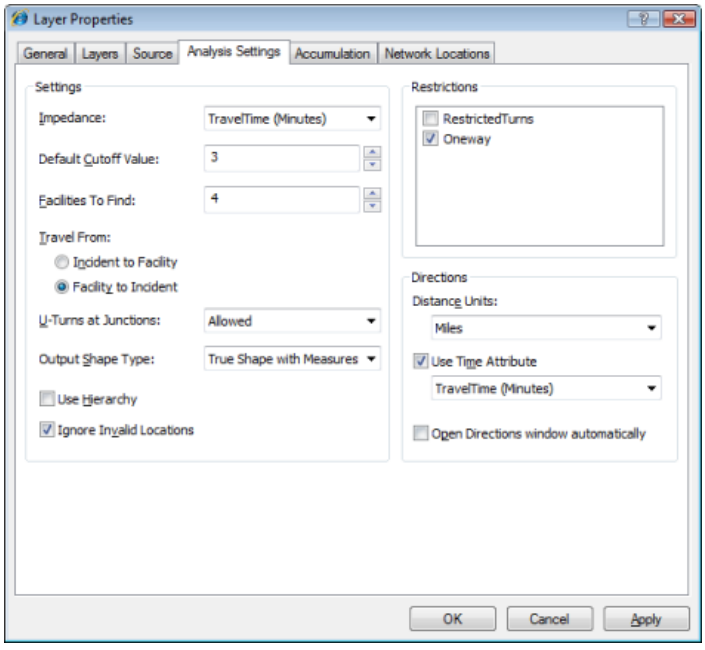
The ***Layer Properties*** dialog box opens.

2. Click the **Analysis Settings** tab.
3. Make sure that **Impedance** is set to **TravelTime (Minutes)**.
4. Enter 3 in the **Default Cutoff Value** text box.

ArcGIS will search for fire stations that are within three minutes of the fire on Twin Peaks Boulevard. Any fire stations outside the cutoff time are ignored.

5. Increase **Facilities to Find** to `4`.
   ArcGIS will search for a maximum of four fire stations from the fire site. However, the three-minute cutoff still applies; therefore, if only three fire stations are within the three-minute cutoff, then a fourth fire station will not be found.
6. Choose **Facility to Incident** for the **Travel From** direction.
   The search results emanate out from the fire stations, which are loaded as facilities. This mimics the fire engines traveling from the stations to the fire (incident).
7. Click the **U-Turns at Junctions** drop-down arrow and choose **Allowed**.
8. Click the **Output Shape Type** drop-down arrow and choose **True Shape with Measures**.
9. Uncheck **Use Hierarchy**.
10. Check **Ignore Invalid Locations**.
11. In the **Restrictions** frame, uncheck **RestrictedTurns**.
    Fire engines don't need to obey this traffic rule in emergencies.
12. In the **Directions** frame, make sure that **Distance Units** is set to **Miles**, **Use Time Attribute** is checked, and the time attribute is set to **TravelTime (Minutes)**.

Your **Analysis Settings** tab should look like the following graphic:



13. Click **OK**.

Identifying the closest facilities

Steps:

1. Click the **Solve** button on the ***Network Analyst*** toolbar.

Routes appear in the map display and in the **Route** class in the ***Network Analyst*** window.

Note that you configured the analysis to find four facilities within a three-minute cutoff; however, only three facilities are within the cutoff.

2. Click the **Directions Window** button on the ***Network Analyst*** toolbar.
   The ***Directions*** dialog box opens.

   Driving directions from each fire station are listed in the window.

3. If you don't plan to work on any other exercise, exit ArcMap. Click **No** to discard any changes.
4. If you plan to work on another exercise, follow the substeps below.
   a. Click **File** > **New.**
      The ***New Document*** dialog box opens.

b. Click **OK**.

c. Click **No** when prompted to save changes.

Exercise 5: Calculating service areas and creating an OD cost matrix

Complexity:
Beginner

Data Requirement:
ArcGIS Tutorial Data Setup

Data Path:
C:\ArcGIS\ArcTutor\Network Analyst\Tutorial

Goal:
Create service area polygons and create an OD cost matrix.

In this exercise, you will create a series of polygons that represent the distance that can be reached from a facility within a specified amount of time. These polygons are known as service area polygons. You will calculate 3-, 5-, and 10-minute service areas for six warehouses in Paris.

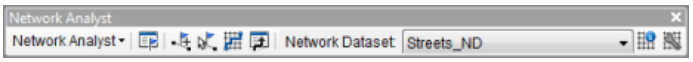
You will also find how many stores are within each of these service areas. You will identify one warehouse that should be relocated to better service the stores. Additionally, you will create an origin–destination cost matrix for delivery of goods from the warehouses to all stores within a 10-minute drive time. Such a matrix is used as an input for logistics, delivery, and routing analyses.

Preparing your display

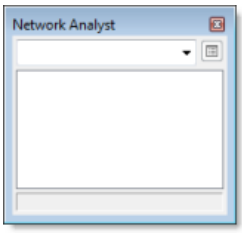
Steps:

1. If you have Exercise05.mxd open in ArcMap, skip to step 6.
2. Start ArcMap by clicking **Start** > **All Programs** > **ArcGIS** > **ArcMap 10.**
3. On the ***ArcMap - Getting Started*** dialog box, click **Existing Maps** > **Browse for more.**
4. Browse to C:\ArcGIS\ArcTutor\Network Analyst\Tutorial.
   This is the default installation location for the tutorial data.
5. Double-click **Exercise05.mxd**.
   The map document opens in ArcMap.
6. Enable the Network Analyst extension.
   a. Click **Customize** > **Extensions.**
      The ***Extensions*** dialog box opens.
   b. Check **Network Analyst**.
   c. Click **Close**.

   If the ***Network Analyst*** toolbar is not displayed, you need to add it.
7. Click **Customize** > **Toolbars** > **Network Analyst.**
   The ***Network Analyst*** toolbar is added to ArcMap.



   If the ***Network Analyst*** window is not displayed, you need to add it.
8. On the ***Network Analyst*** toolbar, click the **Show/Hide Network Analyst Window** button.
   The dockable ***Network Analyst*** window opens.

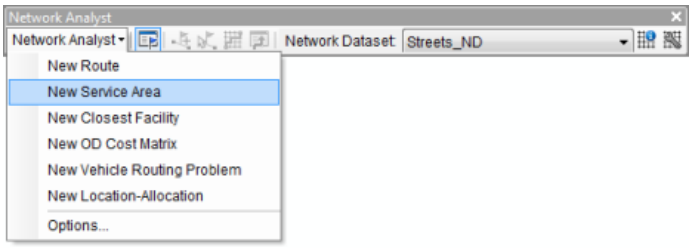


You can dock or undock the ***Network Analyst*** window. In this exercise, it is docked below the ***Table Of Contents*** window.

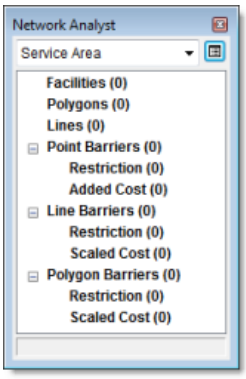
Creating the service area analysis layer

Steps:

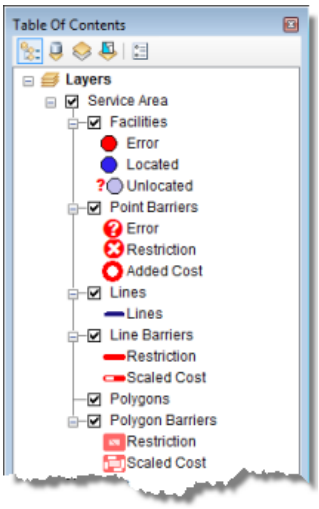
1. Click **Network Analyst** on the ***Network Analyst*** toolbar and click **New Service Area**.



The service area analysis layer is added to the ***Network Analyst*** window. The network analysis classes (Facilities, Polygons, Lines, Point Barriers, Line Barriers, and Polygon Barriers) are empty.



The analysis layer is also added to the ***Table Of Contents*** window.

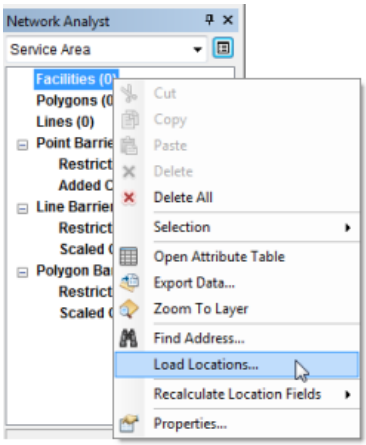


Adding facilities

Next, you will add warehouses as facilities for which the service area polygons will be generated.

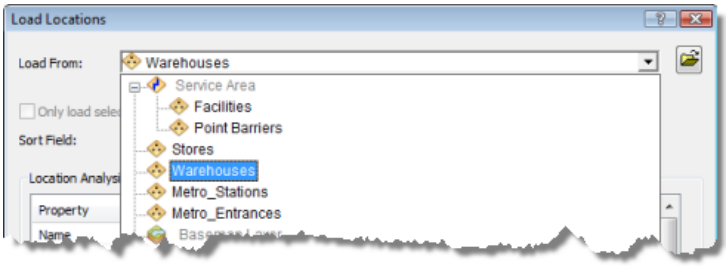
Steps:

1. On the ***Network Analyst*** window, right-click **Facilities (0)** and choose **Load Locations**.



   The ***Load Locations*** dialog box opens.

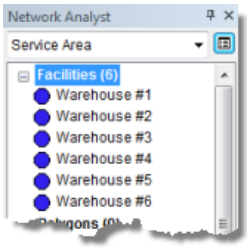
2. In the **Load From** drop-down list, choose **Warehouses**.



3. Click **OK**.

The six facilities are displayed in the map.

4. In the ***Network Analyst*** window, click the plus (+) sign next to **Facilities (6)** to see a list of the loaded facilities.

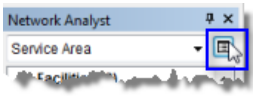


Setting up the parameters for the analysis

Next, you will specify that your service area will be calculated based on drive time (using minutes). Three service area polygons will be calculated for each facility, one at 3 minutes, one at 5 minutes, and another at 10 minutes. You will specify that the direction of travel will be from the facility—not toward the facility, that no U-turns are allowed, and that one-way restrictions must be followed.

Steps:

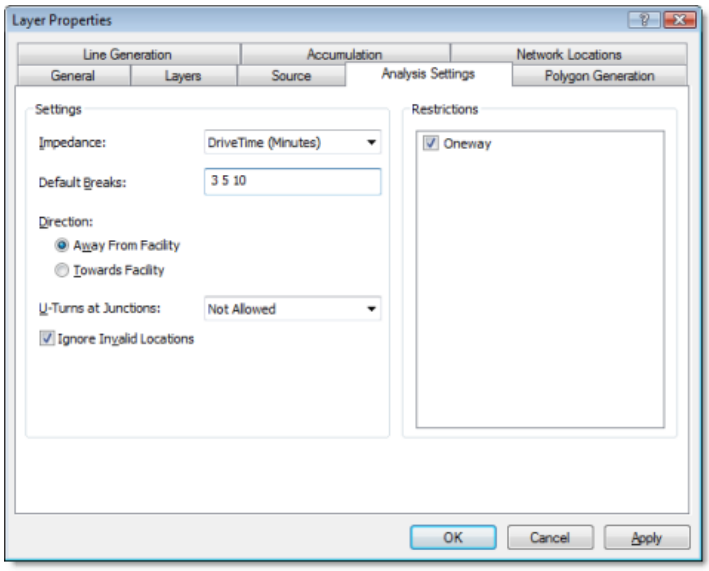
1. Click the **Analysis Layer Properties** button on the ***Network Analyst*** window.



The ***Layer Properties*** dialog box opens.

2. Click the **Analysis Settings** tab.
3. Make sure that **Impedance** is set to use **DriveTime (Minutes)**.
4. Type `3 5 10` in the **Default Breaks** text box.
5. Under **Direction**, click **Away From Facility**.
6. Choose **Not Allowed** from the **U-Turns at Junctions** drop-down list.
7. Leave **Ignore Invalid Locations** checked.
8. Check **Oneway** in the **Restrictions** list.

The **Analysis Settings** tab should now look like this:



9. Click the **Polygon Generation** tab.
10. Make sure that **Generate Polygons** is checked.
11. For **Polygon Type**, click **Generalized**.
    Detailed polygons are more accurate but need more time to be generated.
12. Uncheck the **Trim Polygon** option.
    This is a postprocess that trims the outside polygon to remove spikes but takes a little longer to run.
13. Click **Overlapping** for the **Multiple Facilities Options**.
    This results in individual polygons for each facility. A polygon from one facility might overlap with a polygon from another, nearby facility.
14. Click **Rings** for the **Overlap** type.
    This excludes areas of smaller breaks from the polygons of a bigger break.
15. Click **Apply** to save the settings.
16. Click the **Line Generation** tab.
17. Leave **Generate Lines** unchecked.
18. Click **OK**.

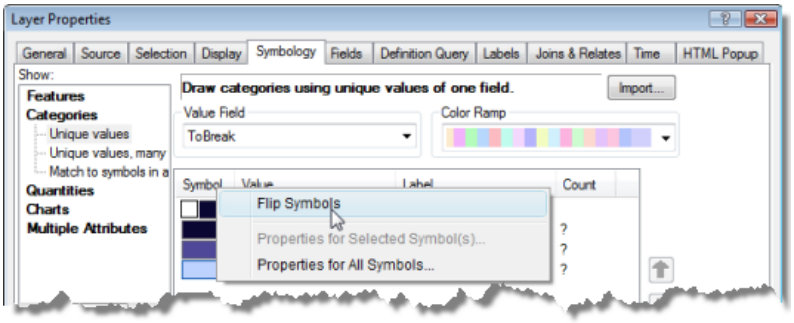
Run the process to compute the service area

Steps:

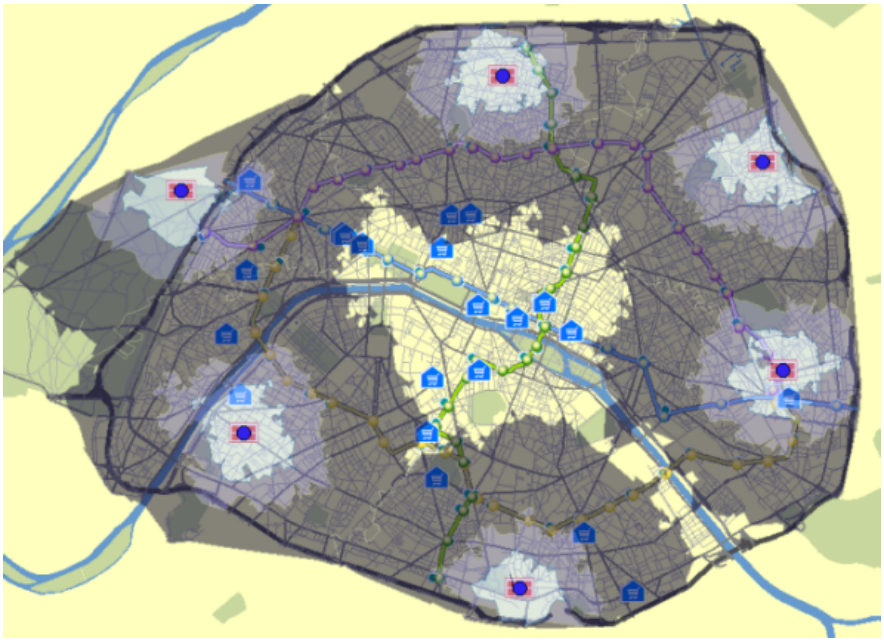
1. Click the **Solve** button on the ***Network Analyst*** toolbar.
   The service area polygons appear on the map and on the ***Network Analyst*** window.

   The polygons are transparent, which allow you to see the underlying streets. However, instead of color coding the breaks from dark to light with increasing distance, you will change them to go from light to dark.
2. In the ***Table Of Contents*** window, right-click the **Polygons** sublayer and choose **Properties**.

3. Click the **Symbology** tab.
4. Click the **Symbol** field name and choose **Flip Symbols**. (Make sure you click—not right-click—**Symbol**; otherwise, you get a different context menu.)



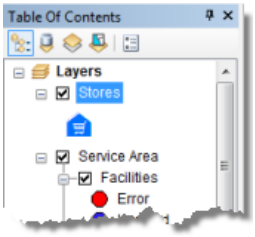
5. Click **OK**.
   The outer and inner service area breaks switch colors, making it clearer what areas the 10-minute breaks cover.



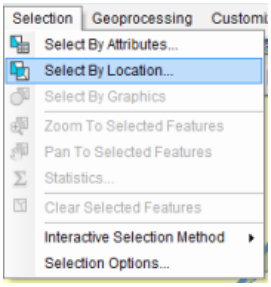
Identifying stores that are outside all service areas

Steps:

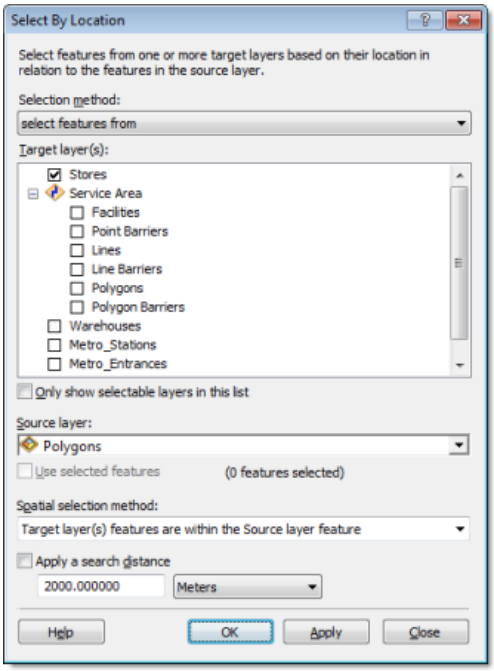
1. In the ***Table Of Contents*** window, click and drag **Stores** to the top of the **Layers** list to improve visibility.



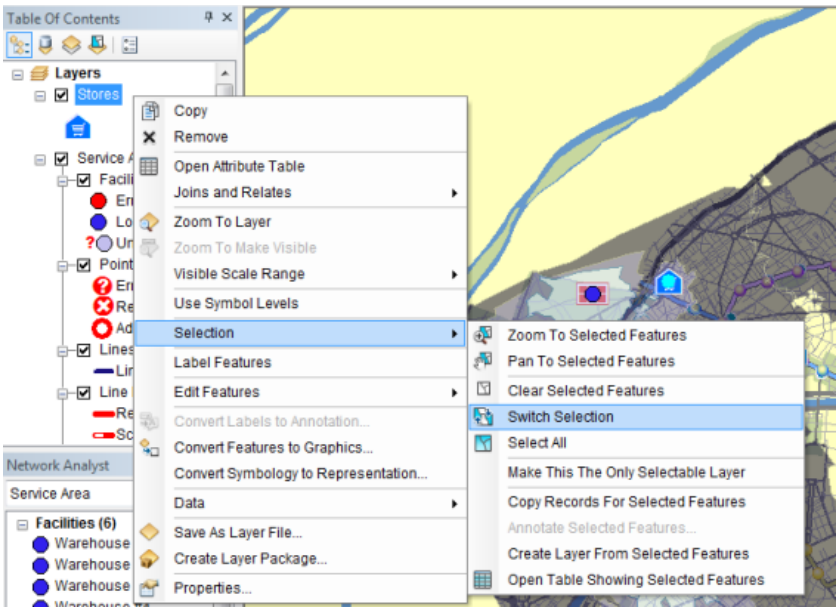
2. Click **Selection** > **Select By Location.**



3. Create the selection query on the ***Select By Location*** dialog box to select features from stores that are completely within polygons, as shown below.



4. Click **OK**.
   The stores that are within the polygons are selected; however, you want to select the stores that are outside the service area polygons.
5. In the ***Table Of Contents*** window, right-click Stores and click **Selection** > **Switch Selection.**



The selection now shows the distribution of stores not contained in any service area polygons. Use this selection to identify the area in which you will relocate a warehouse. The best area appears to be in the center of the map.

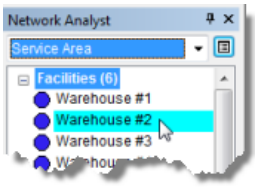
6. On the ***Tools*** toolbar, click the **Clear Selected Features** button .

Relocating the least accessible warehouse

Look at the service area polygons of Warehouse #2. There are not any stores within the 3-, 5-, or 10-minute service areas around Warehouse #2; hence, you will relocate that warehouse to better service the stores.

Steps:

1. On the ***Network Analyst*** window, select **Warehouse #2** under **Facilities (6)**.



2. Click the **Select/Move Network Location Tool** on the ***Network Analyst*** toolbar.

3. On the map display, drag Warehouse #2 to the center of the map as shown below.

Run the process to compute the service area

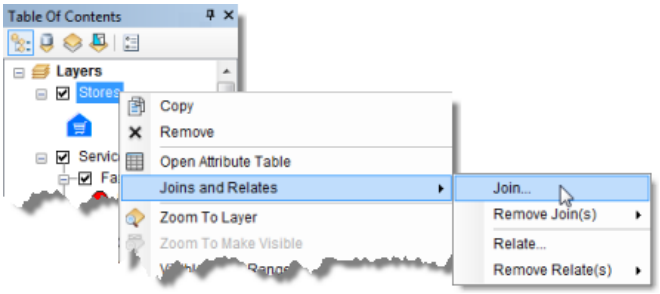
Steps:

1. Click the **Solve** button on the ***Network Analyst*** toolbar.
   The service area polygons appear on the map and the ***Network Analyst*** window.

Identifying the service area polygon that each store is within

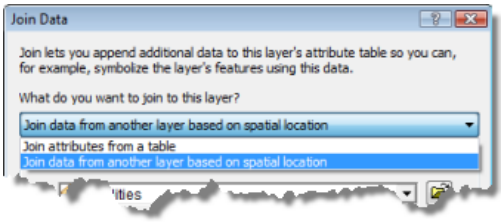
Steps:

1. In the ***Table Of Contents*** window, right-click **Stores** and click **Joins and Relates** > **Join.**

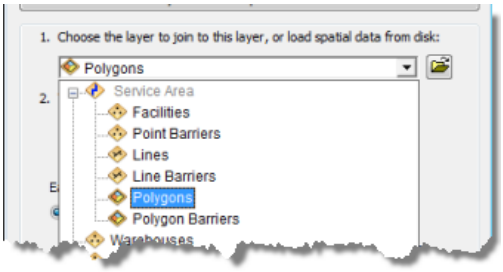


   The ***Join Data*** dialog box opens.

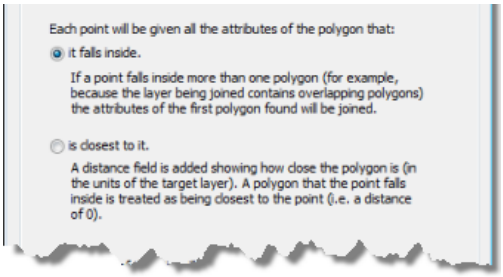
2. Choose **Join data from another layer based on spatial location**.



3. Choose **Polygons** as the layer to join to this layer.

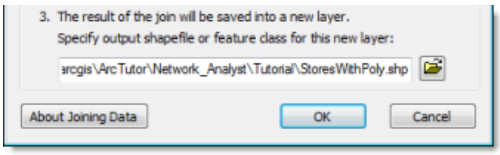


4. Click the **it falls inside** button.



This adds the attributes of the polygon to all points that fall inside the polygon.

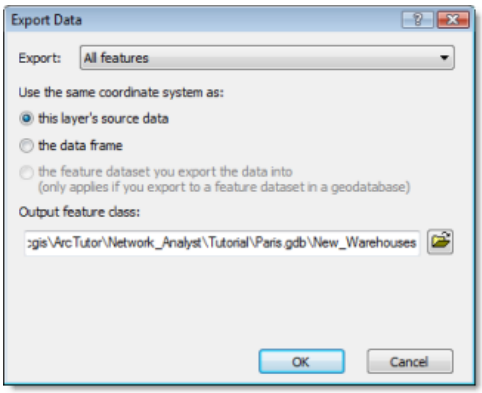
5. Specify an output shapefile or feature class to save the join results to and name it `StoresWithPoly`.



6. Click **OK**.
   ArcGIS performs the join and adds the new layer to the map document.
7. In the ***Table Of Contents*** window, right-click the new **StoresWithPoly** feature layer and choose **Open Attribute Table**.
   Each row in the table displays the name of the store and polygon it falls under. You can use this table to generate other useful categories, such as the number of stores within 0-to 3-minute service areas.
8. Close the attribute table.

You can optionally export your facilities (including the one you moved) as a feature class.

9. In the ***Network Analyst*** window, right-click **Facilities (6)** and choose **Export Data**.
   The ***Export Data*** dialog box opens.
10. In the **Export** drop-down list, choose **All features**.
11. Choose an output location and type (shapefile or feature class).
    You might choose to store a feature class in the Paris geodatabase:
    `C:\arcgis\ArcTutor\Network Analyst\Tutorial\Paris.gdb\New_Warehouses`



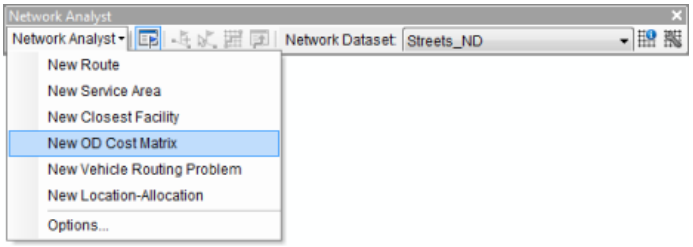
12. Click **OK**.
    A message appears asking if you want to add the exported data to the map.
13. Click **No**.
    You won't need the data for the rest of this exercise.

Creating an OD cost matrix analysis layer

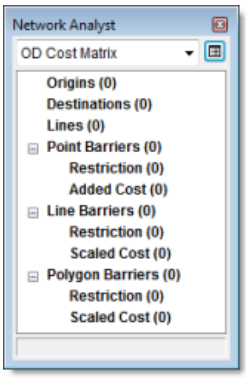
Optionally, you can create an origin–destination cost matrix for deliveries from the new warehouses to each store. The results of this matrix can be used to identify stores that will be serviced by each warehouse within a 10-minute drive time. Also, you can find the total drive time from each warehouse to its stores.

Steps:

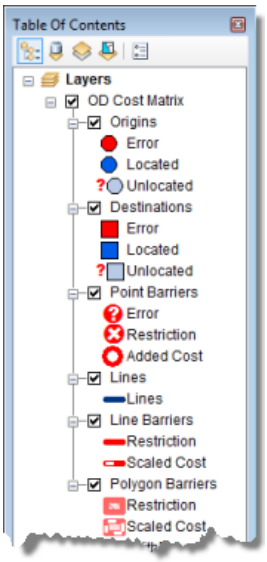
1. In the ***Table Of Contents*** window, uncheck the **Service Area** analysis layer and the **StoresWithPoly** feature layer to improve readability of the map.
2. Click **Network Analyst** on the ***Network Analyst*** toolbar and click **New OD Cost Matrix**.



The OD cost matrix analysis layer is added to the ***Network Analyst*** window. The network analysis classes (Origins, Destinations, Lines, Point Barriers, Line Barriers, and Polygon Barriers) are empty.



The analysis layer is also added to the ***Table Of Contents*** window.

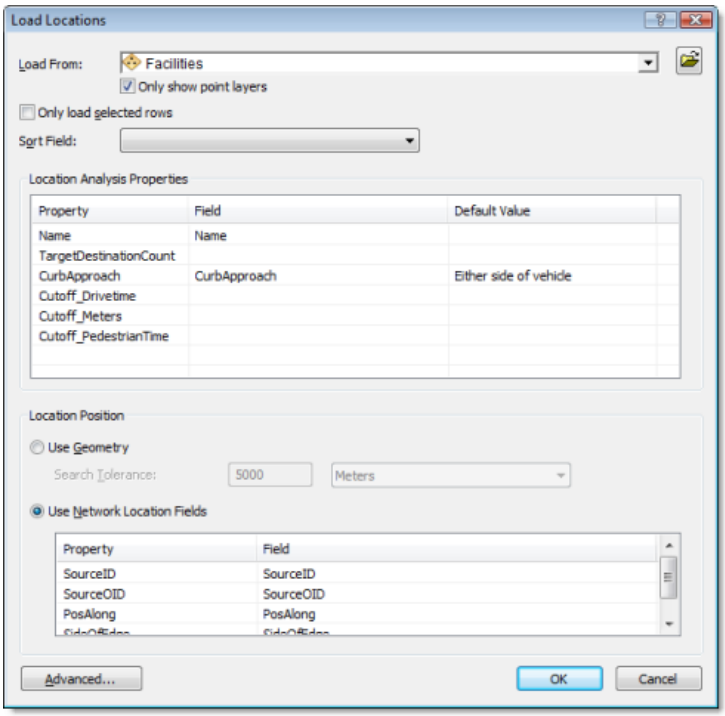


Adding origins

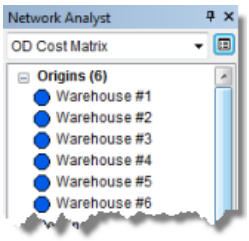
You can use the facilities from the service area analysis (in the previous sections) as origins. If you have not completed the section on service areas, you can use the Warehouses feature layer instead.

Steps:

1. In the ***Network Analyst*** window, right-click **Origins (0)** and choose **Load Locations**.
   The ***Load Locations*** dialog box opens.
2. Click **ServiceArea/Facilities** in the **Load From** drop-down list. (If you did not complete the previous sections on service area analysis, you can choose **Warehouses** instead.)
3. Uncheck **Only load selected rows**.
4. Under **Location Position**, click **Use Network Location Fields**. (If you are loading Warehouses, click **Use Geometry**.)
   Using network location fields allows ArcGIS to use the already-located position of service area facilities to locate them again as origins. This is much faster than using a spatial search to locate them again.



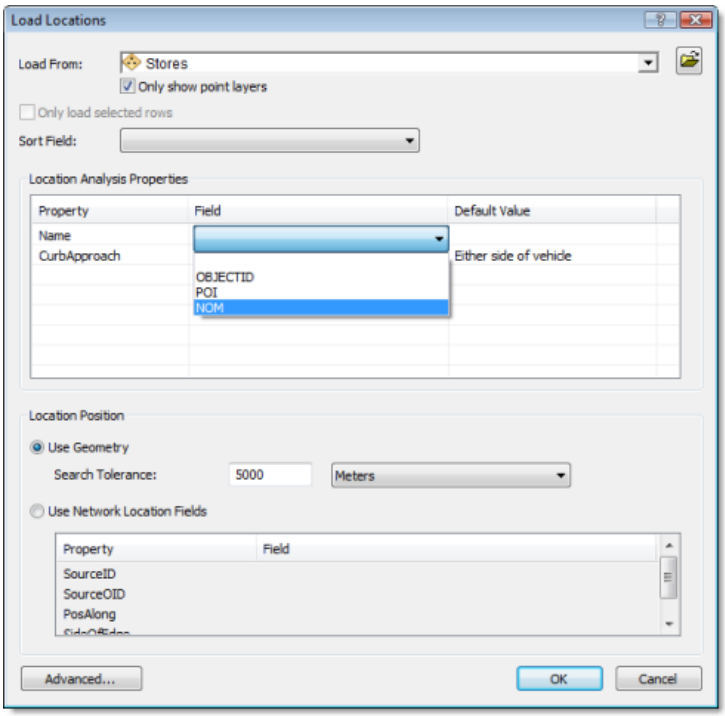
5. Click **OK**.
   The six new origins are displayed on the map and listed in the ***Network Analyst*** window under **Origins**.



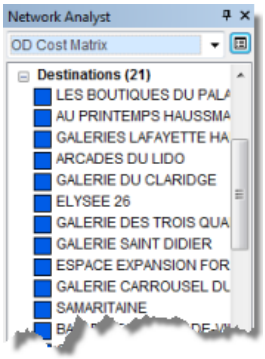
Adding destinations

Steps:

1. In the ***Network Analyst*** window, right-click **Destinations (0)** and choose **Load Locations**.
2. Choose **Stores** in the **Load From** drop-down list.
3. Under **Location Analysis Properties**, for the property name, choose **NOM** from the **Field** drop-down list.
   Since the French field name NOM is not configured in the NASolverConfiguration.xml file, ArcGIS is unable to map the field name automatically.



4. Click **OK**.
   The ***Network Analyst*** window now lists 21 destinations.



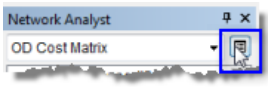
These destinations are also displayed on the map.

Setting up the parameters for the analysis

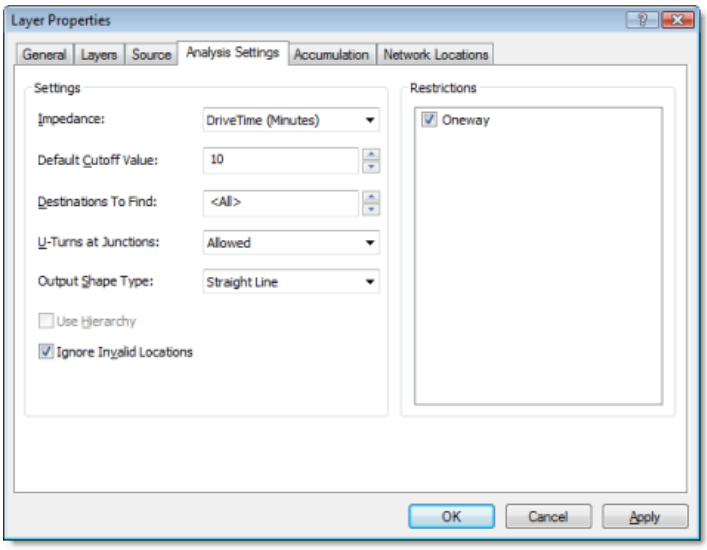
Next, you will specify that your OD cost matrix will be calculated based on drive time. You will set a default cutoff value of 10 minutes and ensure that all destinations are found within the specified cutoff. Additionally, you will specify that U-turns are allowed everywhere and the output Shape type should be a straight line. Since all these trips are on roads, one-way restrictions must be followed. All invalid locations (locations not found) will be ignored.

Steps:

1. Click the **Analysis Layer Properties** button on the ***Network Analyst*** window.



2. Click the **Analysis Settings** tab.
3. Make sure that the **Impedance** drop-down list is set to **DriveTime (Minutes)**.
4. Type `10` in the **Default Cutoff Value** text box.
   This will create origin–destination paths from each warehouse to all stores that can be reached within 10 minutes.
5. Make sure that **Destinations To Find** is set to **<All>**.
6. Click the **U-Turns at Junctions** drop-down arrow and choose **Allowed**.
7. Make sure that **Output Shape Type** is set to **Straight Line**.
8. Make sure that **Ignore Invalid Locations** is checked.
9. Check **Oneway** in the **Restrictions** list.



10. Click **OK**.
    The parameter settings are saved.

Run the process to create the OD cost matrix

Steps:

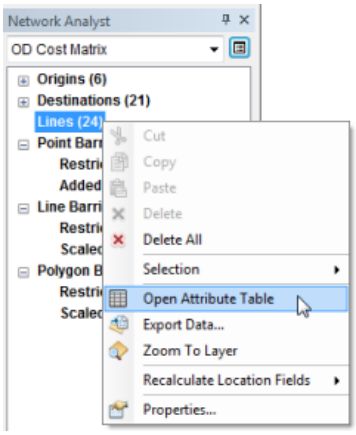
1. Click the **Solve** button on the ***Network Analyst*** toolbar.
   The OD lines appear on the map. There are 24 lines in this example. This number may be different for you, depending on where you relocated Warehouse #2.
2. If the Service Area layer is not displayed, turn it on to show the OD Cost Matrix layer on top of the service areas of the warehouses.

Allocating stores to warehouses

Based on the OD cost matrix, you can now identify the stores that would be served by each warehouse.

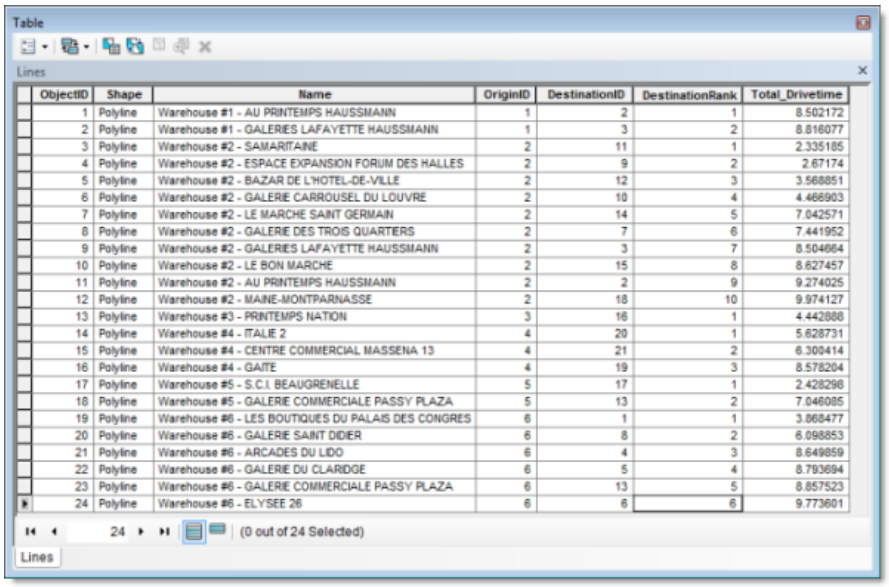
Steps:

1. In the ***Network Analyst*** window, right-click **Lines (24)** and choose **Open Attribute Table**.



   The Lines table opens.

   The Lines table represents the origin–destination cost matrix from each warehouse to the stores within a 10-minute drive time. The OriginID column contains IDs of warehouses. The DestinationID column contains IDs of stores. The DestinationRank is a rank assigned to each destination that is served by a store based on the total drive time. For example, in the table below, for Warehouse #1, DestinationID 2 has a rank of 1, and DestinationID 3 has a rank of 2. This is because it takes less time to go from Warehouse #1 to DestinationID 2. (This may be different for you, as your analysis results are dependent on the source feature class of the origins and destinations.)



Table

Lines

ObjectID	Shape	Name	OriginID	DestinationID	DestinationRank	Total_Drivetime
1	Polyline	Warehouse #1 - AU PRINTEMPS HAUSSMANN	1	2	1	8.502172
2	Polyline	Warehouse #1 - GALERIES LAFAYETTE HAUSSMANN	1	3	2	8.816077
3	Polyline	Warehouse #2 - SAMARITAINE	2	11	1	2.335185
4	Polyline	Warehouse #2 - ESPACE EXPANSION FORUM DES HALLES	2	9	2	2.67174
5	Polyline	Warehouse #2 - BAZAR DE L'HOTEL-DE-VILLE	2	12	3	3.568851
6	Polyline	Warehouse #2 - GALERIE CARROUSEL DU LOUVRE	2	10	4	4.466903
7	Polyline	Warehouse #2 - LE MARCHE SAINT GERMAIN	2	14	5	7.042571
8	Polyline	Warehouse #2 - GALERIE DES TROIS QUARTIERS	2	7	6	7.441952
9	Polyline	Warehouse #2 - GALERIES LAFAYETTE HAUSSMANN	2	3	7	8.504664
10	Polyline	Warehouse #2 - LE BON MARCHE	2	15	8	8.627457
11	Polyline	Warehouse #2 - AU PRINTEMPS HAUSSMANN	2	2	9	9.274025
12	Polyline	Warehouse #2 - MAINE-MONTPARNASSE	2	18	10	9.974127
13	Polyline	Warehouse #3 - PRINTEMPS NATION	3	16	1	4.442888
14	Polyline	Warehouse #4 - ITALIE 2	4	20	1	5.628731
15	Polyline	Warehouse #4 - CENTRE COMMERCIAL MASSENA 13	4	21	2	6.309414
16	Polyline	Warehouse #4 - GAITE	4	19	3	8.578204
17	Polyline	Warehouse #5 - S.C.I. BEAUGRENELLE	5	17	1	2.428296
18	Polyline	Warehouse #5 - GALERIE COMMERCIALE PASSY PLAZA	5	13	2	7.046085
19	Polyline	Warehouse #6 - LES BOUTIQUES DU PALAIS DES CONGRES	6	1	1	3.868477
20	Polyline	Warehouse #6 - GALERIE SAINT DIDIER	6	8	2	6.098853
21	Polyline	Warehouse #6 - ARCADES DU LIDO	6	4	3	8.649859
22	Polyline	Warehouse #6 - GALERIE DU CLARIDGE	6	5	4	8.793694
23	Polyline	Warehouse #6 - GALERIE COMMERCIALE PASSY PLAZA	6	13	5	8.857523
24	Polyline	Warehouse #6 - ELYSEE 26	6	6	6	9.773601

24 (0 out of 24 Selected)

Lines

The OD cost matrix displays the stores serviced by each warehouse along with the total drive time for each route. Some stores are within a 10-minute accessibility zone of more than one warehouse and can be served by any one of them. The OD cost matrix can also be used as an input in logistics routing models that use origin–destination matrices to allocate goods and services.

2. If you don't plan to work on any other exercise, exit ArcMap. Click **No** to discard any changes.
3. If you plan to work on another exercise, follow the substeps below.
    a. Click **File** > **New.**
    The ***New Document*** dialog box opens.
    b. Click **OK**.
    c. Click **No** when prompted to save changes.

Exercise 6: Creating a model for route analysis

In this exercise, you will create a model for finding the fastest delivery route connecting 21 stores in Paris.

Complexity:
Beginner

Data Requirement:
ArcGIS Tutorial Data Setup

Data Path:
C:\ArcGIS\ArcTutor\Network Analyst\Tutorial

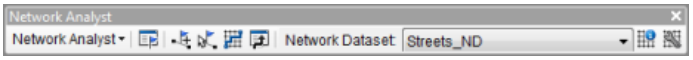
Goal:
Create a geoprocessing model using ModelBuilder and ArcGIS Network Analyst tools.

Preparing your display

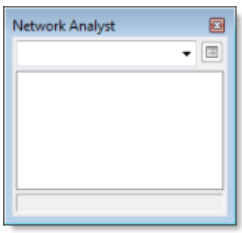
Steps:

1. If you have Exercise06.mxd open in ArcMap, skip to step 6.
2. Start ArcMap by clicking **Start** > **All Programs** > **ArcGIS** > **ArcMap 10.**
3. On the ***ArcMap - Getting Started*** dialog box, click **Existing Maps** > **Browse for more.**
4. Browse to C:\ArcGIS\ArcTutor\Network Analyst\Tutorial.
   This is the default installation location for the tutorial data.
5. Double-click **Exercise06.mxd**.
   The map document opens in ArcMap.
6. Enable the Network Analyst extension.
   a. Click **Customize** > **Extensions.**
      The ***Extensions*** dialog box opens.
   b. Check **Network Analyst**.
   c. Click **Close**.

   If the ***Network Analyst*** toolbar is not displayed, you need to add it.
7. Click **Customize** > **Toolbars** > **Network Analyst.**
   The ***Network Analyst*** toolbar is added to ArcMap.



   If the ***Network Analyst*** window is not displayed, you need to add it.
8. On the ***Network Analyst*** toolbar, click the **Show/Hide Network Analyst Window** button .
   The dockable ***Network Analyst*** window opens.

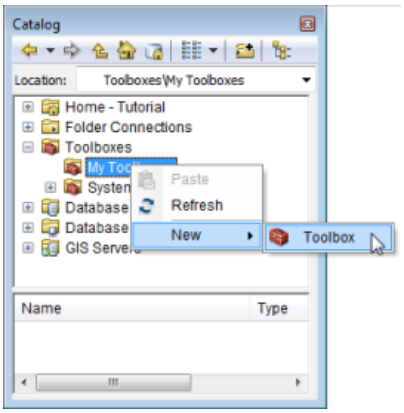


   You can dock or undock the ***Network Analyst*** window. In this exercise, it is docked below the ***Table Of Contents*** window.

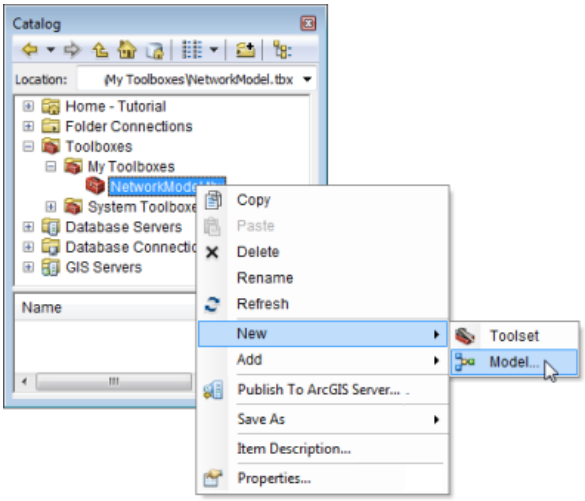
Creating the model

Steps:

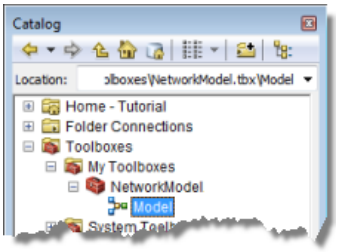
1. Click the **Catalog window** button on the ***Standard*** toolbar.
   The dockable ***Catalog*** window opens.
2. In the ***Catalog*** window, expand **Toolboxes**.
3. Right-click **My Toolboxes** and choose **New** > **Toolbox.**

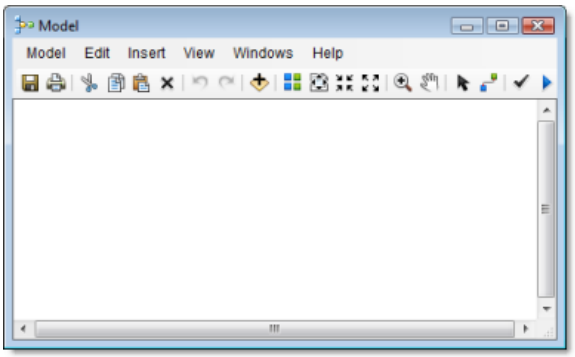


4. Type `NetworkModel` and press ENTER to name the newly added toolbox.
5. Right-click the **NetworkModel** toolbox and click **New** > **Model.**



A new model appears in the toolbox, and the ***Model*** dialog box opens.



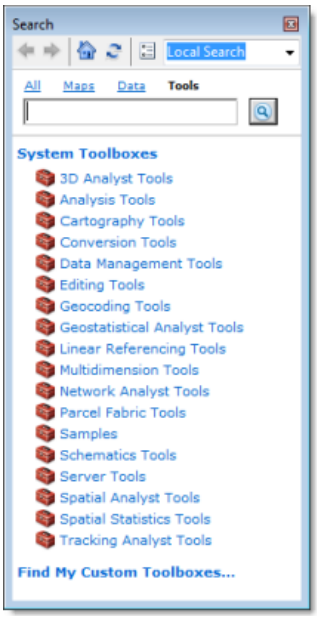


Creating a route layer in the model

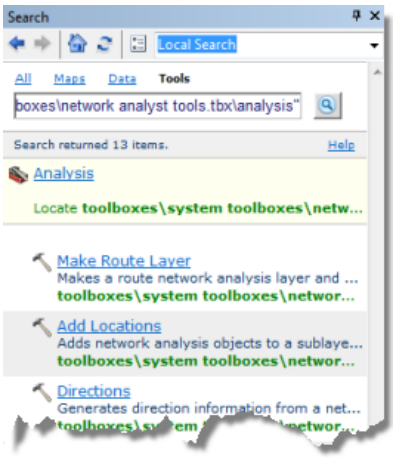
Next, you will create the route layer within the model. The workflow for using Network Analyst in a model is the same as the workflow for using Network Analyst in ArcMap. First, you create a route layer and set properties. Next, you add the network locations (stops) to be used as inputs. Last, you solve and display the results.

Steps:

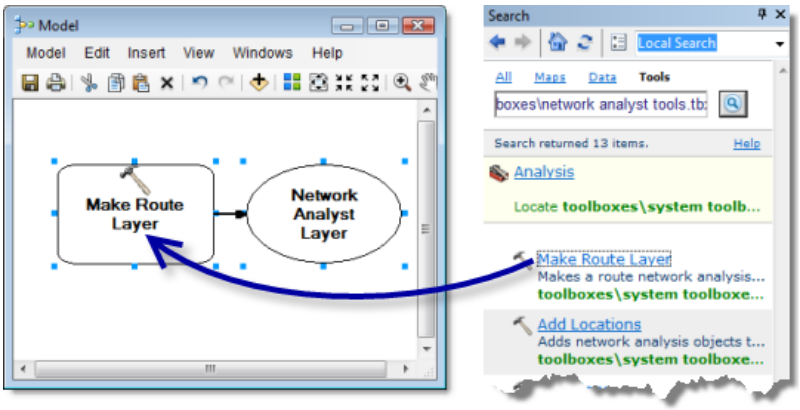
1. On the menu bar, click **Geoprocessing** > **Search For Tools.**
   The dockable ***Search*** window opens with the **Tools** category selected.



2. Click **Network Analyst Tools** in the list of toolboxes in the ***Search*** window.
   A list of toolsets and tools related to the ArcGIS Network Analyst extension are listed.
3. Click **Analysis** in the ***Search*** window.
   Only tools related to network analysis are displayed in the ***Search*** window.

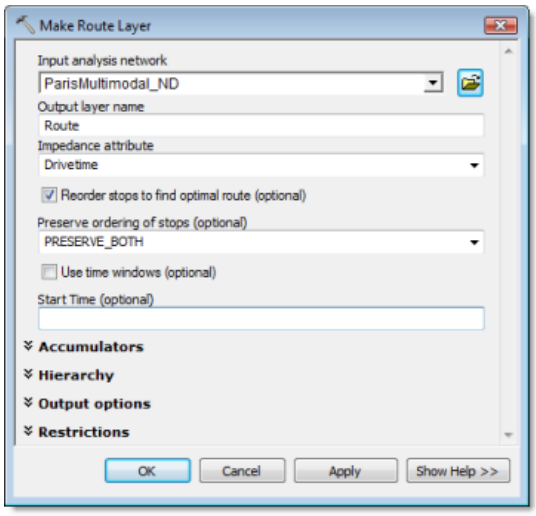


4. Drag the **Make Route Layer** link onto the ***Model*** dialog box.



5. On the ***Model*** dialog box, double-click **Make Route Layer**.
   The ***Make Route Layer*** dialog box opens so you can set its properties.
6. Click the **Input analysis network** drop-down arrow and choose **ParisMultimodal_ND**.
7. In the **Impedance attribute** drop-down list, click **DriveTime**.
8. Check the **Reorder stops to find optimal route** check box.
9. In the **Preserve ordering of stops** drop-down list, click **PRESERVE_BOTH**.

The tool dialog box should look like the one in the graphic below.



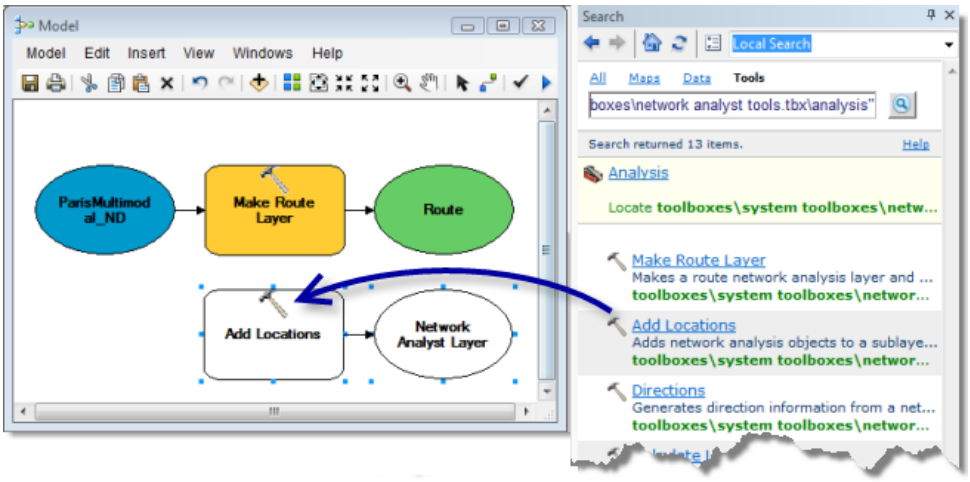
10. Click **OK**.
    The input analysis layer is now added to the model. The Make Route Layer tool turns yellow, and the output turns green.
11. Click the **Full View** button .
    The entire model is displayed.

Adding stops to the route layer

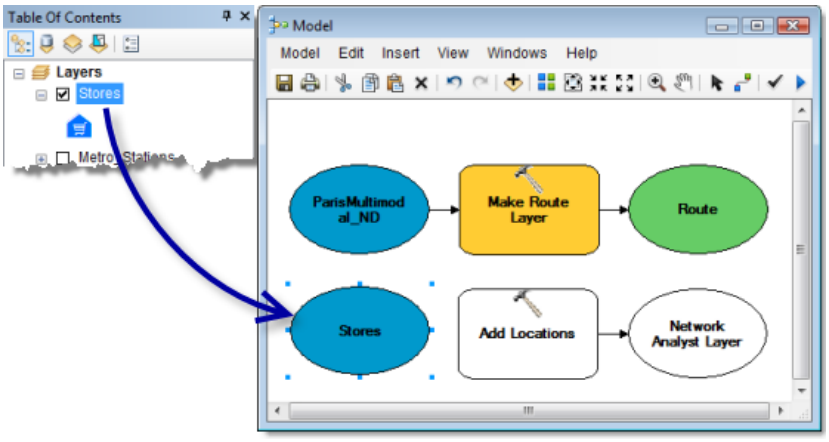
Next, you will add the stores as stops by using the Add Locations tool.

Steps:

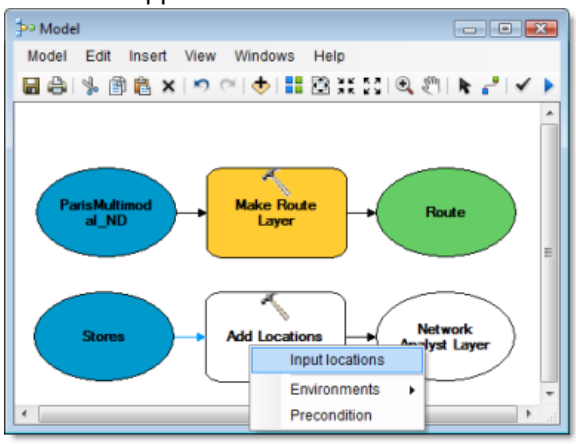
1. Drag the **Add Locations** tool from the ***Search*** window onto the ***Model*** dialog box.



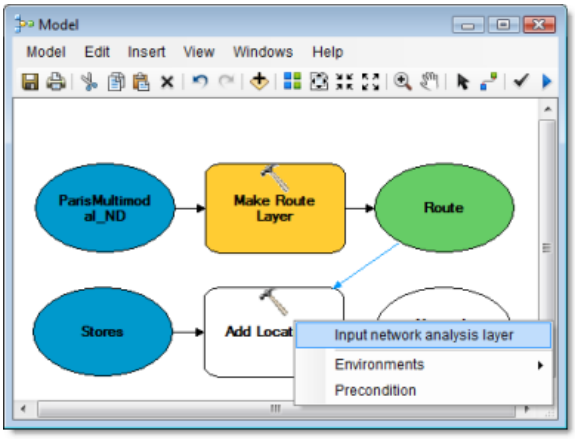
2. Select the **Stores** feature layer in the ***Table Of Contents*** window and drag it onto the model to the left of **Add Locations**.



3. On the ***Model*** dialog box, click the **Connect** tool .
4. Click **Stores** and click **Add Locations** to connect them. Click **Input locations** on the context menu that appears.



5. Using the **Connect** tool , connect **Route** to **Add Locations**. Click **Input network analysis layer** on the context menu that appears.



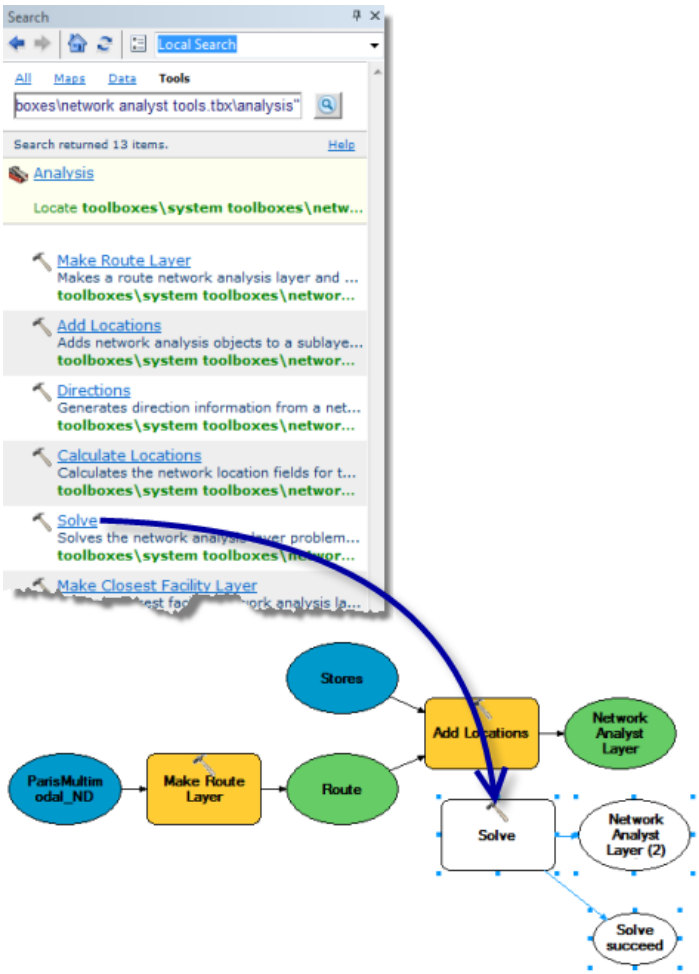
6. Click the **Auto Layout** button .
   The model is arranged in a logical order.

7. Click the **Full View** button .

Adding the Solve tool

Steps:

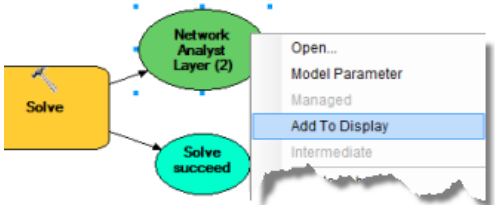
1. Drag the **Solve** tool from the ***Search*** window onto the ***Model*** dialog box.



2. Using the **Connect** tool , connect the output layer, **Network Analyst Layer**, to **Solve**. Click **Input network analysis layer** on the context menu that appears.
   The **Solve** tool turns yellow, the output layer turns green, and **Solve succeeded** turns cyan.
3. Click the **Auto Layout** button .

4. Click the **Full View** button .

5. Click the **Select** tool .
6. Right-click the output layer of the **Solve** tool, which is labeled **Network Analyst Layer (2)**, and click **Add To Display**.



This tells the model to add the final output to the map display.

Running the model to find the best route

Steps:

1. Click the **Save** button to save the model.
2. Click the **Run** button .
   A status window appears while ArcGIS performs the route analysis.
3. When completed, close the status window and close the ***Model*** dialog box so you can inspect the results.
   A message appears prompting you to save the model.
4. Click **Yes**.

A new route layer is added to the ***Table Of Contents*** window. The ***Network Analyst*** window has all the stops and the resultant route. The map displays the stops that were loaded and the resultant route.

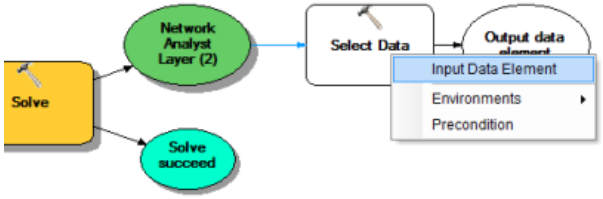
Configuring the model to save the results to disk

Steps:

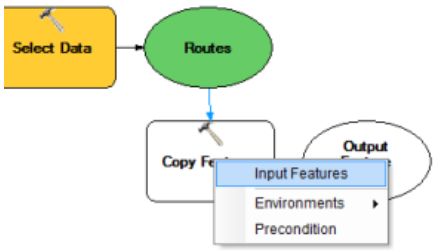
1. In the ***Catalog*** window, expand the **NetworkModel** toolbox, right-click **Model**, then choose **Edit**.

   To access the shortest path feature class for further analysis, you will need to copy features from memory onto disk.

2. Type `Select Data` in the ***Search*** window text box and press ENTER.
3. Drag the **Select Data** tool from the search results and drop it in the ***Model*** window.
4. Using the **Connect** tool , connect the final output layer to **Select Data**. Click **Input Data Element** on the context menu that appears.



5. In the ***Model*** window, double-click **Select Data**.
   The ***Select Data*** dialog box opens.
6. Choose **Routes** from the **Child Data Element** drop-down list.
7. Click **OK**.
   The dialog box closes.
8. Type `Copy Features` in the ***Search*** window text box and press ENTER.
9. Drag the **Copy Features** tool from the search results onto the ***Model*** dialog box.
10. Using the **Connect** tool , connect the final output layer to **Copy Features**. Click **Input Features** on the context menu that appears.



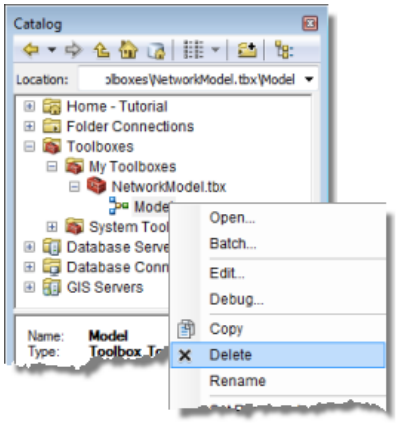
11. On the ***Model*** dialog box, double-click **Copy Features**.
    The ***Copy Features*** dialog box opens.
12. Enter an output location for saving the route as a feature class or shapefile.
    For example, you might type `C:\arcgis\ArcTutor\Network Analyst\Tutorial\Paris.gdb\path`.
13. Click **OK**.

Now running the model will solve the best route, select the route sublayer, and export it to a feature class. You can run the model by clicking the **Run** button .

Deleting the model

Steps:

1. In the ***Catalog*** window, navigate to the **NetworkModel** toolbox, right-click **Model**, then choose **Delete**.



   A message appears prompting you to confirm deletion.

   If you ran the model, you may also want to navigate to the location that you specified for the output of the Copy Features tool and delete the feature class that was created.

2. Click **Yes**.
3. Exit ArcMap and do not save any changes to Exercise06.mxd.

Exercise 7: Servicing a set of orders with a fleet of vehicles

In this exercise, you will find the best routes for a fleet of vehicles, operated by a distribution company, to deliver goods from a distribution center to a set of 25 grocery stores. Each store has a specific quantity of demand for the goods, and each truck has a limited capacity for carrying the goods. The main objective is to assign trucks in the fleet a subset of the stores to service and to sequence the deliveries in a way that minimizes the overall transportation costs.

Complexity:
Beginner

Data Requirement:
ArcGIS Tutorial Data Setup

Data Path:
C:\ArcGIS\ArcTutor\Network Analyst\Tutorial

Goal:
Solve a vehicle routing problem analysis.

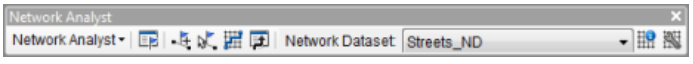
This can be achieved by solving a vehicle routing problem (VRP). Once the delivery sequence is determined, you will generate the turn-by-turn directions for the resulting routes, which can be electronically distributed or printed and given to the drivers to make the deliveries.

Preparing your display

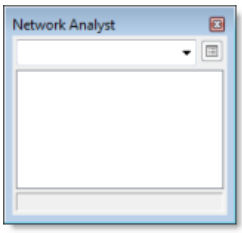
Steps:

1. If you have Exercise07.mxd open in ArcMap, skip to step 6.
2. Start ArcMap by clicking **Start** > **All Programs** > **ArcGIS** > **ArcMap 10.**
3. On the ***ArcMap - Getting Started*** dialog box, click **Existing Maps** > **Browse for more.**
   The ***Open ArcMap Document*** dialog box appears.
4. Browse to C:\ArcGIS\ArcTutor\Network Analyst\Tutorial.
   This is the default installation location for the tutorial data.
5. Double-click **Exercise07.mxd**.
   The map document opens in ArcMap.
6. Enable the Network Analyst extension.
   a. Click **Customize** > **Extensions.**
      The ***Extensions*** dialog box opens.
   b. Check **Network Analyst**.
   c. Click **Close**.

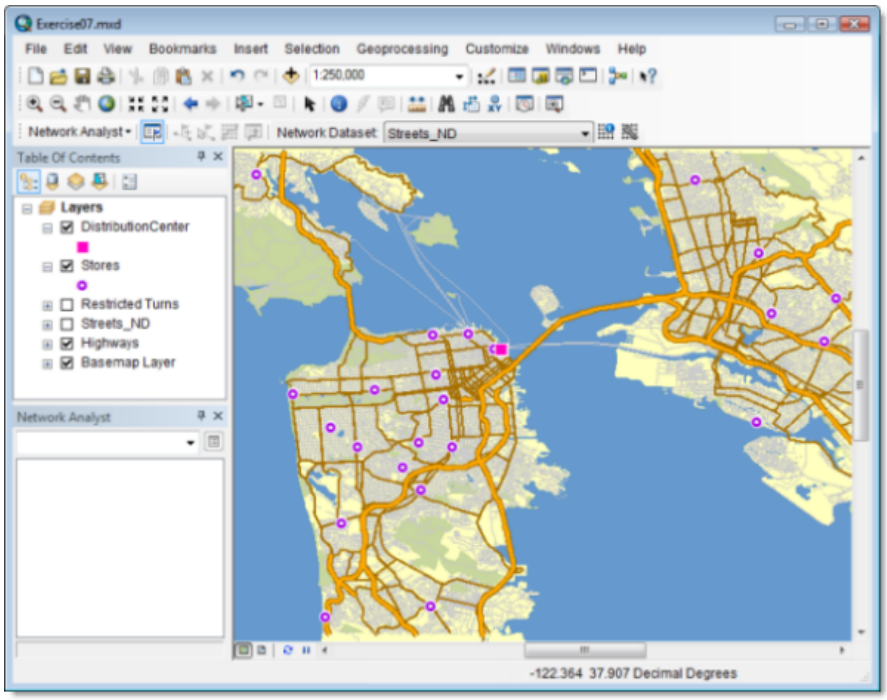
   If the ***Network Analyst*** toolbar is not displayed, you need to add it.
7. Click **Customize** > **Toolbars** > **Network Analyst.**
   The ***Network Analyst*** toolbar is added to ArcMap.



   If the ***Network Analyst*** window is not displayed, you need to add it.
8. On the ***Network Analyst*** toolbar, click the **Show/Hide Network Analyst Window** button.
   The dockable ***Network Analyst*** window opens.



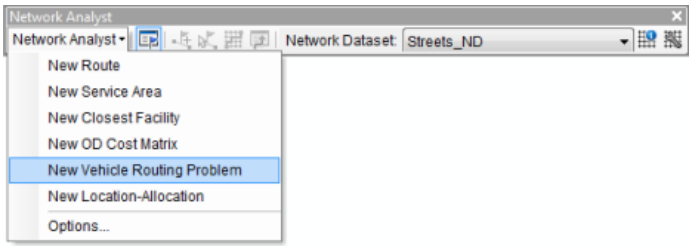
You can dock or undock the ***Network Analyst*** window. In this exercise, it is docked below the ***Table Of Contents*** window.



Creating the vehicle routing problem analysis layer

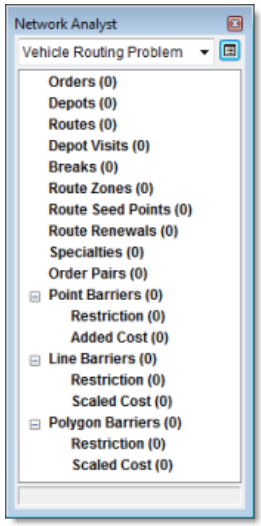
Steps:

1. Click **Network Analyst** on the ***Network Analyst*** toolbar and click **New Vehicle Routing Problem**.

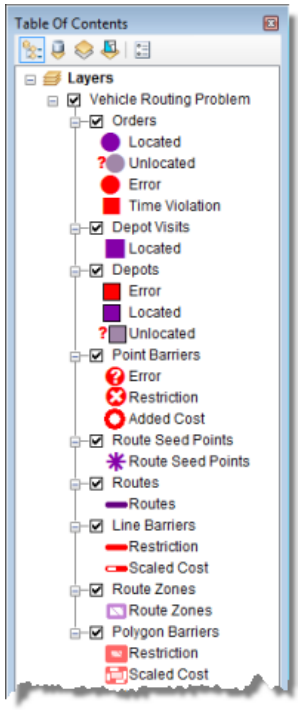


The vehicle routing problem analysis layer is added to the ***Network Analyst*** window. The network analysis classes (Orders, Depots, Routes, Depot Visits, Breaks, Route Zones, Route

Seed Points, Route Renewals, Specialties, Order Pairs, Point Barriers, Line Barriers, and Polygon Barriers) are empty.



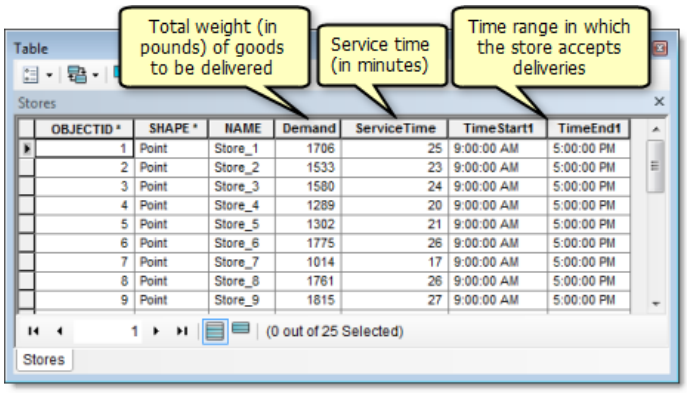
The analysis layer is also added to the ***Table Of Contents*** window.



Adding orders

You will add the grocery store locations to the Orders network analysis class. You can think of orders as orders to be filled, since each grocery store has requested goods to be delivered to it from the distribution center. Members of the Orders class will eventually become stops along the vehicle's routes.

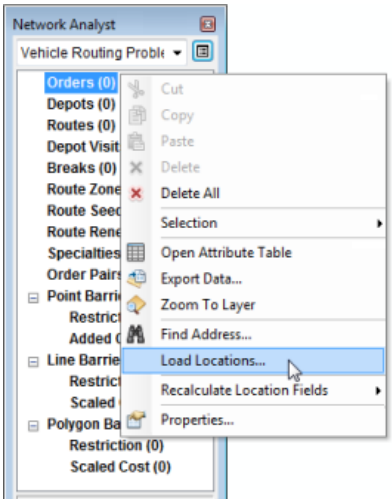
The grocery store locations are already added as a feature layer, Stores, in the map document. The attributes of Stores contain information about the total weight of goods (in pounds) required at each store, the time window during which the delivery has to be made, and the service time (in minutes) incurred while visiting a particular store. The service time is the time required to unload the goods.



You will add these point features of stores as orders in the analysis layer.

Steps:

1. In the ***Network Analyst*** window, right-click **Orders (0)** and choose **Load Locations**.



   The ***Load Locations*** dialog box opens

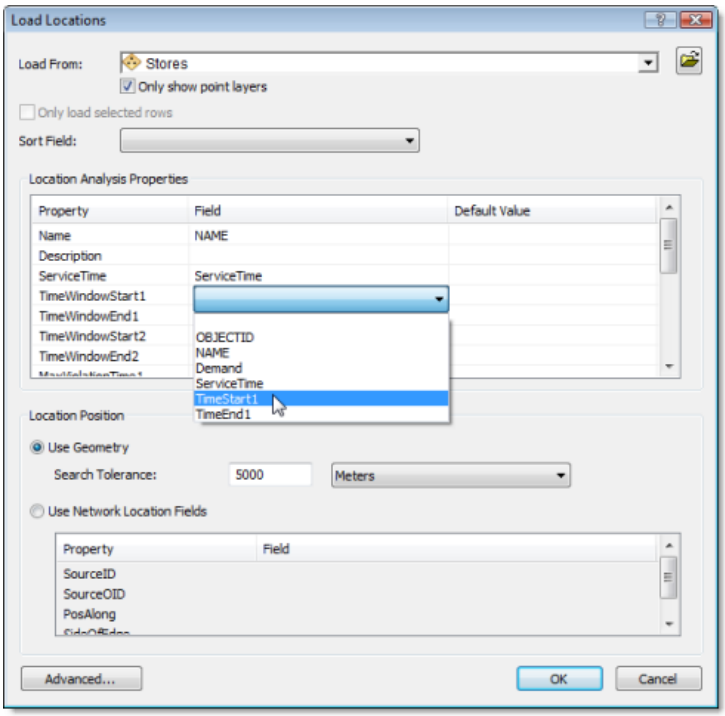
2. Select **Stores** from the **Load Locations** drop-down list.

   The **Location Analysis Properties** section on the ***Load Locations*** dialog box lets you specify which attributes of the Stores feature class contain the values that ArcGIS Network Analyst will use to help solve this vehicle routing problem.

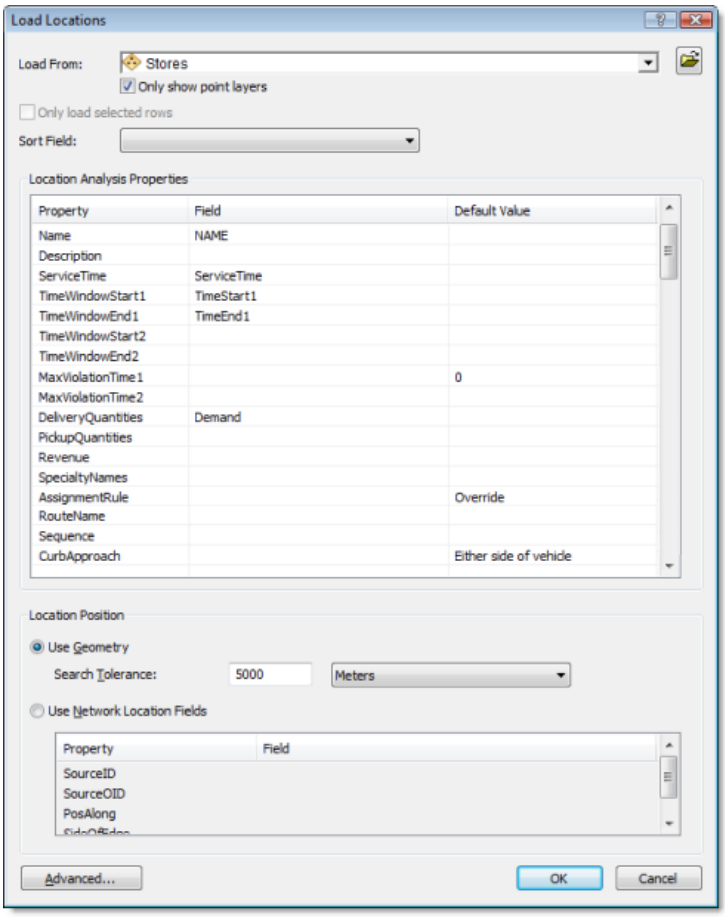
3. In the **Location Analysis Properties** section, make sure that the **Name** property is automatically matched to the **NAME** field, and the **ServiceTime** property is matched to the **ServiceTime** field.

Network Analyst tries to match location analysis properties automatically for a newly created vehicle routing problem layer based on a configuration file (located in the ArcGIS installation directory within [...]\NetworkAnalyst\NetworkConfiguration\NASolverConfiguration.xml).

4. Set the **Field** value of **TimeWindowStart1** to **TimeStart1**.



5. Set the **Field** value of **TimeWindowEnd1** to **TimeEnd1**.
6. Set the **Field** value of **DeliveryQuantities** to **Demand**.
7. Type `0` under **Default Value** for the **MaxViolationTime1** property.
   Setting this property to zero specifies that the time window should not be violated.



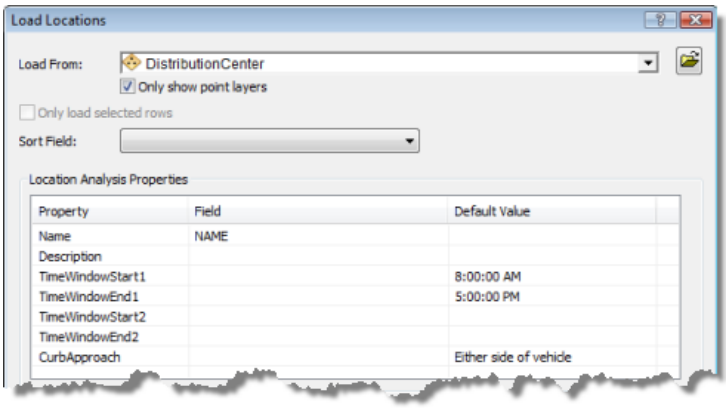
8. Click **OK**.
   Twenty-five stores are listed in the ***Network Analyst*** window under **Orders** and are displayed as orders on the map.

Adding depots

The goods are delivered from a single distribution center whose location is shown in the DistributionCenter feature layer in ArcMap. The distribution center operates between 8:00 a.m. and 5:00 p.m. You will add this point feature to the Depots network analysis class.

Steps:

1. In the ***Network Analyst*** window, right-click **Depots (0)** and choose **Load Locations**.
   The ***Load Locations*** dialog box opens.
2. Select **DistributionCenter** from the **Load Locations** drop-down list.
3. In the **Location Analysis Properties** section, make sure that the **Name** property is automatically matched to the **NAME** field.
4. Type `8 AM` under **Default Value** for the **TimeWindowStart1** property.
5. Type `5 PM` under **Default Value** for the **TimeWindowEnd1** property.



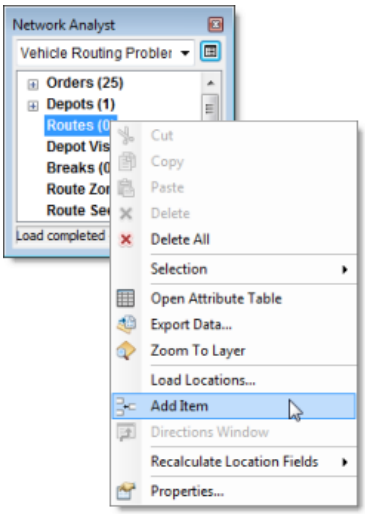
6. Click **OK**.
   One distribution center is listed in the ***Network Analyst*** window under **Depots** and displayed as a depot on the map.

Adding Routes

The distribution center has three trucks, each with a maximum capacity to carry 15,000 pounds of goods. You will add three routes (one for each vehicle) and set the properties for the routes based on the center's operational procedures.

Steps:

1. In the ***Network Analyst*** window, right-click **Routes (0)** and choose **Add Item**.

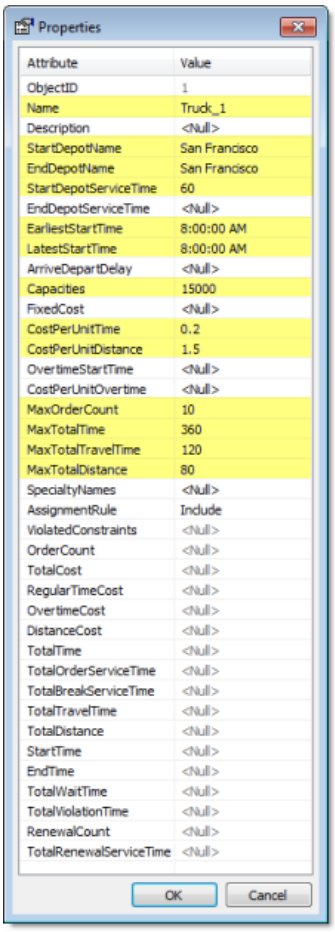


   A new route, **Item 1**, is added under the **Routes** class in the ***Network Analyst*** window, and the ***Properties*** window for the route opens.

2. In the ***Properties*** window, specify the attributes for the route as shown in the table below. The description column of the table explains the use of particular values. Leave default values for attributes not in the table.

Attribute	Value	Description

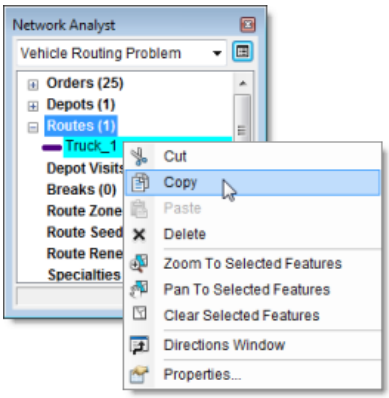
Name	Truck_1	Name of the vehicle.
StartDepotName	San Francisco	The truck starts at the distribution center.
EndDepotName	San Francisco	The truck returns to the distribution center at the end of the route.
StartDepotServiceTime	60	Time (in this case, minutes) required to fully load the truck with goods.
EarliestStartTime	8 AM	The truck can start operation as soon as the distribution center opens at 8:00 a.m.
LatestStartTime	8 AM	The truck must start operation as soon as possible.
Capacities	15000	The truck can carry a maximum of 15,000 pounds of goods.
CostPerUnitTime	0.20	The truck driver is paid 12 dollars per hour, so the wage is: $12.00/60 minutes = $0.20 per minute.
CostPerUnitDistance	1.5	The average dollar amount spent per mile on fuel consumption, truck depreciation, and maintenance.
MaxOrderCount	10	The maximum number of stores that can be serviced by a truck.
MaxTotalTime	360	Due to workday constraints, drivers can't have a work shift of more than six hours (360 minutes).
MaxTotalTravelTime	120	To satisfy the workday constraints and still be able to serve a reasonable number of stores—while taking into account the service time needed at a store—the truck should not spend more than two hours (120 minutes) driving on the streets.
MaxTotalDistance	80	To balance daily fuel and maintenance costs among the fleet, any one truck should not travel more than 80 miles on its route.



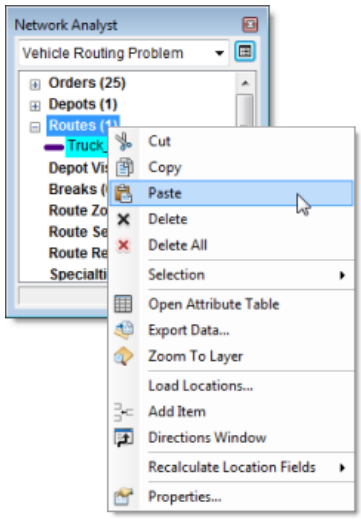
3. Click **OK**.
   A new route, **Truck_1**, is added to the routes class in the ***Network Analyst*** window.

   Since the three trucks at the distribution center are the same, you can make two copies of the first truck you entered and rename them.

4. Right-click the **Truck_1** route object in the ***Network Analyst*** window and choose **Copy**.

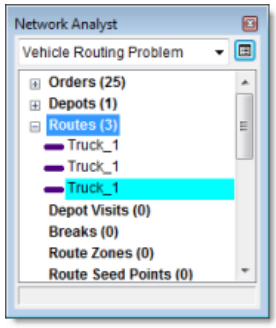


5. Right-click the **Route (1)** class in the ***Network Analyst*** window and choose **Paste**.

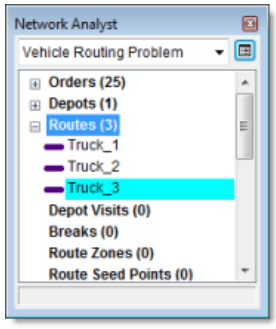


The Routes class contains two identical route objects.

6. Repeat the last step to create a third route object.



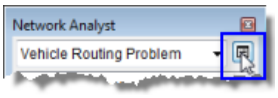
7. Double-click the second **Truck_1** object in the list.
   The ***Properties*** window opens.
8. Click the **Name** property and type `Truck_2`.
9. Press ENTER twice.
   The route is given a unique name, and the window closes.
10. Use the same procedure to change the name of the last route to Truck_3.



Setting up the properties for the vehicle routing problem analysis

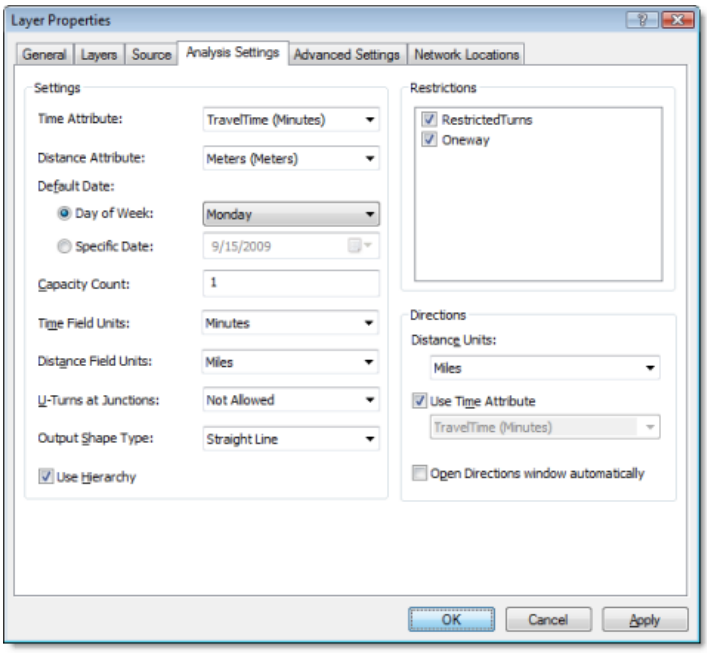
Steps:

1. Click the **Analysis Layer Properties** button on the ***Network Analyst*** window.



   The ***Layer Properties*** dialog box opens.

2. Click the **Analysis Settings** tab.
3. Make sure that the **Time Attribute** drop-down list is set to **TravelTime (Minutes)**.
   The VRP solver will use this attribute to calculate time-based costs between orders and the depot.
4. Click the **Distance Attribute** drop-down list and choose **Meters**.
   This attribute is used to determine travel distances between orders and the depot for constraint purposes and creating directions; however, the VRP solver's objective is to minimize time costs.
5. Set the **Default Date** to **Day of Week**. Choose **Monday** in the **Day of Week** drop-down list.
6. Make sure that **Capacity Count** is set to **1**.
   This setting indicates that the goods being delivered have only one measurement. In this case, that measurement is weight (pounds). If the capacities were specified in terms of two measurements, such as weight and volume, then the capacity count would be set to 2.
7. Make sure that **Minutes** is selected for **Time Field Units**.
   This specifies that all time-based attributes, such as ServiceTime and MaxViolationTime1 for Orders and MaxTotalTime, MaxTotalTravelTime, and CostPerUnitTime for Route, are in minutes.
8. Make sure that **Distance Field Units** is set to **Miles**.
   This specifies that all distance-based attributes, such as MaxTotalDistance and CostPerUnitDistance for Routes, are in miles.
9. Since it is difficult for these delivery trucks to make U-turns, set **U-Turns at Junctions** to **Not Allowed**.
10. Select **Straight Line** in the **Output Shape Type** drop-down list.
    You could select either the **True Shape with Measures** or **True Shape** option if you wanted the routes to follow the streets. Note that this option only affects the display of the routes, not the results determined by the VRP solver.
11. Make sure that **Use Hierarchy** is checked.
12. In the **Restrictions** frame, make sure that **RestrictedTurns** and **Oneway** are checked.
13. Leave the options that are in the **Directions** frame set to their default values.



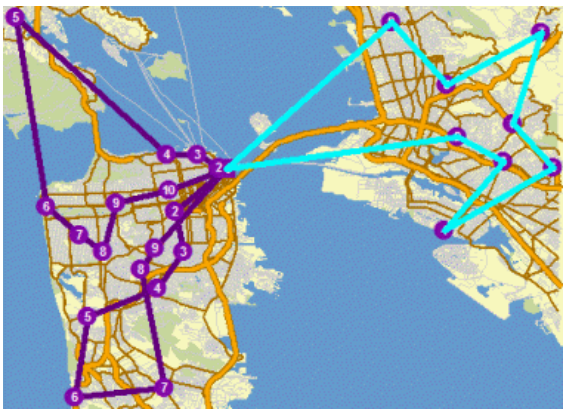
14. Click **OK**.

Run the process to determine the best route assignment and order sequence

Steps:

1. Click the **Solve** button on the ***Network Analyst*** toolbar.
   The VRP solver calculates the three routes required to service the orders and draws lines connecting the orders. Each route begins and ends at the distribution center and serves a set of orders along the way.

   If you receive any error messages, make sure that the value of the **Capacities** attribute for the routes is set to 15000 instead of 15,000 and each route has a unique name.



Determine turn-by-turn directions for the routes

Steps:

1. Right-click **Routes (3)** in the ***Network Analyst*** window and click **Selection** > **Clear Selected Features.**
2. Click the **Directions Window** button on the ***Network Analyst*** toolbar.
   The ***Directions*** dialog box opens.
3. Optionally, you can export the Vehicle Routing Problem layer as a layer file (<filename>.lyr) by right-clicking **Vehicle Routing Problem** in the ***Table Of Contents*** window and choosing **Save As Layer File**. This saves the analysis on disk so that you can add it to a different map document and reuse it later.
4. If you want to continue on to the following advanced sections of this tutorial exercise, close the ***Directions*** window. Otherwise, exit ArcMap and do not save any changes to Exercise 07.mxd.

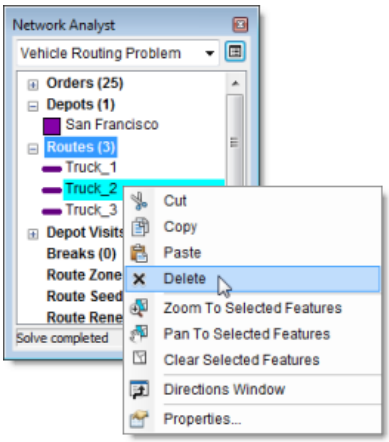
Make changes to the existing solution to solve a different scenario

The vehicle routing problem solution obtained earlier worked well for the company. After a few weeks, however, the driver assigned to Truck_2 went on vacation. So now the distribution company has to service the same stores but with just two trucks. To accommodate the extra workload, the company decided to pay overtime to the other two drivers and provide them with one paid break during the day. The distribution company also acquired two additional satellite distribution centers. These centers can be used by the trucks to renew their truckload while making their deliveries instead of returning to the main distribution center for renewal. You will modify the solution obtained from the previous step to accommodate these changes.

Deleting an existing route from a solution

Steps:

1. In the ***Network Analyst*** window, right-click the **Truck_2** object in the **Routes** class and click **Delete**.



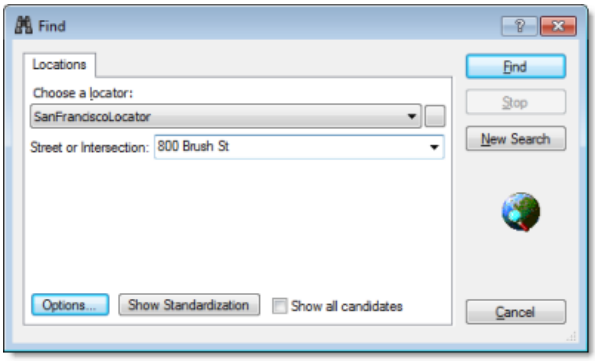
Adding route renewals

The two satellite distribution centers that the company acquired are at 800 Brush Street and 100 Old County Road, and they can act as renewal locations for the trucks. The trucks can refill their cargo by visiting these renewal locations and thus save time by not returning to the starting depots. You will add the

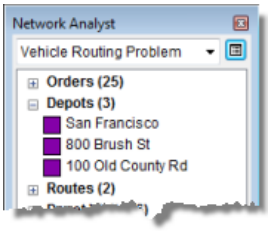
renewal locations to the Depots network analysis class by geocoding their addresses. The routes that can renew at a renewal location and the service time for the renewal are specified in the Route Renewals network analysis class.

Steps:

1. In the ***Network Analyst*** window, right-click **Depots (1)** and choose **Find Address**.
   The **Find** dialog box opens.
2. Choose **SanFranciscoLocator** from the **Choose an address locator** drop-down list.
3. In the **Street or Intersection** box, type `800 Brush St`.

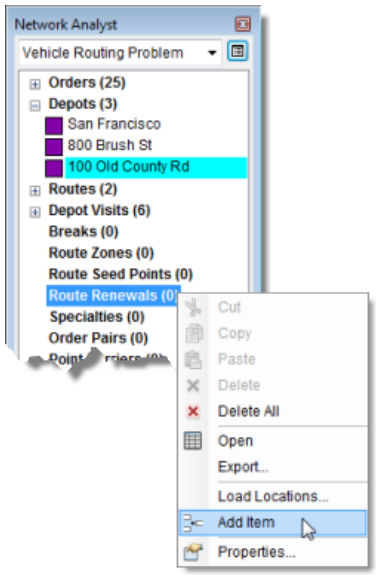


4. Click **Find**.
   The SanFranciscoLocator, which is an address locator that was already added to the Exercise07.mxd, finds the address and shows the result at the bottom of the ***Find*** dialog box.
5. Right-click the result on the ***Find*** dialog box and choose **Add as Network Analysis Object**.
   The located address is added as a depot in the ***Network Analyst*** window and the map display.
6. In the **Street or Intersection** box of the ***Find*** dialog box, type `100 Old County Rd`.
7. Click **Find**.
8. Right-click the new result at the bottom of the ***Find*** dialog box and choose **Add as Network Analysis Object**.
   A third depot is added to the Depots network analysis class.



9. Close the ***Find*** dialog box.

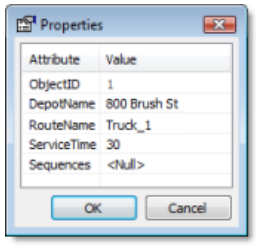
   Since both trucks are allowed to renew their loads at the 800 Brush Street and 100 Old County Road locations, you will associate each truck with the two renewal locations. The VRP solver will figure out the best renewal location for the trucks.
10. In the ***Network Analyst*** window, right-click **Route Renewals (0)** and click **Add Item**.



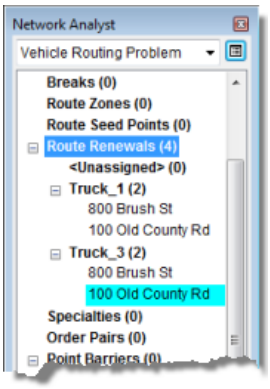
A new route renewal object, Item1, is added under the Route Renewals class in the ***Network Analyst*** window, and the ***Properties*** window for Item1 opens.

11. In the ***Properties*** window, specify the attributes for the route renewal as shown below.

Attribute	Value	Description
DepotName	800 Brush St	The truck can use this depot location for renewal.
RouteName	Truck_1	Name of the vehicle.
ServiceTime	30	Time in minutes required to load the truck.



12. Click **OK**.
    A new route renewal object, **800 Brush St**, is listed within the **Truck_1** item in the ***Network Analyst*** window.
13. Follow the last three steps to add three more route renewal objects such that each truck (Truck_1 and Truck_3) can reload at both the renewal locations (800 Brush St, 100 Old County Rd).
    The ***Network Analyst*** window should now have two route renewal objects listed within the **Truck_1** and **Truck_3** items, respectively.



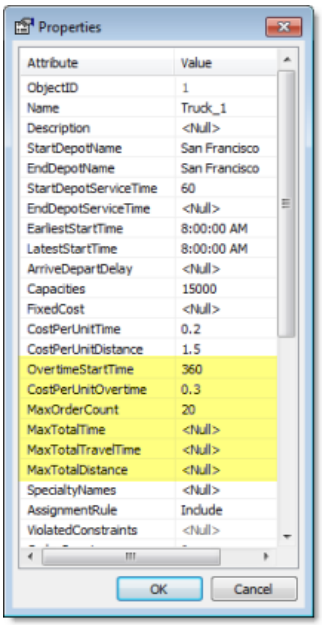
Modifying routes to include overtime

To accommodate the extra workload, the company wants to remove the maximum time, maximum travel time, and maximum distance constraints for the routes. Since the drivers have to work longer than before, they are provided with overtime pay at the rate of $18 per hour after completing six hours of work. In this step, you will make these changes to the routes.

Steps:

1. In the ***Network Analyst*** window, under the **Routes** network analysis class, double-click **Truck_1**.
   The ***Properties*** window opens.
2. Make changes to the attributes of Truck_1 so they match the values in the table below.

Attribute	Value	Description
OvertimeStartTime	360	The driver is paid overtime if he or she works for more than six hours (360 minutes).
CostPerUnitOvertime	0.3	The truck driver is paid $18 per hour for the overtime. So the wage in dollars per minute is: $18.00/60 minutes = $0.30 per minute.
MaxOrderCount	20	Since the driver is paid overtime, he or she is expected to service more stores.
MaxTotalTime	<Null>	There are no restrictions on the total duration of the work shift for the driver.
MaxTotalTravelTime	<Null>	There are no restrictions on the time spent driving on the streets.
MaxTotalDistance	<Null>	There are no restrictions on the total distance traveled by a truck.



3. Click **OK**.
4. Repeat the last three steps for **Truck_3**.

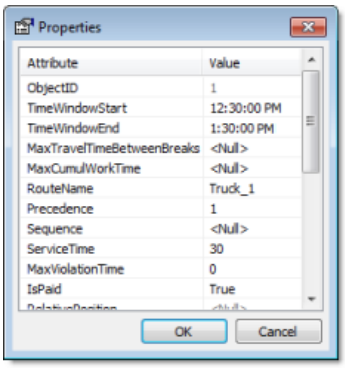
Adding breaks

Since the drivers have to work longer, they will require one half hour break during their work shift. In this step, you will specify the breaks for each route.

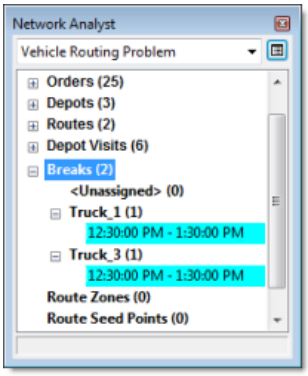
Steps:

1. In the ***Network Analyst*** window, right-click **Breaks (0)** and choose **Add Item**. The ***Properties*** window opens.
2. Specify the attribute values for the new break as shown in the table below.

Attribute	Value	Description
TimeWindowStart	`12:30 PM`	The break has to start sometime after 12:30 p.m.
TimeWindowEnd	`1:30 PM`	The break has to start sometime before 1:30 p.m.
RouteName	`Truck_1`	The name of the route to which this break applies.
ServiceTime	`30`	The break duration in minutes.
MaxViolationTime	`0`	The break has to start between 12:30 p.m. and 1:30 p.m. The zero value indicates that the break can't start after 1:30 p.m. (that is, the break time-window is rigid).
IsPaid	`True`	It is a paid break, so the cost is included in the total cost of the route.



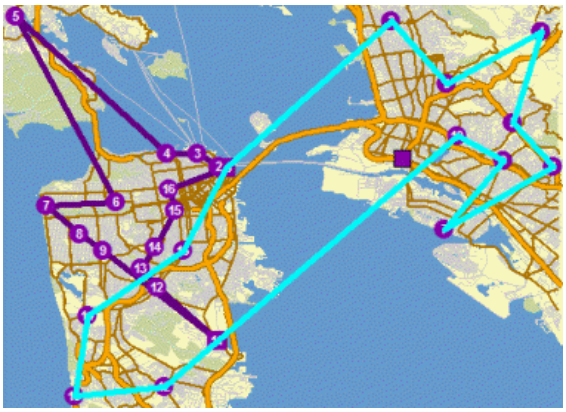
3. Click **OK**.
4. Repeat the last three steps, entering **Truck_3** for the RouteName property.
   The ***Network Analyst*** window now has two objects listed under the **Breaks** class: Truck_1 and Truck_3.



Determining the solution

Steps:

1. Click the **Solve** button on the ***Network Analyst*** toolbar.
   The VRP solver calculates the two routes that can be used to service the orders and draws straight lines connecting the orders. Each route begins and ends at the distribution center, serves a set of orders along the way, visits a renewal location to load the truck again, continues to service the remaining orders, and finally returns to the distribution center.



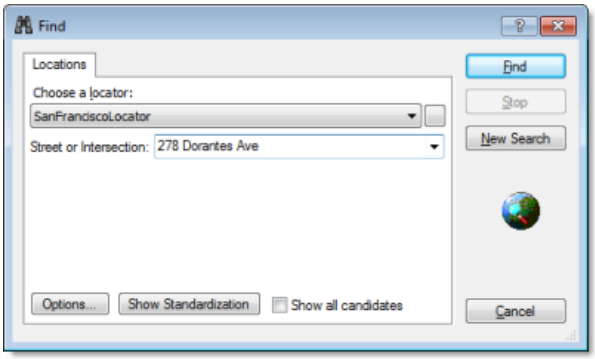
This solution meets all the constraints specified by the distribution company. However, after giving the route itinerary to the two drivers, the company discovered that the driver of Truck_1 prefers driving in the downtown area and the driver of Truck_3 prefers driving in the East Bay area. The company would like to determine a new solution in which the routes service the orders that are in the areas their drivers prefer. In the next steps, you will add route seed points to incorporate these driver preferences.

Adding route seed points

In this step, you will add route seed points for Truck_1 and Truck_3 by geocoding addresses. Note that the route seed points can also be imported from an existing point feature class or can be created interactively by using the **Create Network Location** tool .

Steps:

1. In the ***Network Analyst*** window, right-click **Route Seed Points (0)** and choose **Find Address**.
   The ***Find*** dialog box opens.
2. In the **Street or Intersection** combo box, type `278 Dorantes Ave`.

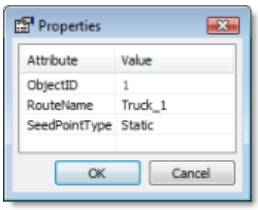


3. Click **Find**.
   The SanFranciscoLocator finds the address and shows the result at the bottom of the dialog box.
4. Right-click the result and choose **Add as Network Analysis Object**.

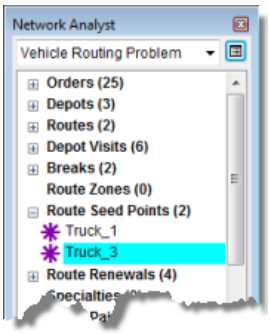
The location of the address is added as a route seed point. It is shown in the ***Network Analyst*** window and the map display.

5. Close the ***Find*** dialog box.
6. In the ***Network Analyst*** window, double click the new route seed point, **278 Dorantes Ave**. The ***Properties*** dialog box opens.
7. Specify the attribute values for the route seed point as shown in the table below.

Attribute	Value	Description
RouteName	`Truck_1`	The name of the route to which this seed point applies.
SeedPointType	`Static`	This makes it more likely that the orders near the specified seed point will be assigned to Truck_1.



8. Repeat steps 1–5 in this section to add another route seed point at `1888 Peralta St`.
9. Repeat steps 6 and 7 to change the **RouteName** attribute of the second seed point to `Truck_3`.



Determine the solution

Steps:

1. Click the **Solve** button on the ***Network Analyst*** toolbar.
   The VRP solver calculates the two routes that can be used to service the orders and draws straight lines connecting the orders. The route for Truck_1 includes orders in the downtown region only.
2. Exit ArcMap without saving any changes.

Exercise 8: Finding best routes to service paired orders

Complexity:
Beginner

Data Requirement:
ArcGIS Tutorial Data Setup

Data Path:
C:\ArcGIS\ArcTutor\Network Analyst\Tutorial

Goal:
Solve a vehicle routing problem analysis with order pairs.

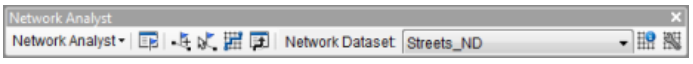
In this exercise, your goal is to find the best routes for a fleet of vans to transport people who would otherwise not have access to transportation from their homes to different hospitals for medical appointments. You will accomplish this by solving a vehicle routing problem (VRP) analysis using order pairs, which relate and sequence two orders (stops) so that the vans will pick up riders and take them to their proper destinations. Using other features of the VRP analysis layer, you'll also make sure that additional requirements are met. For instance, you will enter a max transit time for order pairs so that riders don't spend too much time in transit. You'll use time windows on orders so that riders are not late for their appointments. Some riders require wheelchairs; you'll use specialties to match those riders with vans that have wheelchair lifts. Once the routes are determined, you will generate turn-by-turn directions of the resulting routes, which can be electronically distributed or printed and given to the drivers.

Preparing your display

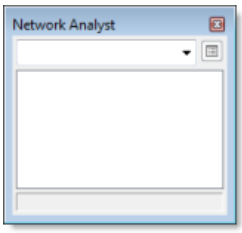
Steps:

1. If you have Exercise08.mxd open in ArcMap, skip to step 6.
2. Start ArcMap by clicking **Start** > **All Programs** > **ArcGIS** > **ArcMap 10.**
3. On the ***ArcMap - Getting Started*** dialog box, click **Existing Maps** > **Browse for more.**
   The ***Open ArcMap Document*** dialog box appears.
4. Browse to C:\ArcGIS\ArcTutor\Network Analyst\Tutorial.
   This is the default installation location for the tutorial data.
5. Double-click **Exercise08.mxd**.
   The map document opens in ArcMap.
6. Enable the Network Analyst extension.
   a. Click **Customize** > **Extensions.**
      The ***Extensions*** dialog box opens.
   b. Check **Network Analyst**.
   c. Click **Close**.

   If the ***Network Analyst*** toolbar is not displayed, you need to add it.
7. Click **Customize** > **Toolbars** > **Network Analyst.**
   The ***Network Analyst*** toolbar is added to ArcMap.



   If the ***Network Analyst*** window is not displayed, you need to add it.
8. On the ***Network Analyst*** toolbar, click the **Show/Hide Network Analyst Window** button.
   The dockable ***Network Analyst*** window opens.

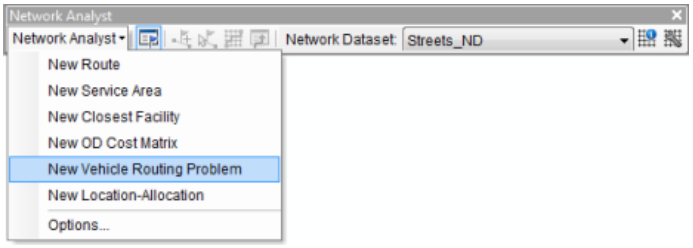


You can dock or undock the ***Network Analyst*** window. In this exercise, it is docked below the ***Table Of Contents*** window.

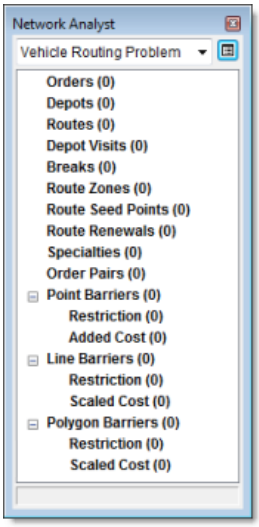
Creating the vehicle routing problem analysis layer

Steps:

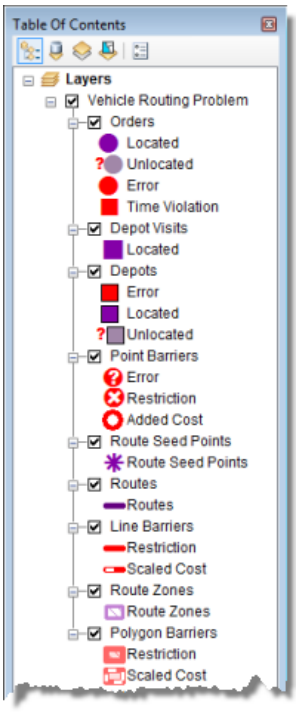
1. Click **Network Analyst** on the ***Network Analyst*** toolbar and click **New Vehicle Routing Problem**.



The vehicle routing problem analysis layer is added to the ***Network Analyst*** window. The network analysis classes (Orders, Depots, Routes, Depot Visits, Breaks, Route Zones, Route Seed Points, Route Renewals, Specialties, Order Pairs, Point Barriers, Line Barriers, and Polygon Barriers) are empty.



The analysis layer is also added to the ***Table Of Contents*** window.

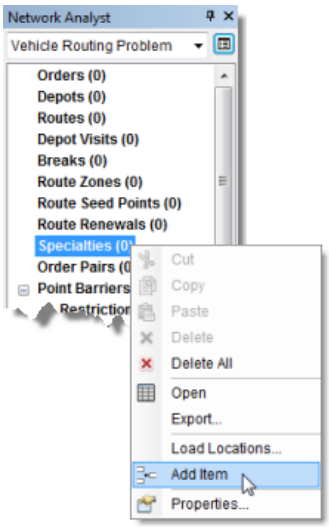


Adding specialties

The logistics company has three vans. One of the vans that operates in the downtown area is equipped to provide access for wheelchairs. You will add Wheelchair as a specialty so that the orders that require this specialty can be assigned to the route that has a wheelchair lift.

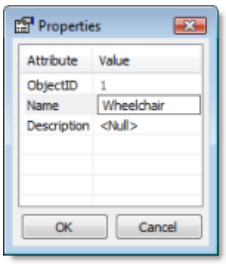
Steps:

1. In the ***Network Analyst*** window, right-click **Specialties (0)** and click **Add Item**.



A new specialty, Item 1, is added under the **Specialties** class in the ***Network Analyst*** window. The ***Properties*** window for the new specialty opens.

2. In the ***Properties*** window, enter `Wheelchair` as the value of **Name**.



3. Click **OK**.

Adding orders

A spreadsheet is provided with the tutorial data. It contains information about each patient, including their name and home address; the name and the address of the hospital they must be taken to; the time window within which the patient has to be picked up; and so on. The following table describes the fields in the spreadsheet:

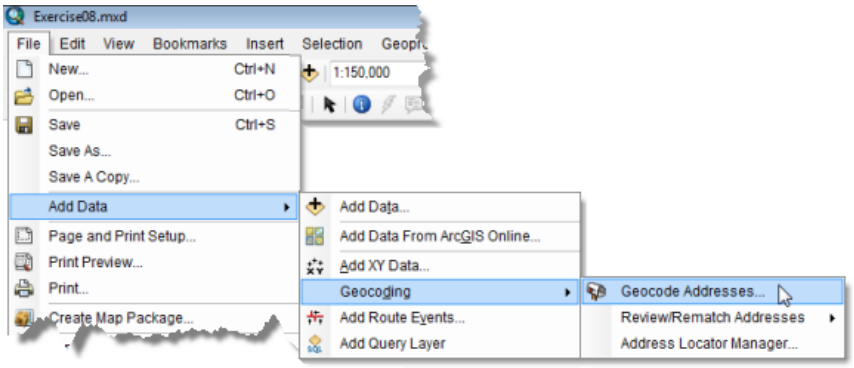
Attribute	Description
OrderName1	The name of the patient needing transportation
PatientAddress	The location where the patient will be picked up
OrderName2	A unique name for the destination
HospitalAddress	The location where the patient has the appointment
PickFrom	The earliest time the patient may be picked up from PatientAddress
PickTo	The latest time the patient may be picked up from PatientAddress
TotalPassengers	The total number of passengers to be picked up
MaxTransitTime	The maximum time the patient can spend in the van
SpecialtyNames	Specifies the special needs that are required by the passenger, for example, a wheelchair

In this case, the passengers and hospital visits are related to each other since each passenger has to visit a predetermined hospital. You can model this situation with order pairs—by loading both patient and hospital locations into the Orders network analysis class and relating them with new order pair objects.

In the following steps, you will geocode the patient and hospital addresses and load the resulting points as orders.

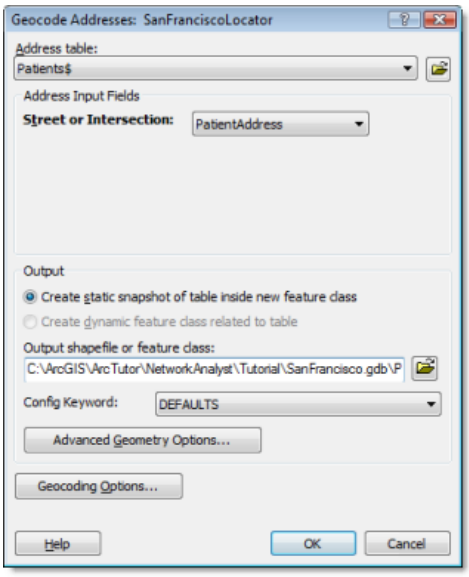
Steps:

1. Click **File** > **Add Data** > **Geocoding** > **Geocode Addresses.**

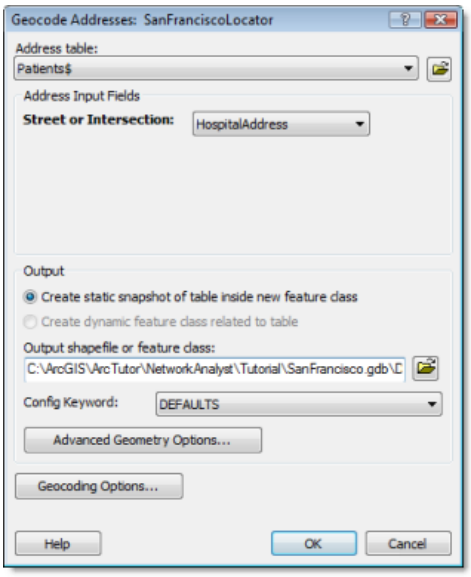


The ***Choose an Address Locator to use*** dialog box opens.

2. Click **SanFranciscoLocator**.
   The SanFranciscoLocator is included with Exercise08.mxd.
3. Click **OK**.
   The ***Geocode Addresses: SanFranciscoLocator*** dialog box opens.
4. Click the **browse** button next to the **Address table** drop-down list.
   The ***Choose a table containing addresses*** dialog box opens.
5. Click the **Look in** drop-down list and choose **Home - Tutorial**.
   The table that you will add is stored in an Excel spreadsheet that is included in the ArcGIS Network Analyst tutorial data.
6. Double-click **OrderPairs.xls**.
7. Double-click **Patients$**.
   The **Patients** worksheet is added to the **Address table** drop-down list.
8. In the **Street or Intersection** drop-down list, choose **PatientAddress**.
9. Click the **browse** button next to the **Output shapefile or feature class** text box.
   The ***Saving Data*** dialog box opens at the home location for Exercise08.mxd.
10. Click the **Look in** drop-down list and choose **Home - Tutorial**.
11. Click the **Save as type** drop-down list and choose **File and Personal Geodatabase feature classes**.
    The list of files and workspaces is updated.
12. Double-click **SanFrancisco.gdb**.
13. Delete the name in the **Name** text box and type `Patients`.
    Patients will be the name of the output feature class.
14. Click **Save**.
    The **Output shapefile or feature class** text box on the ***Geocode Addresses: SanFranciscoLocator*** dialog box is updated to show the new output path.



15. Click **OK**.
    The ***Geocoding Addresses*** dialog box opens and indicates that all 15 addresses were matched.
16. Click **Close**.
    The geocoded addresses are added to the map document as a point feature layer, **Geocoding Result: Patients**.
17. Repeat steps 1–16 to load the patients' destination hospitals, but make the following changes:
    a. In step 8, set **Street or Intersection** to **HospitalAddress**.
    b. In step 13, type `DestinationHospitals` in the **Name** text box.



The ***Table of Contents*** window should now have two feature layers, **Geocoding Results: DestinationHospitals** and **Geocoding Results: Patients**.

18. In the ***Table Of Contents*** window, uncheck the two geocoding results layers so that they are not visible in the map display.

    In the next steps, you will load these layers into the Orders network analysis class.

19. In the ***Network Analyst*** window, right-click **Orders (0)** and choose **Load Locations**.
    The ***Load Locations*** dialog box opens.

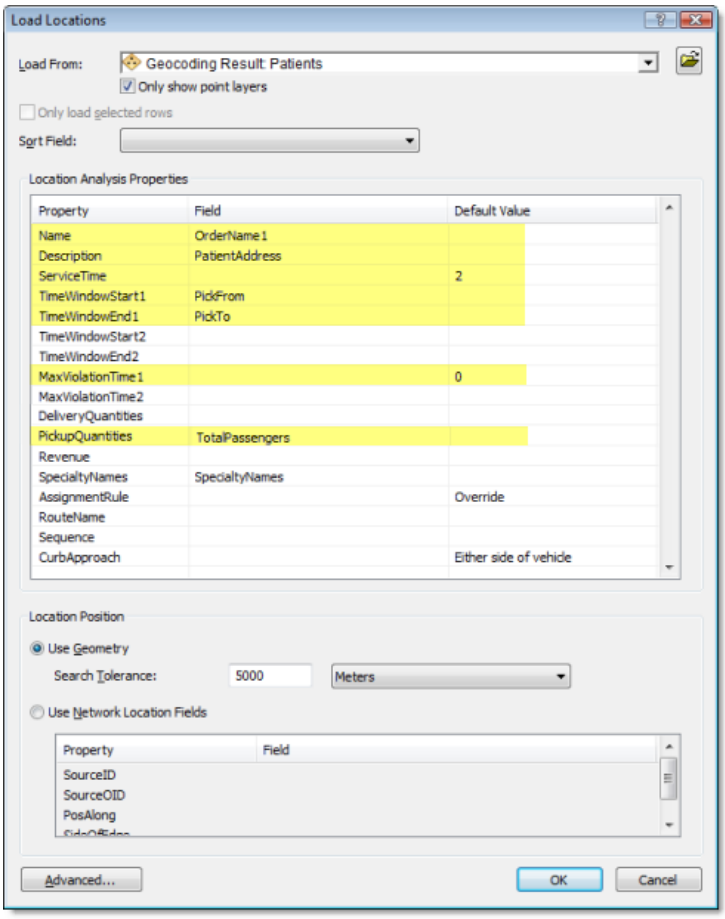
20. Choose **Geocoding Results: Patients** from the **Load From** drop-down list.

    The **Location Analysis Properties** section on the ***Load Locations*** dialog box lets you specify which attributes of the Geocoding Results: Patients layer contain the values that Network Analyst will reference in this vehicle routing problem.

21. Configure the properties that are listed in the **Location Analysis Properties** section so that they copy field values from the Geocoding Results: Patients layer in the way specified by the substeps below. (The next graphic highlights these changes.)
    a. Map the **Name** property to the **OrderName1** field.
    b. Map the **Description** property to the **PatientAddress** field.
    c. Map the **TimeWindowStart1** property to the **PickFrom** field.
    d. Map the **TimeWindowEnd1** property to the **PickTo** field.
    e. Map the **PickupQuantities** property to the **TotalPassengers** field.
    f. Make sure that the **SpecialtyNames** property is automatically matched to the **SpecialtyNames** field.

22. Type `2` under **Default Value** for the **ServiceTime** property.
    All patient address locations that are loaded will have a ServiceTime value of 2 to account for the average time (in minutes) that is taken for passengers to board the van.

23. Type `0` under **Default Value** for the **MaxViolationTime1** property.
    By setting all the MaxViolationTime1 properties to zero, the VRP solver will only search for routes that visit the orders within their time windows.



24. Click **OK**.
    Fifteen orders are loaded. You can see them in the map display and in the ***Network Analyst*** window.

    In the next steps, you will load the destination hospitals as orders too.

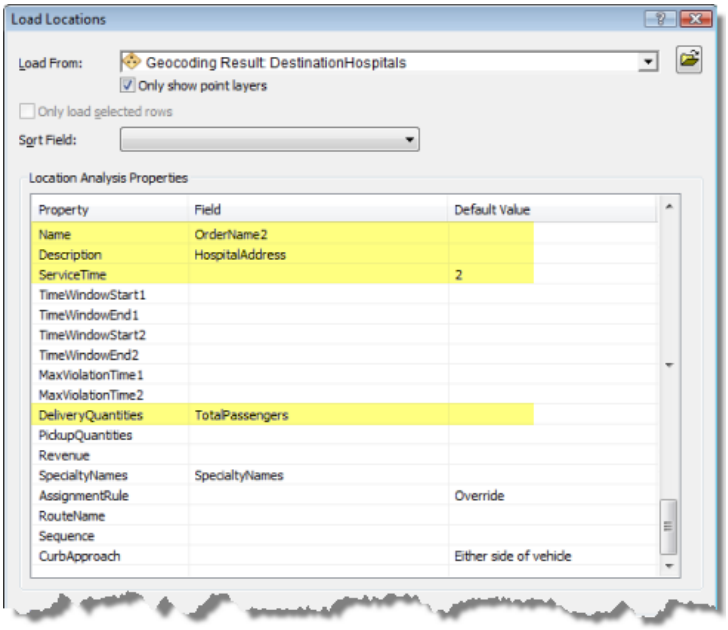
25. In the ***Network Analyst*** window, right-click **Orders (15)** and choose **Load Locations**.
    The ***Load Locations*** dialog box opens.

26. Choose **Geocoding Results: DestinationHospitals** from the **Load From** drop-down list.

27. Configure the properties that are listed in the **Location Analysis Properties** section so that they copy field values from the Geocoding Results: DestinationHospitals layer in the way specified by the substeps below. (The next graphic highlights these changes.)
    a. Map the **Name** property to the **OrderName2** field.
       Note that the value for the Name attribute has to be unique in the Orders network analysis class. In this case, there are many patients who need to visit the same hospital. So if the hospital addresses were used to derive the value of the Name attribute for Orders, then the VRP solver would return error messages as there would be duplicate Name values.
    b. Map the **Description** property to the **HospitalAddress** field.
    c. Map the **DeliveryQuantities** property to the **TotalPassengers** field.

d. Make sure that the **SpecialtyNames** property is automatically matched to the **SpecialtyNames** field.

28. Type 2 under **Default Value** for the **ServiceTime** property.



29. Click **OK**.
Thirty orders are listed in the ***Network Analyst*** window under the Orders network analysis class and are displayed as orders on the map in the Vehicle Routing Problem layer.

Adding order pairs

The passengers have to be taken to a predetermined hospital. By adding objects to the Order Pairs network analysis class, you can add the information that specifies which hospital the patients have to be taken to and the maximum time the patients can sit in the van during a one-way trip.

Steps:

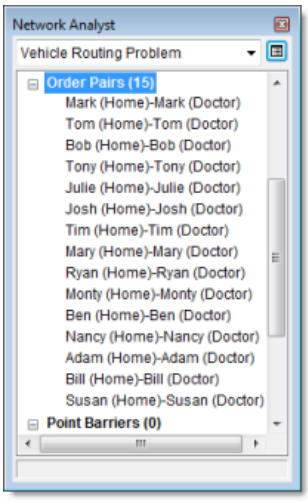
1. In the ***Network Analyst*** window, right-click **Order Pairs (0)** and choose **Load Locations**.
The ***Load Locations*** dialog box opens.
2. Click the **browse** button next to the **Load From** drop-down list.
3. Click the **Look in** drop-down list and choose **Home - Tutorial**.
The table that you will add is stored in an Excel spreadsheet that is included in the Network Analyst tutorial data.
4. Double-click **OrderPairs.xls**.
5. Double-click **Patients$**.
The **Patients** table is added to the **Load From** drop-down list on the ***Load Locations*** dialog box.
6. Configure the properties that are listed in the **Location Analysis Properties** section so that they pull field values from the Patients$ table in the way specified by the substeps below.

a. Map the **FirstOrderName** property to the **OrderName1** field.

b. Map the **SecondOrderName** property to the **OrderName2** field.

c. Make sure that the **MaxTransitTime** property is automatically matched to the **MaxTransitTime** field.

7. Click **OK**.
   Fifteen order pairs are listed in the ***Network Analyst*** window under the **Order Pairs** network analysis class.

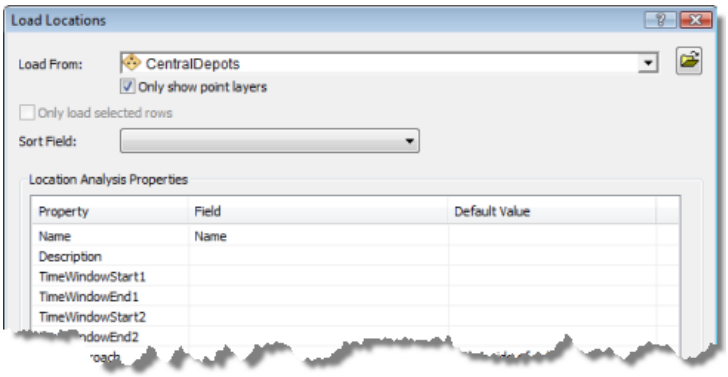


Adding depots

The logistics company operates vans from three depots whose locations are shown in the **CentralDepots** feature layer in ArcMap. You will now add these point features to the Depots network analysis class.

Steps:

1. In the ***Network Analyst*** window, right-click **Depots (0)** and choose **Load Locations**.
   The ***Load Locations*** dialog box opens.
2. Select **CentralDepots** from the **Load From** drop-down list.
3. In the **Location Analysis Properties** section, make sure that the **Name** property is automatically matched to the **Name** field.



4. Click **OK**.
   Three depots are listed in the ***Network Analyst*** window under the **Depots** network analysis class and are displayed on the map in the Vehicle Routing Problem layer.

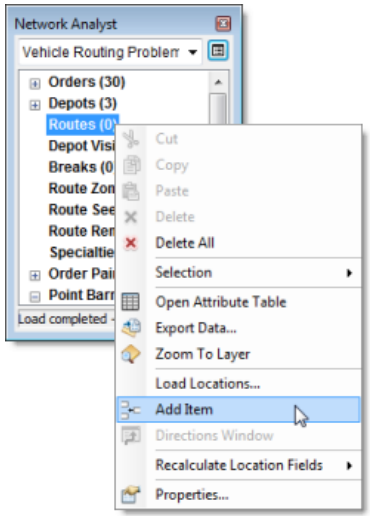
Adding routes

The logistics company has three vans, each with a maximum capacity of six passengers. The vans start and return to the depots after completing all the trips. One of the vans that operates within the downtown area has a lift to provide easy access for wheelchairs.

You will add three routes (one for each van) and set the property for the downtown van to include Wheelchair as a specialty.

Steps:

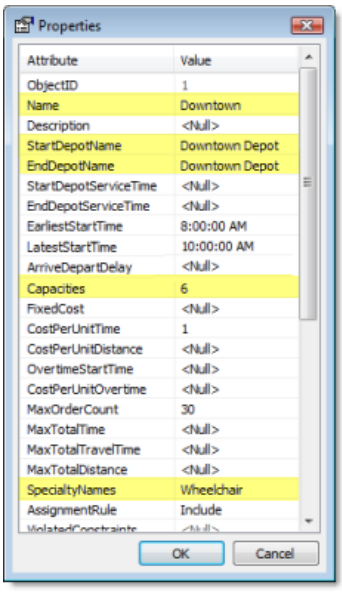
1. In the ***Network Analyst*** window, right-click **Routes (0)** and choose **Add Item**.



   A new route, **Item1**, is added under the Routes network analysis class, and the route's ***Properties*** window opens.

2. In the ***Properties*** window, specify the attributes for the route as shown in the table below, leaving the default values for the other attributes. The Description column in the table explains the use of particular values.

Attribute	Value	Description
Name	`Downtown`	Name of the route.
StartDepotName	`Downtown Depot`	The van starts at the depot in the downtown area.
EndDepotName	`Downtown Depot`	The van returns to the depot in the downtown area at the end of the route.
Capacities	`6`	The van can carry a maximum of six passengers at a time.
SpecialtyNames	`Wheelchair` (Check **Wheelchair** to set it as the value.)	The van is equipped to provide access for wheelchairs.



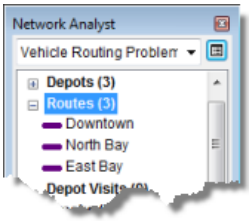
3. Click **OK**.
   A new route, **Downtown**, is listed in the ***Network Analyst*** window.
4. Repeat steps 1–3 to add two more routes representing the vans that operate in the North Bay and East Bay areas. Use the following tables for these new routes instead of the properties listed in step 2.

Attribute	Value
Name	`North Bay`
StartDepotName	`North Bay Depot`
EndDepotName	`North Bay Depot`
Capacities	`6`

Attribute	Value
Name	`East Bay`
StartDepotName	`East Bay Depot`
EndDepotName	`East Bay Depot`
Capacities	`6`

Note that these vans are not equipped to allow access for wheelchairs.

The ***Network Analyst*** window displays three route objects listed within the **Routes** network analysis class.

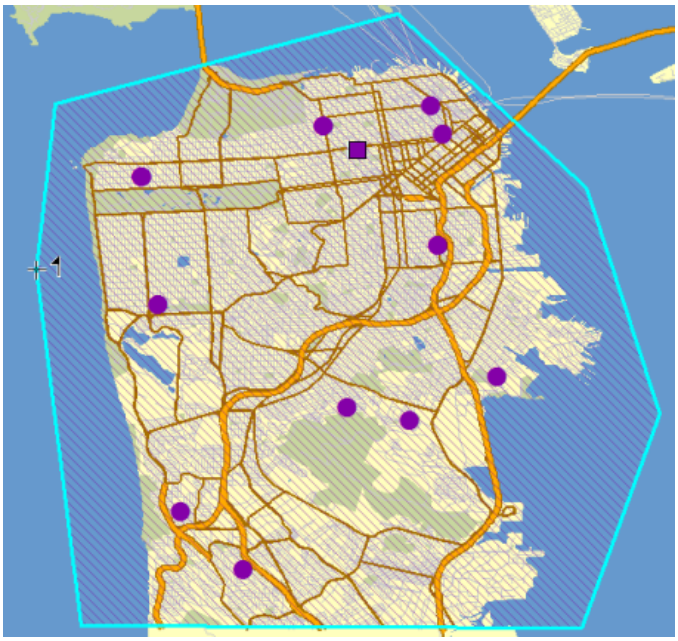


Adding route zones

The three vans used by the company are only licensed to service orders in a predetermined area. You will add route zones and associate them with the vans/routes.

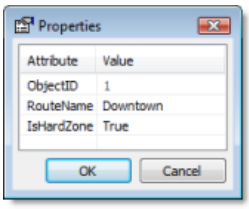
Steps:

1. In the ***Network Analyst*** window, select **Route Zones (0)**.
2. Click the **Create Network Location Tool** on the ***Network Analyst*** toolbar.
3. On the map display, digitize a polygon that roughly covers the downtown area as shown below.
   Click to add vertices; double-click to complete the polygon.

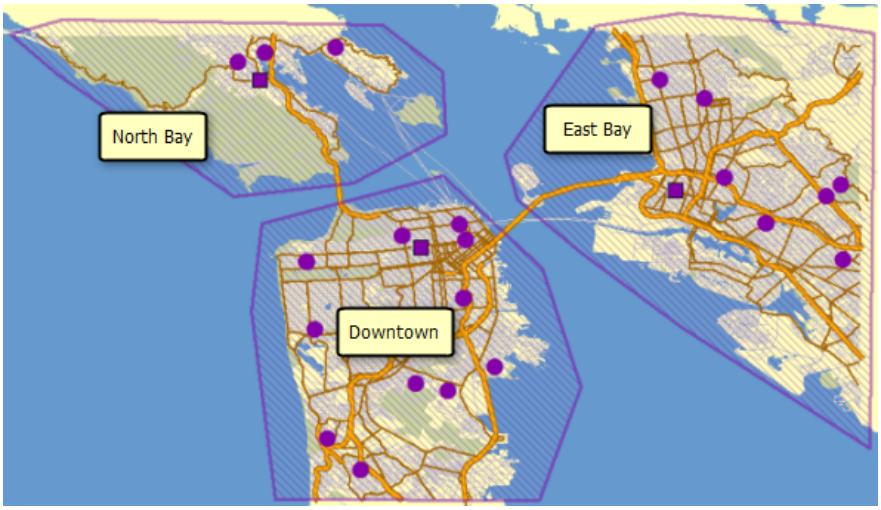


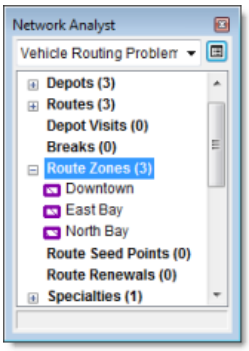
   A new route zone, **Graphic Pick 1**, is added to the route zones class in the ***Network Analyst*** window.
4. In the ***Network Analyst*** window, double-click the new route zone object, **Graphic Pick 1**.
   The route zone's ***Properties*** window opens.
5. Set the properties of the route zone as shown in the table below.

Attribute	Value	Description
RouteName	`Downtown`	The name of the route that this route zone is associated with.
IsHardZone	`True`	The van can't service orders that are outside the route zone. Setting this value to True ensures that the van is only assigned orders that are within the route zone.



6. Repeat steps 1–6 to add two more route zones: one for the North Bay and one for the East Bay.
   The map and the ***Network Analyst*** window should contain three route zone objects.



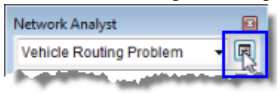


Setting up the properties for analysis

Next you will specify the properties for your vehicle routing problem analysis.

Steps:

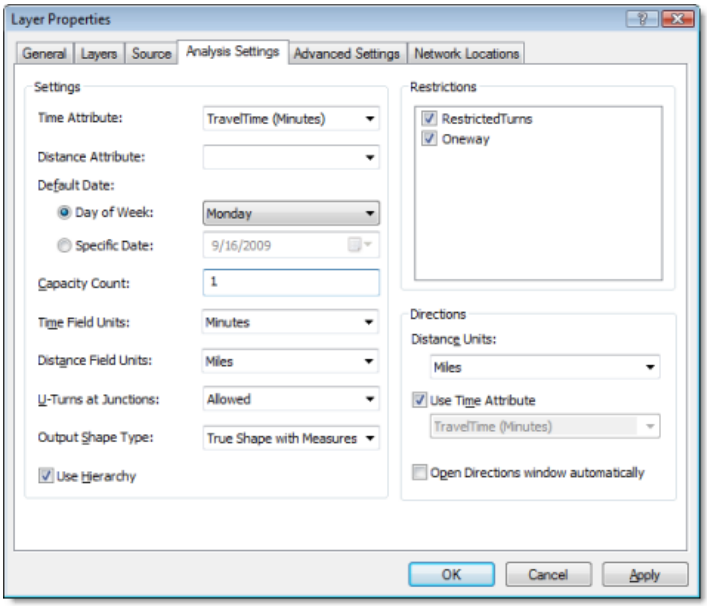
1. Click the **Analysis Layer Properties** button on the ***Network Analyst*** window.



   The ***Layer Properties*** dialog box opens.

2. Click the **Analysis Settings** tab.

3. Make sure that the **Time Attribute** drop-down list is set to **TravelTime (Minutes)**.
   The VRP solver will use this attribute to calculate time-based costs between orders and depots.
4. Make sure that nothing is selected in the **Distance Attribute** drop-down list.
   Since you are not using any distance-based cost parameters, such as CostPerUnitDistance or MaxTotalDistance, setting the distance attribute is not required.
5. Set the **Default Date** to **Day of Week**. In the **Day of Week** drop-down list, choose **Monday**.
6. Since the van capacity is measured only by the total number of passengers that can be accommodated, make sure that **Capacity Count** is set to 1.
   If the capacity had been measured by the total number of passengers and the maximum number of wheelchairs that can be accommodated in the van, the capacity count would be 2.
7. Leave the default options for the other properties.

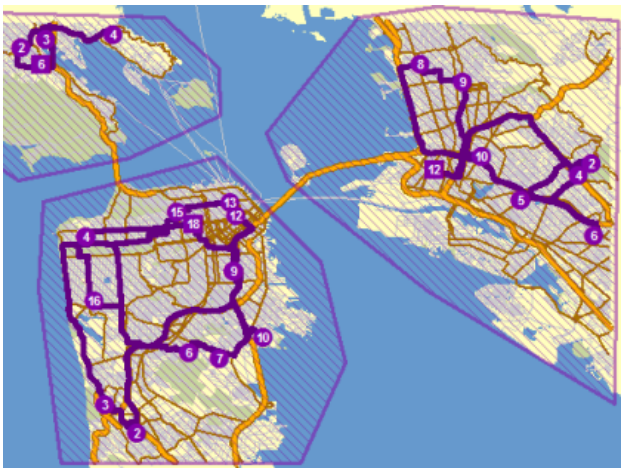


8. Click **OK**.

Run the process to determine the solution

Steps:

1. Click the **Solve** button on the ***Network Analyst*** toolbar.
   The VRP solver calculates the routes for each van. Each route begins at a depot, picks up one or more people if the time they spend on the van is less than the MaxTransitTime specified in the order pair, drops them at their hospital locations, continues to pick up and drop off other people, and returns to the depot at the end. The routes only service orders in their assigned route zones.



Determine turn-by-turn directions for the routes

Steps:

1. Click the **Directions Window** button on the ***Network Analyst*** toolbar.
   The ***Directions*** dialog box opens.
2. You can optionally export the vehicle routing problem as a layer file (<filename>.lyr) on disk so that you can load it in a different map document.
3. Exit ArcMap without saving any changes.

Exercise 9: Choosing optimal store locations using location-allocation

In this exercise, you will choose the store locations that would generate the most business for a retail chain. The main objective is to locate stores close to population centers, which provide demand for the stores. This objective is based on the premise that people tend to shop more at nearby stores than at those that are farther away. You will perform the location-allocation analysis using three different problem types: maximize attendance, maximize market share, and target market share. The differences among these problem types will become apparent as you work through the exercise.

Complexity:
Beginner

Data Requirement:
ArcGIS Tutorial Data Setup

Data Path:
C:\ArcGIS\ArcTutor\Network Analyst\Tutorial

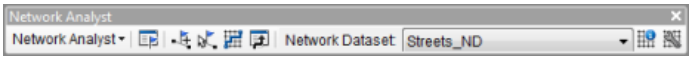
Goal:
Choose store locations using a location-allocation analysis.

Preparing your display

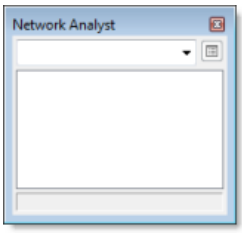
Steps:

1. If you have Exercise09.mxd open in ArcMap, skip to step 6.
2. Start ArcMap by clicking **Start** > **All Programs** > **ArcGIS** > **ArcMap 10.**
3. On the ***ArcMap - Getting Started*** dialog box, click **Existing Maps** > **Browse for more.**
4. Browse to C:\ArcGIS\ArcTutor\Network Analyst\Tutorial.
   This is the default installation location for the tutorial data.
5. Double-click **Exercise09.mxd**.
   The map document opens in ArcMap.
6. Enable the Network Analyst extension.
   a. Click **Customize** > **Extensions.**
      The ***Extensions*** dialog box opens.
   b. Check **Network Analyst**.
   c. Click **Close**.

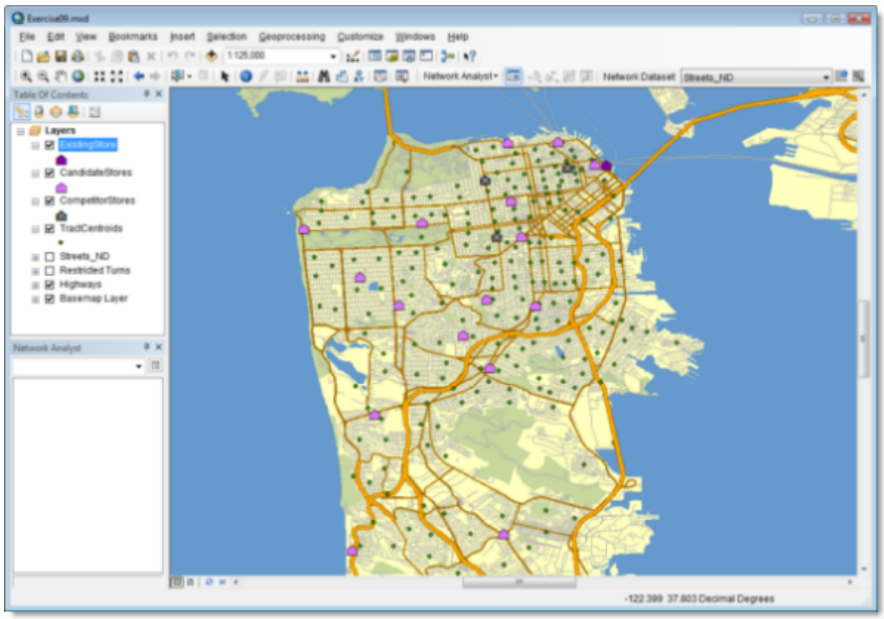
   If the ***Network Analyst*** toolbar is not displayed, you need to add it.
7. Click **Customize** > **Toolbars** > **Network Analyst.**
   The ***Network Analyst*** toolbar is added to ArcMap.



   If the ***Network Analyst*** window is not displayed, you need to add it.
8. On the ***Network Analyst*** toolbar, click the **Show/Hide Network Analyst Window** button.
   The dockable ***Network Analyst*** window opens.



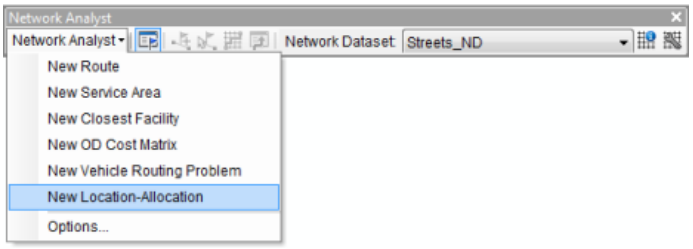
You can dock or undock the ***Network Analyst*** window. In this exercise, it is docked below the ***Table Of Contents*** window.



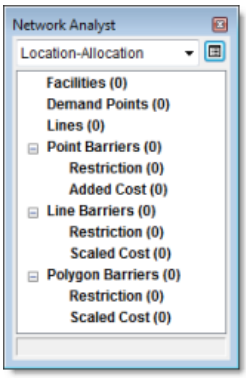
Creating the location-allocation analysis layer

Steps:

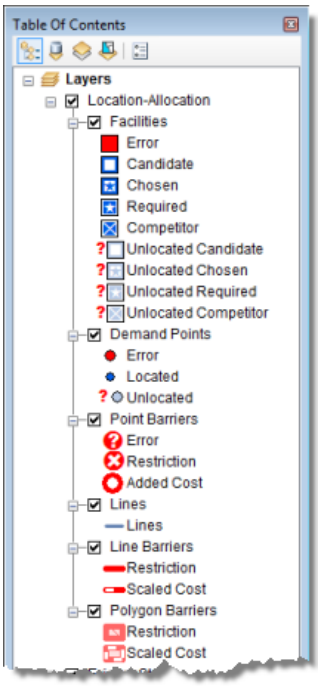
1. Click **Network Analyst** on the ***Network Analyst*** toolbar and click **New Location-Allocation**.



The location-allocation analysis layer is added to the ***Network Analyst*** window. The network analysis classes (Facilities, Demand Points, Lines, Point Barriers, Line Barriers, and Polygon Barriers) are empty.



The analysis layer is also added to the ***Table Of Contents*** window.



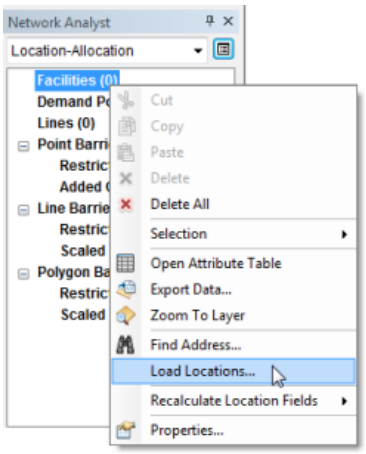
Adding candidate facilities

You will add the candidate store locations to the network analysis class Facilities. These are the potential places where you can open a store. The solution from the location-allocation process will include a subset of these stores.

The candidate store locations are already added as a layer (CandidateStores) in the map document. The names of the stores are contained in the layer's attribute table. You will load the point features from CandidateStores into the Facilities class of the location-allocation layer.

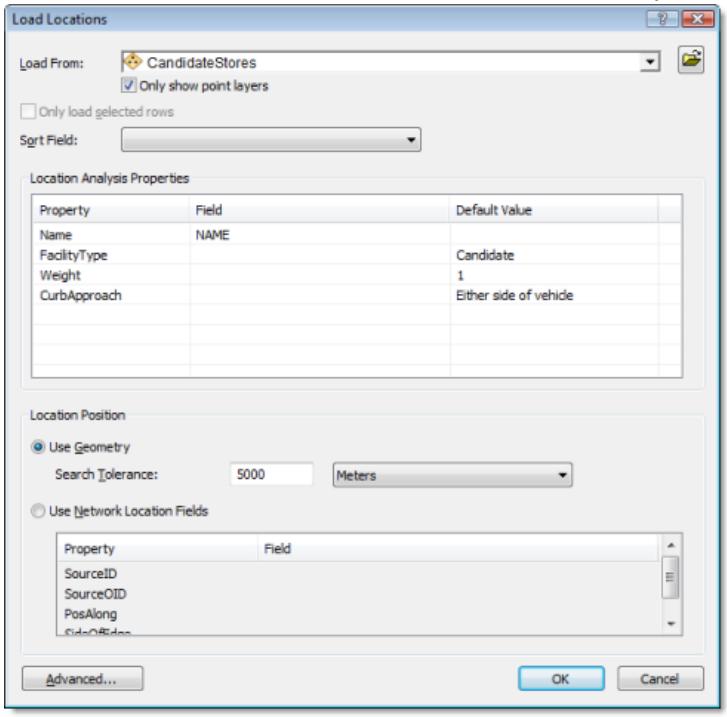
Steps:

1. In the ***Network Analyst*** window, right-click **Facilities (0)** and choose **Load Locations**.



The ***Load Locations*** dialog box opens.

2. Select **CandidateStores** from the **Load Locations** drop-down list.



The **Location Analysis Properties** section of the ***Load Locations*** dialog box lets you specify which attributes of the CandidateStores feature class contain the values that Network Analyst will use to solve this location-allocation problem.

3. In the **Location Analysis Properties** section, make sure the **Name** property is automatically mapped to the **NAME** field.

   Network Analyst tries to match location analysis properties automatically for a newly created location-allocation layer based on a configuration file (usually located in C:\Program Files\ArcGIS\Desktop10.0\NetworkAnalyst\NetworkConfigurations\NASolverConfiguration.xml).

4. Click **OK**.

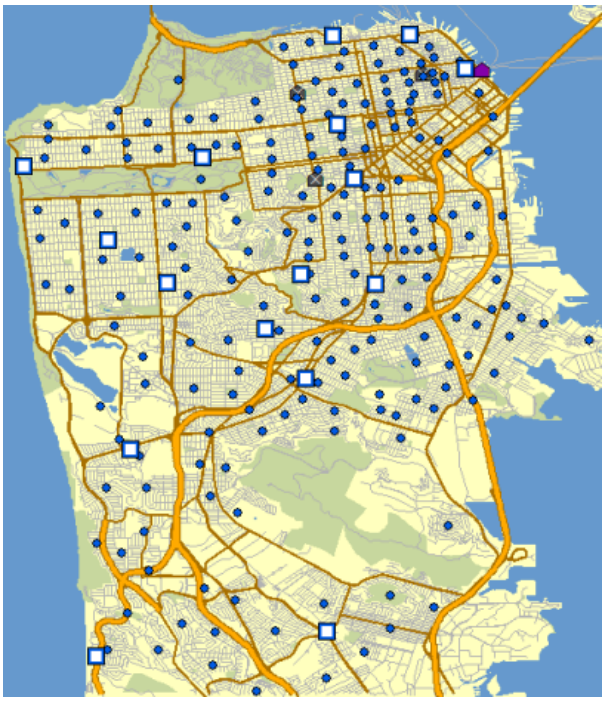
Sixteen candidate stores are loaded into the Facilities network analysis class. The new facilities are listed in the ***Network Analyst*** window and displayed on the map.

Adding Demand Points

The stores need to be located to best service the existing populations. A point layer of census tract centroids is already added to ArcMap. Now you will load these centroids into the demand points network analysis class.

Steps:

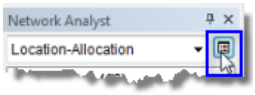
1. In the ***Network Analyst*** window, right-click **Demand Points (0)** and choose **Load Locations**.
2. Select **TractCentroids** from the **Load Locations** drop-down list.
3. In the **Location Analysis Properties** section, make sure the **Name** property is automatically mapped to the **NAME** field.
4. Click the **Field** column for the **Weight** property and choose **POP2000**.
   Each demand point will be weighted by the population from the 2000 census.
5. Click **OK**.
   The 208 census tract centroids are loaded into the Demand Points class. The new demand points are listed in the ***Network Analyst*** window and displayed on the map.



Setting up the properties of the location-allocation analysis

Steps:

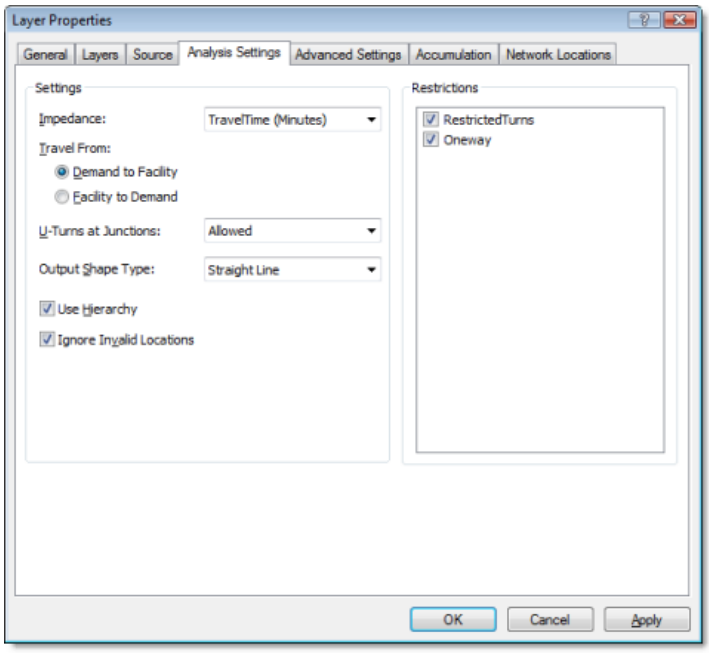
1. Click the **Analysis Layer Properties** button on the ***Network Analyst*** window.



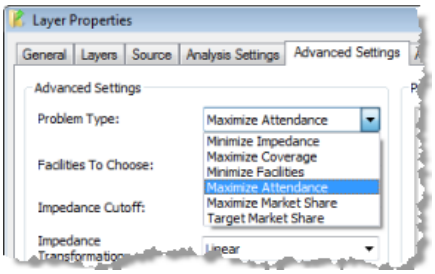
   The ***Layer Properties*** dialog box opens.

2. Click the **Analysis Settings** tab.
3. Make sure that **Impedance** is set to **TravelTime (Minutes)**.
4. Set **Travel From** to **Demand to Facility**.
   The default option, **Facility to Demand**, is a good choice for the classic minimize impedance and maximize coverage problem types. However, for maximize attendance, maximize market share, and target market share, the demand tends to travel to the facilities, thus **Demand to Facility** is often a good choice for them.
5. Click the **U-Turns at Junctions** drop-down arrow and choose **Allowed**.
6. Set **Output Shape Type** to **Straight Line**.
   Although the output will be displayed with straight lines, the travel costs are still measured along the network.
7. Make sure that the **Use Hierarchy** and **Ignore Invalid Locations** boxes are checked.
8. In the **Restrictions** frame, make sure that **RestrictedTurns** and **Oneway** are checked.

Your **Analysis Settings** tab should look like the following graphic:



9. Click the **Advanced Settings** tab.
10. Click the **Problem Type** drop-down list and choose **Maximize Attendance**.
    These problem types are often referred to as models. Maximize attendance is a good problem type for choosing retail store locations, since it assumes that all stores are equally attractive and people are more likely to shop at nearby stores.

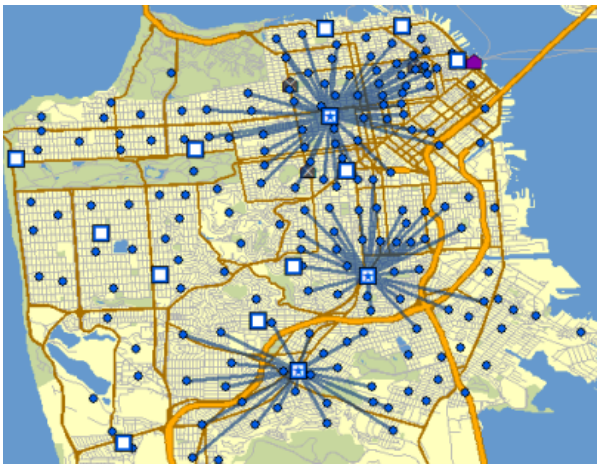


11. Increase **Facilities To Choose** to **3**.
    ArcGIS will try to choose 3 facilities out of the 16 to optimally serve the 208 demand points.
12. Increase **Impedance Cutoff** to **5**.
    This setting implies that people are not willing to travel more than five minutes to shop at these stores. The units for this value are determined by the units of the impedance attribute. Therefore, since TravelTime uses minutes, this value is also in minutes.
13. Make sure that **Impedance Transformation** is set to **Linear**. ArcGIS will use a linear decay in calculating people's propensity to visit a store. That is, with a five-minute impedance cutoff and a linear impedance transformation, the probability of visiting a store decays at 1/5, or 20 percent; therefore, a store one minute away from a demand point has an 80 percent probability of a visit compared to a store four minutes away, which only has a 20 percent probability.
14. Click **OK**.

Run the process to determine the best store locations

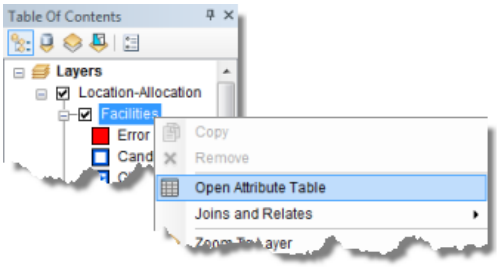
Steps:

1. Click the **Solve** button on the ***Network Analyst*** toolbar.
   Once the solve process is completed, lines in the map display connect chosen stores to their associated demand points. The lines also appear in the Lines class in the ***Network Analyst*** window.



   Now you will inspect the results in more detail.

2. In the **Table Of Contents**, right-click the **Facilities** sublayer and choose **Open Attribute Table**.



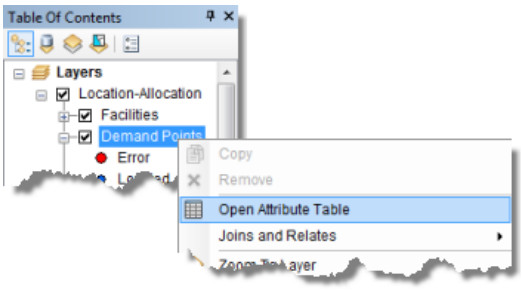
   Examine the attributes of the Facilities table. Three of the features have their FacilityType field values set to Chosen instead of the default status, Candidate.

   The DemandCount column lists the number of demand points assigned to each of the chosen facilities. Note that out of the 208 demand points, only 113 were allocated to the chosen facilities because some of the points were farther than the five-minute cutoff.

   The DemandWeight column lists the demand that is allocated to each facility. In this case, the value represents the number of people that are likely to shop at the store.

3. Close the ***Facilities*** table.

4. In the **Table Of Contents**, right-click the **Demand Points** sublayer and choose **Open Attribute Table**.



Examine the attributes of the Demand Points table. The Facility ID column has a value of <Null> if the demand point was outside the five-minute cutoff, but if a numeric value is present, it represents the ID of the chosen facility the demand point was allocated to.

The Weight column contains the population count that was loaded from the census tract feature class. The AllocatedWeight column contains the amount of demand that was apportioned to the associated facility. The amount of weight allocated is based on the linear distance decay and the five-minute cutoff parameters you set in the ***Layer Properties*** dialog box.

5. In the **Table Of Contents**, right-click the **Lines** sublayer and choose **Open Attribute Table**.

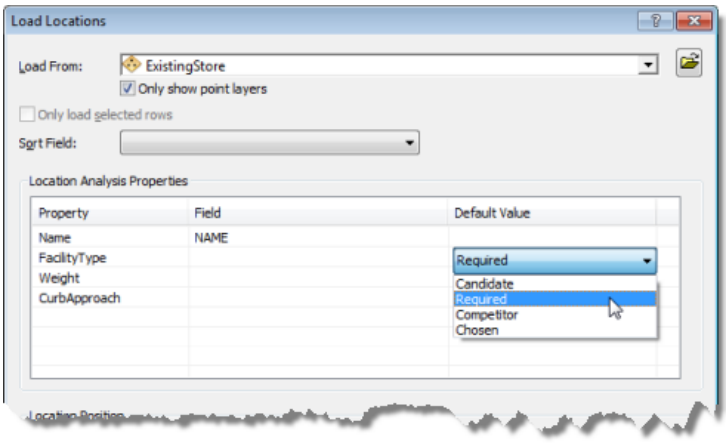
   This table contains one record for each demand point allocated to a facility. It also lists the shortest path impedance between the two locations and the weight captured by the facility.

Adding a required facility

In the previous section, you generated results for where to locate three new stores. In this section, you will use location-allocation to solve a store-expansion scenario, in which you will start with an existing store and optimally locate two additional stores.

Steps:

1. In the ***Network Analyst*** window, right-click **Facilities (16)** and choose **Load Locations**.
   The ***Load Locations*** dialog box opens.
2. Select **ExistingStore** from the **Load From** drop-down list.
3. In the **Location Analysis Properties** section, make sure that the **Name** property is automatically matched to the **NAME** field.
4. In the **Default Value** column for **Facility Type**, change **Candidate** to **Required**.
   This ensures that when the store is loaded as a facility, it will have a status of Required. Required facilities must always be part of the solution.



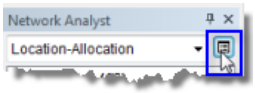
5. Click **OK**.

Setting up the properties of the analysis (maximize attendance with required facility)

You will use the same properties from the previous solution to solve this problem.

Steps:

1. Click the **Analysis Layer Properties** button on the ***Network Analyst*** window.



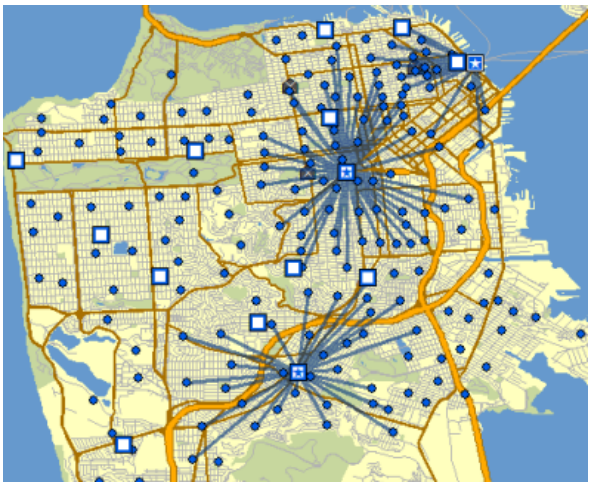
The ***Layer Properties*** dialog box opens.

2. Make sure that the problem type is set to **Maximize Attendance**, the facilities to find is **3**, the impedance cutoff is **5**, and the impedance transformation is **Linear**.
3. Click **OK**.

Run the process to determine the best store locations (maximize attendance with required facility)

Steps:

1. Click the **Solve** button on the ***Network Analyst*** toolbar.
   When the solve process is complete, lines connect chosen stores to demand points. Note that the original solution changed, and the ExistingStore location is now part of the solution. The other two chosen facility locations are now at different places.

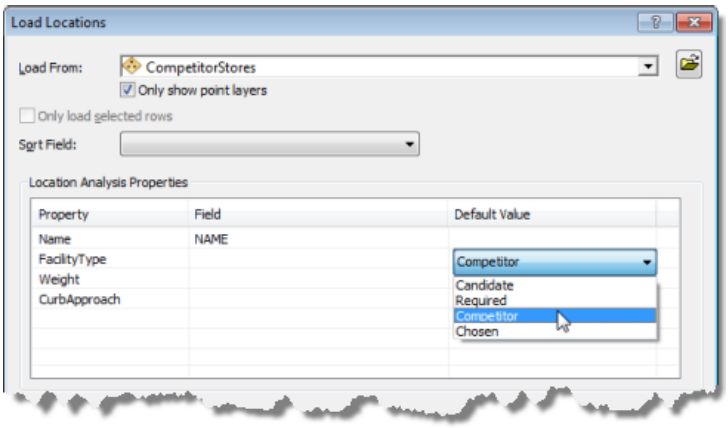


Adding competing facilities

Location-allocation can locate new stores to maximize market share in light of competing stores. The market share is computed using a Huff, or gravity, model. A Huff model assumes that demand points have a probability of visiting stores based on some properties of the store as well as the distance away from that store.

Steps:

1. In the ***Network Analyst*** window, right-click **Facilities (17)** and choose **Load Locations**.
2. Choose **CompetitorStores** in the **Load From** drop-down list.
3. In the **Location Analysis Properties** section, make sure that the **Name** property is automatically matched to the **NAME** field.
4. In the **Default Value** column for **Facility Type**, change **Candidate** to **Competitor**.



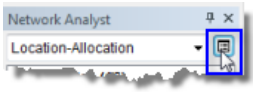
5. Click **OK**.

Setting up the properties of the analysis (maximize market share)

You will change the properties of the location-allocation analysis layer so that it solves using the maximize market share problem type.

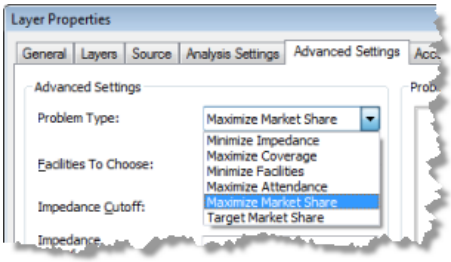
Steps:

1. Click the **Analysis Layer Properties** button on the ***Network Analyst*** window.



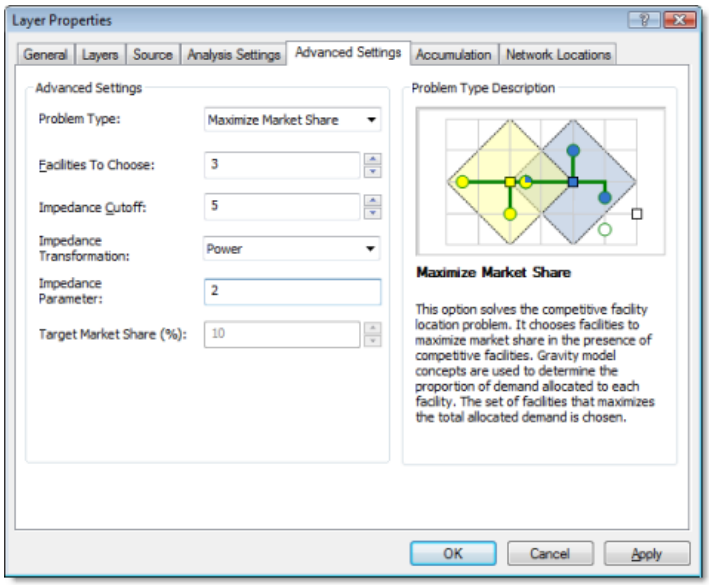
   The ***Layer Properties*** dialog box opens.

2. Click the **Advanced Settings** tab.
3. Click the **Problem Type** drop-down list and choose **Maximize Market Share**.



4. Click the **Impedance Transformation** drop-down list and choose **Power**.
   ArcGIS will use a power distance decay in determining people's propensity to visit a store. Notice that **Impedance Parameter** becomes available for you to edit.
5. Change the **Impedance Parameter** value to **2**.
   An impedance parameter of 2 on a power impedance transformation means the probability of visiting a store decays with the square of the distance between a demand point and a facility location. Usually, an accurate value of the impedance parameter is computed from other analyses, such as those provided by using ArcGIS Business Analyst.

The **Advanced Settings** tab should look like the following graphic:



6. Click **OK**.

Run the process to determine the best store locations (maximize market share)

Steps:

1. Click **Network Analyst** on the ***Network Analyst*** toolbar and click **Options**.
   The ***Network Analyst Options*** dialog box opens.
2. Click the **General** tab.
3. Click **All Messages**.
   By choosing **All Messages** with a market share problem, the market share you capture will be reported in a dialog box once the solve process is completed.
4. Click **OK**.
5. Click the **Solve** button on the ***Network Analyst*** toolbar.
   When the solve process is completed, a message indicates how much of the market share you captured.
6. Close the message box.

   Lines in the map connect demand points to chosen and competitor stores. Notice the chosen stores have changed to maximize the amount of demand given the presence of the three competitors.

   The lines overlap more than in the previous solutions, since each demand point in the maximize market share problem can interact with all the facilities that are within the impedance cutoff.
7. In the ***Table Of Contents***, right click the **Facilities** sublayer and choose **Open Attribute Table**.

   Three facilities have a FacilityType value of Competitor, one has a value of Required, and two have a value of Chosen, which indicates the solver chose them as the best facilities to open.

The DemandCount column lists the number of demand points assigned to each of the facilities. Note that some demand points were not assigned, since they were outside the five-minute cutoff.

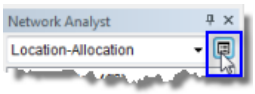
The DemandWeight column lists the sum of the demand weight assigned to each of the chosen facilities. The weight assigned to your stores versus that assigned to the competitor stores can be used to figure out the market share that was reported after the solve process finished.

Achieving a target market share

In the last section, the three stores chosen accounted for 33.79 percent of the market share. Say, however, you want to capture 70 percent of the market share. You need to know the minimum number of stores that would be needed, and where they should be located, to accomplish that goal. The target market share problem type can help you find the answer.

Steps:

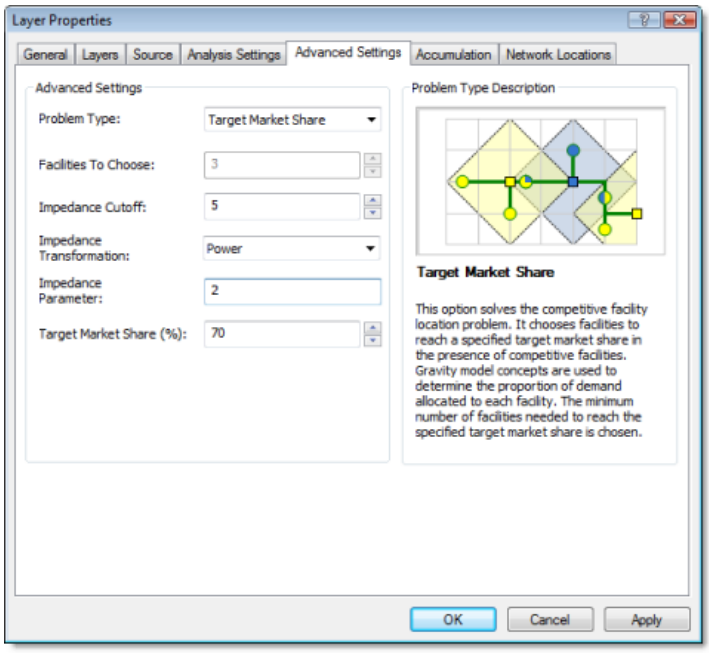
1. Click the **Analysis Layer Properties** button on the ***Network Analyst*** window.



   The ***Layer Properties*** dialog box opens.

2. Click the **Advanced Settings** tab.
3. Click the **Problem Type** drop-down list and choose **Target Market Share**.
   Notice that when you change the problem type to **Target Market Share**, the **Target Market Share (%)** property becomes available for you to edit.
4. Change **Target Market Share (%)** to `70`.

The **Advanced Settings** tab should look like the following graphic:



5. Click **OK**.

Run the process to determine the best store locations (target market share)

Steps:

1. Click the **Solve** button on the ***Network Analyst*** toolbar.
   When the solve process is complete, a message indicates how much of the market share you captured and the total number of facilities required to capture that share. The percentage is more than the 70 percent you had indicated, because opening any fewer facilities would result in a market share below your target of 70 percent.
2. Close the message box.

   Once again, lines connect the solution facilities to demand points in the map display.
3. In the ***Table Of Contents***, right-click the **Facilities** sublayer and choose **Open Attribute Table**.

   In addition to the three competitor facilities and the one required facility, nine facilities now have a FacilityType value of Chosen. This means nine additional stores are needed to achieve the 70 percent market share.
4. If you don't plan to work on any other exercise, exit ArcMap. Click **No** to discard any changes.
5. If you plan to work on another exercise, follow the substeps below.
   a. Click **File** > **New.**
      The ***New Document*** dialog box opens.
   b. Click **OK**.
   c. Click **No** when prompted to save changes.