ArcGIS® 9

ArcGIS Network Analyst Tutorial

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DATA CREDITS

Shapefile and geodatabase data used to create and build Network Datasets in exercises 1, 4, 5, 8, and 9 supplied by TeleAtlas, Boston, Massachusetts, and is used here with permission.

Geodatabase based street data used to create and build Network Datasets in exercises 2, 3, 6, and 7 supplied by NAVTEQ, Chicago, Illinois, and is used here with permission.

Geodatabase based transit data used to create and build Network Datasets in exercises 3, 6, and 7 supplied by RATP from the city of Paris, and is used here with permission.

CONTRIBUTING WRITERS

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ArcGIS Network Analyst Tutorial

IN THIS TUTORIAL

ESRI® 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:

- Use ArcCatalog™ to create and build a network dataset from a streets shapefile.
- 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 tools in ArcToolbox™ to create geoprocessing models that perform network analysis.

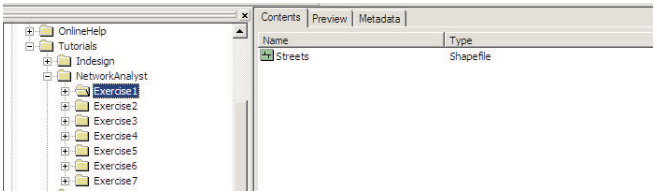
In order to use this tutorial, you need to have the Network Analyst extension and ArcGIS installed and have the tutorial data installed on a local or shared network drive on your system. Ask your system administrator for the correct path to the tutorial data if you do not find it at the default installation path (C:\ArcGIS\ArcTutor\Network_Analyst) as specified in the tutorial.

Exercise 1: Creating a shapefile-based network dataset

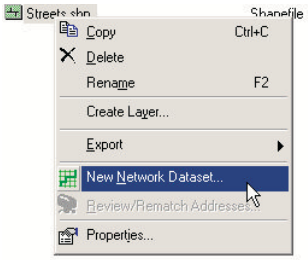
In this Exercise you will create a simple shapefile-based network dataset from a single line feature class.

Creating a network dataset

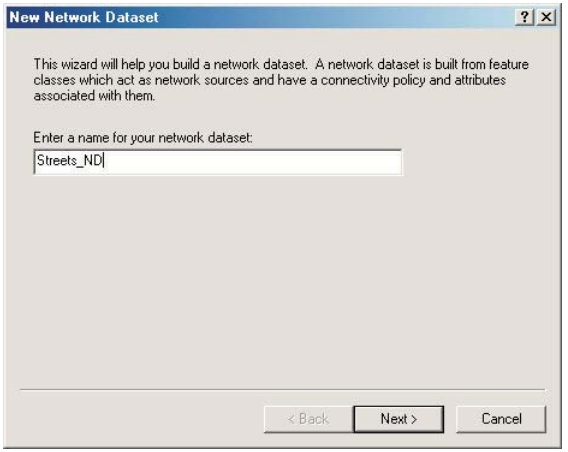
1. Start ArcCatalog™ by either double-clicking a shortcut installed on your desktop or using the programs list in your Start menu.
2. Navigate to the C:\arcgis\ArcTutor\Network_Analyst folder in the Catalog Tree. (This is the default install location for this data.)
3. Click the Exercise1 folder to show its contents.



4. If the Network Analyst Extension is not enabled, on the Tools menu, click Extensions, and in the Extensions dialog box, click Network Analyst and close the Extensions dialog box.
5. Right-click the Streets shapefile and choose New Network Dataset. This shapefile contains street data for downtown San Francisco.



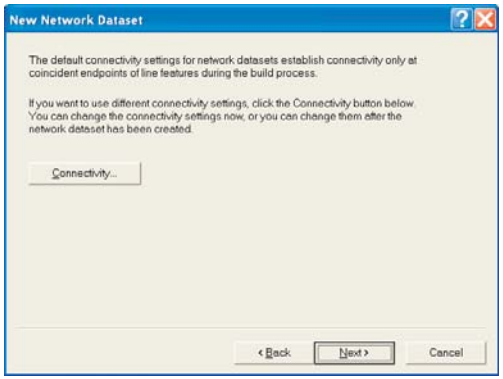
6. The name of the network dataset is set to Streets_ND by default. Click Next to continue.



Network Connectivity defines how features that participate in a network connect to each other. The default connectivity for a network dataset places all sources in one connectivity group and assigns all edge sources endpoint connectivity. In a shapefile based network there is only one edge source, hence there is no

need for multiple connectivity groups. Also, we wish to model streets with endpoint connectivity. (To see how this is modeled, click the Connectivity button.)

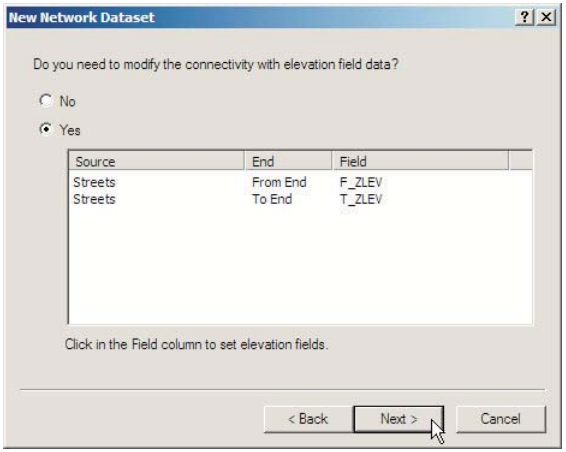
7. To accept the default connectivity, click Next to continue.



Earlier versions of ArcView® GIS and ARC/INFO™ support optional elevation fields to establish connectivity. Each feature in a shapefile or a coverage would be assigned two Z-elevation values, one for each endpoint. If the endpoints of line features have the same Z-elevation value, connectivity is established. If the values are different, they do not connect (e.g., in the case of bridges or tunnels).

The elevation field contains logical elevation values for establishing connectivity only and does not provide height information for the feature. ArcGIS® Network Analyst can use Z-elevation values to further modify the connectivity settings established in the previous step. ArcGIS Network Analyst automatically searches and maps the relevant fields.

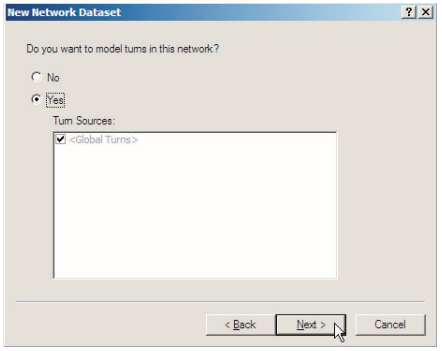
8. Click Next to accept the default elevation fields settings. If ArcGIS Network Analyst finds elevation fields data in your shapefile, it automatically chooses the Yes radio button and assigns the appropriate fields.



ArcGIS Network Analyst supports turns in a shapefile based network. Turn information (such as turning restrictions and delays) enhance the quality of network analysis. Earlier versions of ARC/INFO and ArcView GIS used turn tables. These turn tables can be converted into turn features and used in the network dataset. You will use turn features in Exercise 2.

In addition, by default, Global Turns are selected. Global Turns are rules that can be set, such as all left turns have a delay of 15 seconds. Such a rule gives preference to right turning movements. The advantage of Global Turns is that you do not need to create individual turn features for rules that apply to every turn in the network.

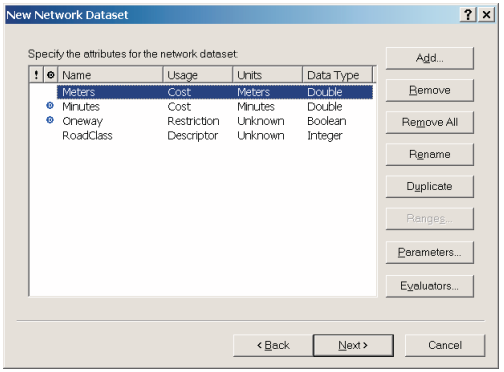
9. Click Yes to model turns in the network.
10. Click Next to continue.



Network attributes are properties of the network that are used to control navigation. Common examples are costs that function as impedances over the network. Restrictions like one-way traversal are also examples of network attributes.

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

11. Since the attributes are automatically defined and assigned values, click Next to continue.

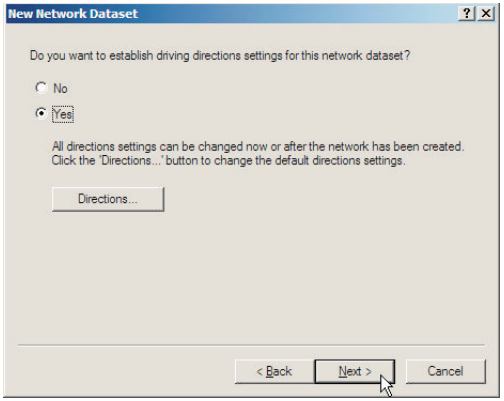


To use driving directions in a network analysis, they should be set in the network dataset.

12. Select Yes to establish driving directions settings for this network dataset.

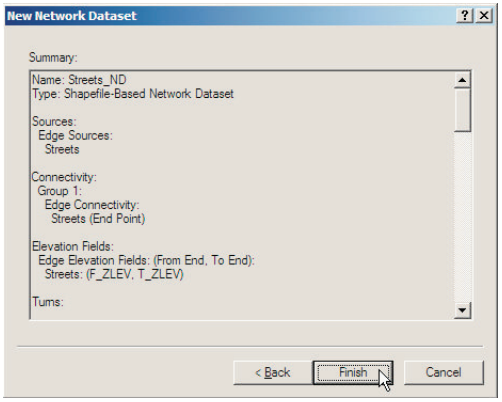
The Network Analyst automatically finds and maps the field in the streets source that will be used to report street names. Additionally Length and Time fields are automatically mapped as well.

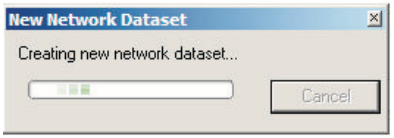
13. Click Next to continue.



14. A summary of all the settings that have been chosen is displayed in the following window for your review.

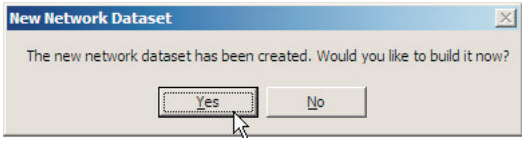
    Click Finish to create the new shapefile based network dataset.



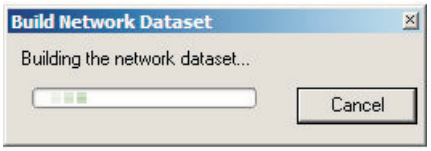


    Once created, the system prompts for the network to be built.

15. Click Yes to build the network.

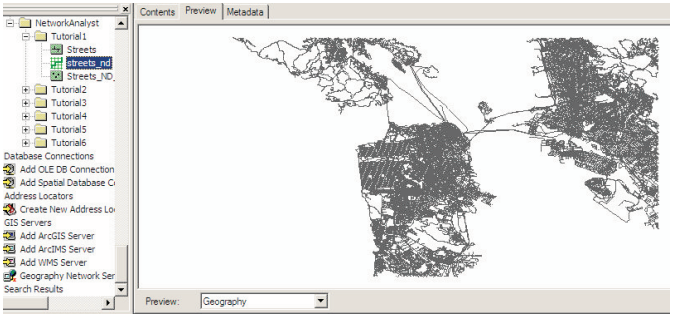


    The network dataset has been built when the progress bar disappears.



    The shapefile based network, Streets_ND, is added to ArcCatalog along with the system junctions shapefile Streets_ND_Junctions.

16. Select Streets_ND and click on the Preview tab to see the built network dataset.



17. Close ArcCatalog.

Exercise 2: Creating a geodatabase network dataset

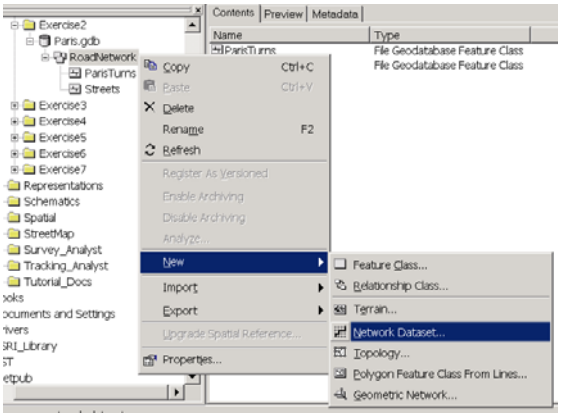
In this Exercise you will create a geodatabase network dataset using the streets feature class and a turn feature class for Paris.

Creating a network dataset

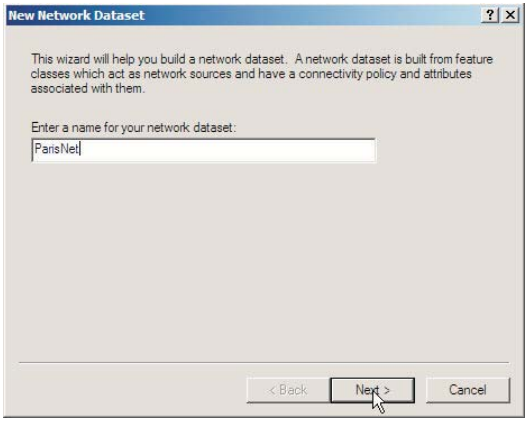
1. Start ArcCatalog by either double-clicking a shortcut installed on your desktop or using the programs list in your Start menu.

   If the Network Analyst Extension is not enabled, on the Tools menu, click Extensions, and in the Extensions dialog box, click Network Analyst then close the Extensions dialog box.

2. Navigate to the C:\arcgis\ArcTutor\Network_Analyst folder in the Catalog Tree. (This is the default install location for this data.)
3. Double-click the Exercise2 folder to expand it.
4. Click the plus sign on Paris.gdb. This will expand the connection tree to show you the contents of the geodatabase.
5. Click the RoadNetwork feature dataset. The contents will be listed in the Contents tab.
6. Right-click the RoadNetwork feature dataset, click New, then click Network Dataset. This will open the New Network Dataset Wizard.

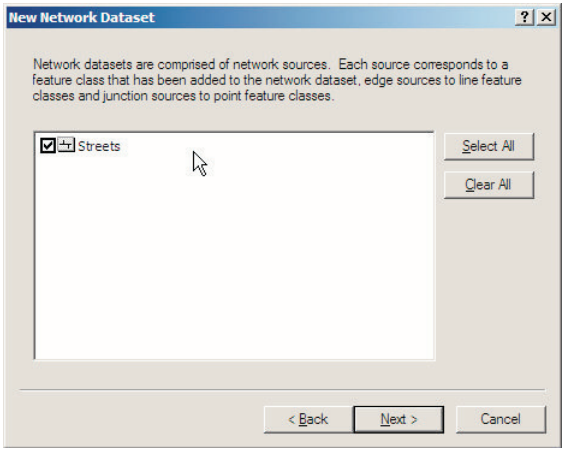


7. Type “ParisNet” as a name for your network dataset.



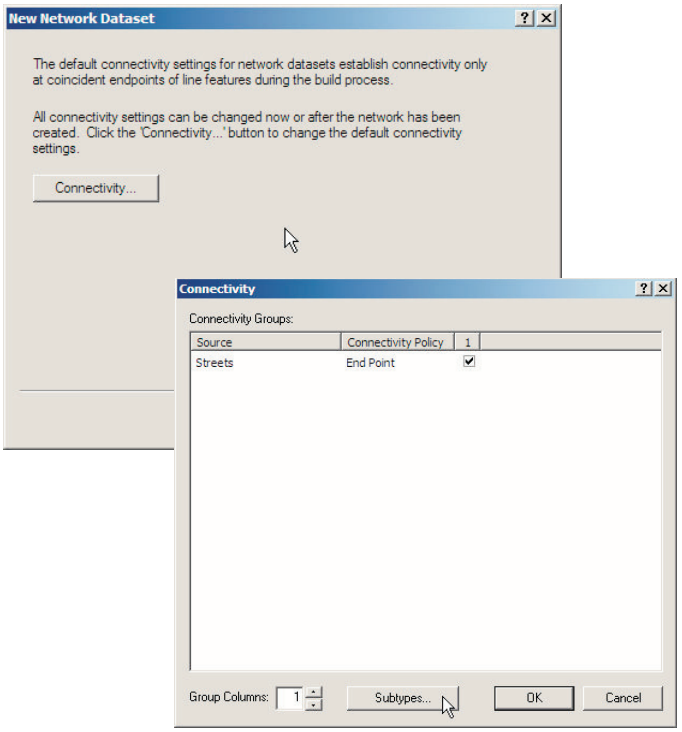
8. Click Next.

9. Check the Streets feature class to use it as a source for the network dataset.



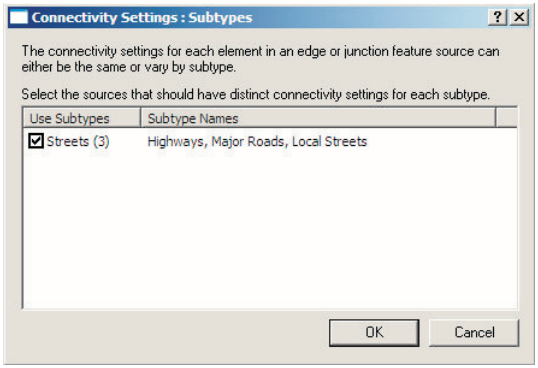
10. Click Next.

11. Click Connectivity to set up the connectivity model for the network.

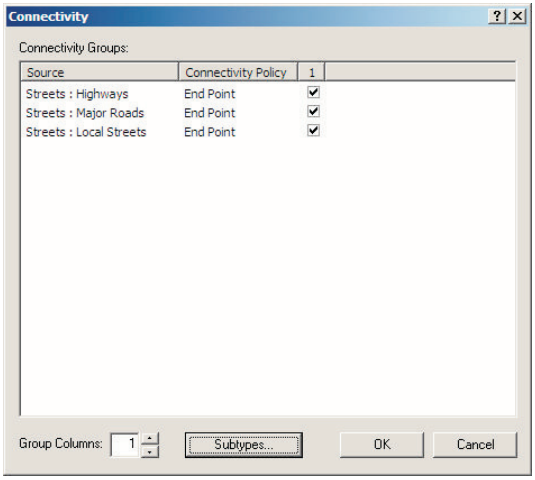


The Streets feature class has three subtypes that we wish to use to set up the connectivity: Highways, Major Roads, and Local Streets.

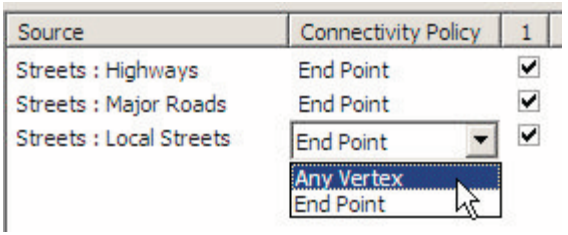
12. Click the Subtypes button to bring up the Connectivity Settings: Subtypes dialog box. Check the Box next to Streets (3) to use the three subtypes of Streets.



13. Click OK to return to the Connectivity dialog box. There are now three rows, one for each subtype.



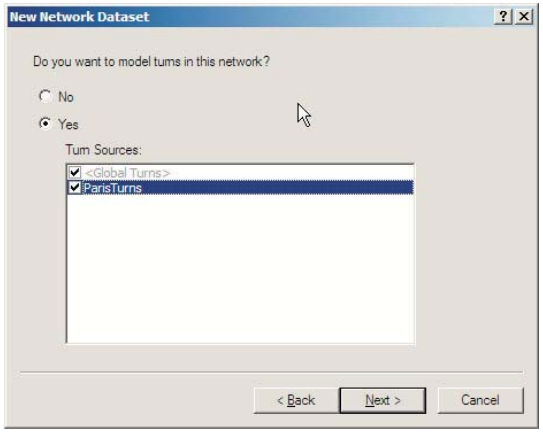
14. For this network, Highways and Major Roads connect to each other at end points. Local Streets connect at any vertex of geometric coincidence. Change the connectivity policy of Streets: Local Streets to Any Vertex.



15. Click OK to close the Connectivity Group dialog box.
16. Click Next.
17. Check No since here is no elevation field data for this dataset.

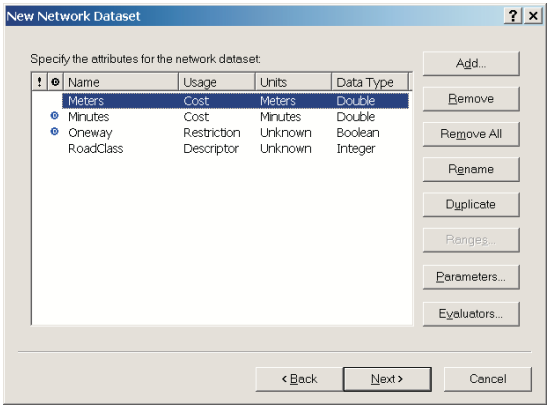
    Elevation fields have been used since the earlier versions of ARC/INFO and ArcView GIS to model connectivity. ArcGIS Network Analyst supports this connectivity model. Each feature in a shapefile or a coverage would be assigned two Z-elevation values, one for each endpoint. If the endpoints of line features have the same Z-elevation value, connectivity is established. If the values are different, they do not connect (e.g., in the case of bridges or tunnels). The elevation field contains logical elevation values for establishing connectivity only and does not provide height information for the feature.
18. Click Next.

19. Check Yes for modeling turns in the network. Check the box by ParisTurns to select the turn feature source.



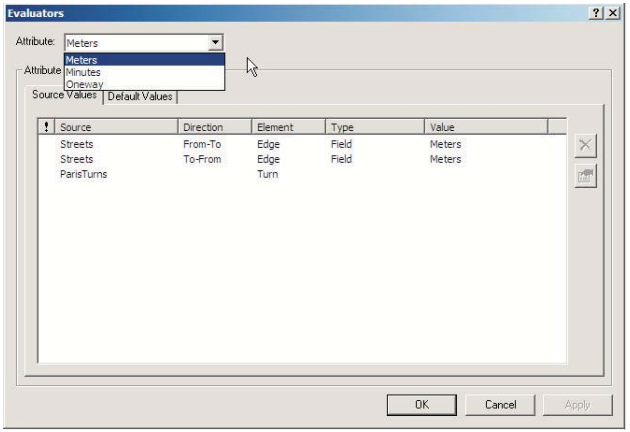
20. Click Next.

21. There are four attributes that are added by default: Road Class, Oneway, Minutes, and Meters.



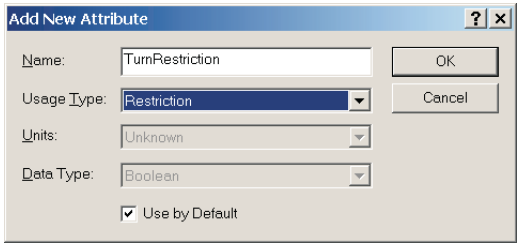
ArcGIS Network Analyst inspects all sources and tries to automatically assign values for these three attributes.

22. Click Evaluators to examine how the values of network attributes are determined by source. Select each attribute from the pull-down menu and inspect the type of evaluator and value assigned to it.

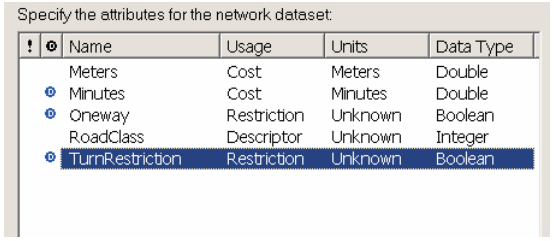


23. Click OK to return to the New Network Dataset Wizard.

24. You will add a new attribute that will restrict movement over the turn elements created from ParisTurns. Click Add to bring up the Add New Attribute dialog box. Type "TurnRestriction" for the attribute and select Restriction as the Usage type. Note that the Use by Default option is checked. This restriction will be used by default when a new network analysis layer is created. If checked here, it can be disabled during analysis.

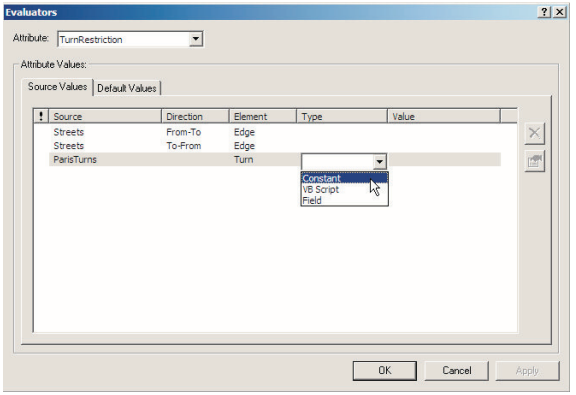


25. Click OK. A new attribute called TurnRestriction is added to the list.

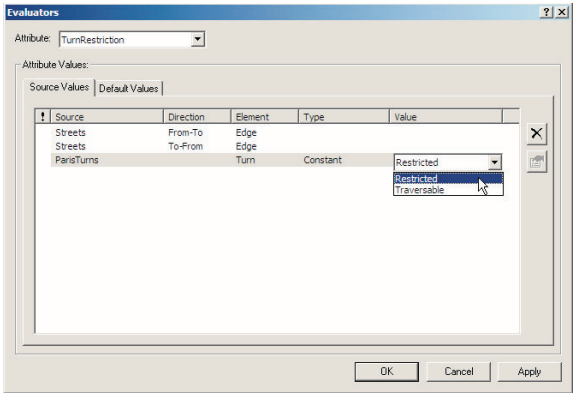


26. Click Evaluators to assign values by source.

27. Set the Type of Evaluator for ParisTurns to Constant by clicking in the Type column for the ParisTurns row and selecting Constant from the drop-down box.



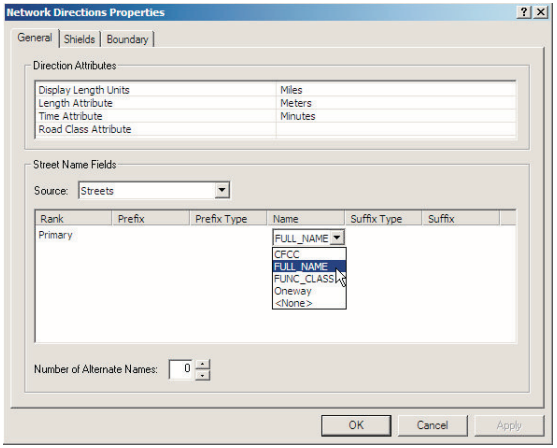
28. Change the Value for ParisTurns to Restricted. The evaluators for other sources are set automatically to Traversable under Default Values.



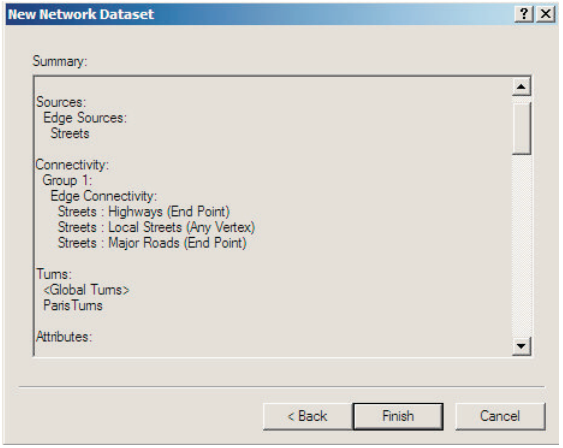
29. Click OK to return to the New Network Dataset Wizard.

30. Click Next to continue.

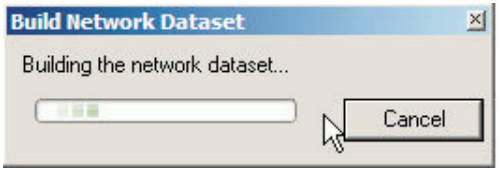
31. Click Yes to set up directions. Click Directions to open the Network Directions properties page. Here, you will set up the fields used to report directions after network analysis.
32. In the General tab, click under the Name column for the Primary row and select FULL_NAME from the drop-down list. In the Paris streets data, this field contains the street names that will be used to generate directions.



33. Click OK to return to the New Network Dataset Wizard.
34. Click Next to see a summary of the settings defined.



35. Click Finish to create the new network dataset.
36. Click Yes to build the network dataset.



Once the network dataset is built, you should see a new network dataset called ParisNet along with the system junctions feature class ParisNet_Junctions. Preview the network dataset by selecting it and clicking on Preview.

37. Close ArcCatalog.

Exercise 3: Creating a multimodal network dataset

In this Exercise you will create a multimodal network dataset from multiple feature classes within a feature dataset in a geodatabase.

Creating a network dataset

1. Start ArcCatalog by either double-clicking a shortcut installed on your desktop or using the programs list in your Start menu.

   If the Network Analyst Extension is not enabled, on the Tools menu, click Extensions, and in the Extensions dialog, click Network Analyst and then close the Extension dialog.

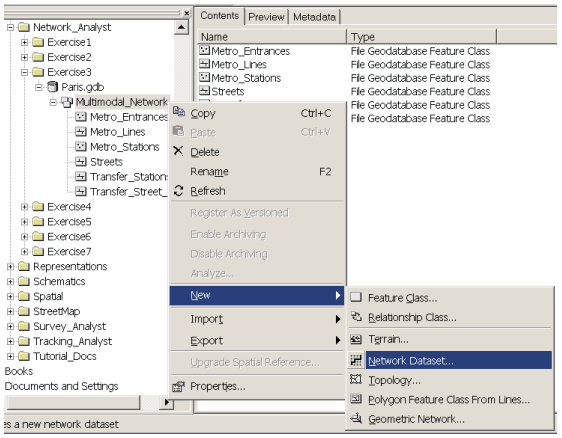
2. Navigate to the C:\arcgis\ArcTutor\Network_Analyst\Exercise3 folder in the Catalog Tree. (This is the default install location for this data.)

3. Double-click the Exercise3 folder to expand it.

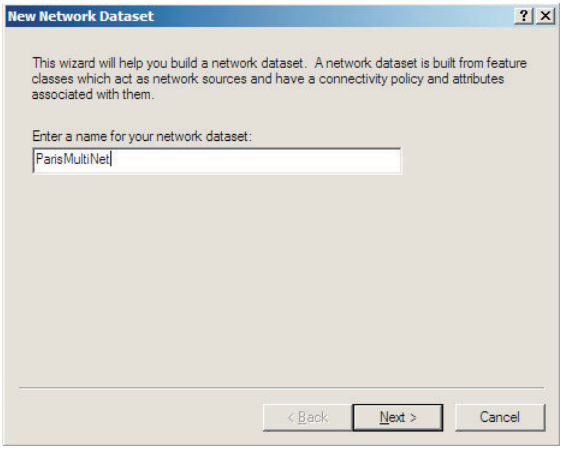
4. Click the plus sign on Paris.gdb. This will expand the connection tree to show you the contents of the geodatabase.

5. Click the Multimodal_Network feature dataset. The contents will be listed in the Contents tab.

6. Right-click the Multimodal_Network feature dataset, click New, then click Network Dataset. This will open the New Network Dataset Wizard.

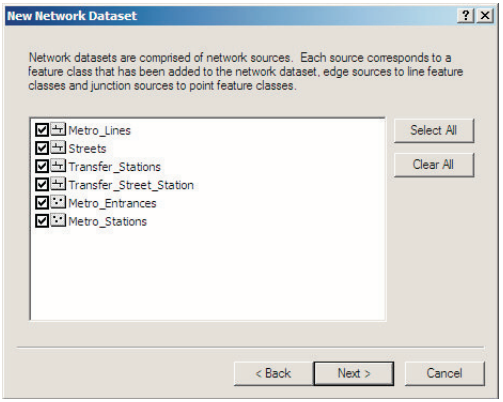


7. Type “ParisMultiNet” as a name for your network dataset.



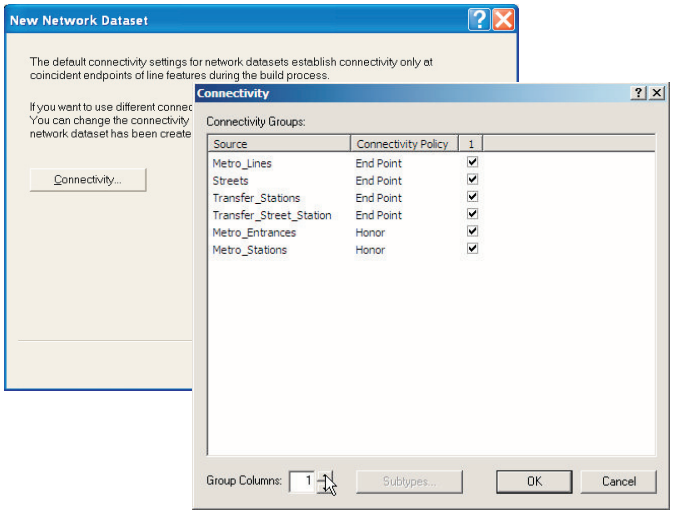
8. Click Next.

9. Click Select All to select all the feature classes to participate as sources in the network.



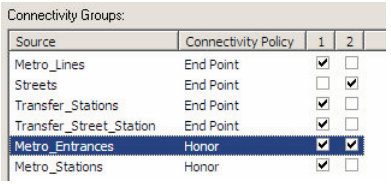
10. Click Next.

11. Click Connectivity to set up the connectivity model for the network.



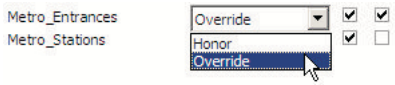
12. Click the Group Column up-arrow once, to increase the number of connectivity groups to 2. Connectivity group 1 represents the metro system and connectivity group 2 represents the street network.

13. Check the boxes under the Connectivity Group numbers to assign each source to the group they belong to. Click under the column labeled 2 for the Streets row to move Streets to connectivity group 2, as shown in the graphic below. Click under the column labeled 2 for the Metro_Entrances row to assign Metro_Entrances to both groups 1 and 2. They are the points of transfers between the two networks.



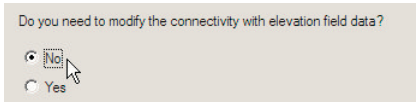
14. Click under the Connectivity Policy column for Metro_Entrances and select Override from the drop-down list.

    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 are to be connected to the streets at the coincident vertex, you have set the Metro_Entrances to override the default endpoint connectivity of the streets.

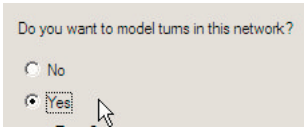


15. Click OK to close the Connectivity Group dialog box.
16. Click Next.
17. There is no elevation field data for this dataset, therefore be sure No is selected.

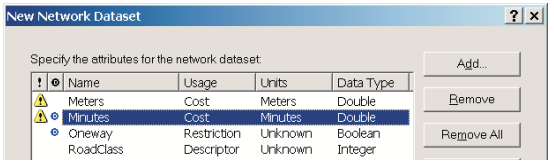
    Elevation fields have been used since the earlier versions of ARC/INFO and ArcView GIS to model connectivity. ArcGIS Network Analyst supports this connectivity model. Each feature in a shapefile or a coverage would be assigned two Z-elevation values, one for each endpoints. If the endpoints of line features have the same Z-elevation value, connectivity is established. If the values are different, they do not connect (e.g., in the case of bridges or tunnels). The elevation field contains logical elevation values for establishing connectivity only and does not provide height information for the feature.



18. Click Next.
19. Select Yes for modeling turns in the network. Although you have no turn feature classes for this network, selecting yes allows the network dataset to support global turns. Turn information can be added to an existing network dataset, if it supports turns. If you choose no here, you will not be able to add turns to this network on a later date.



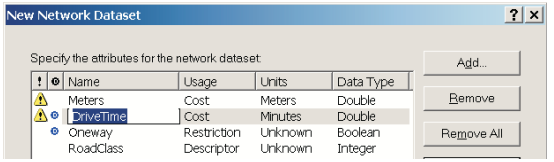
20. Click Next.
21. There are four attributes that are added by default: RoadClass, Oneway, Minutes, and Meters.



Since this is a multimodal network you will add different time attributes based on mode. For automobiles, you will have an attribute called Drivetime and for pedestrians, you shall have a Pedestrian_Time attribute.

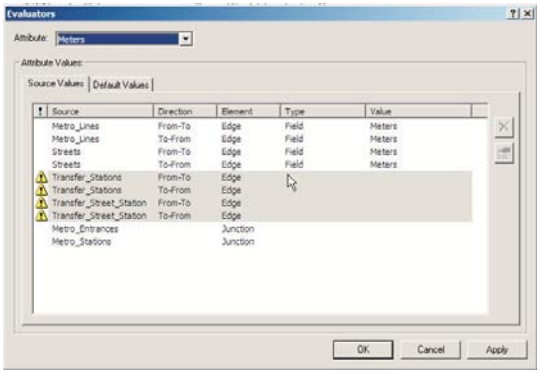
The attribute Minutes is added by the Network Analyst by default. We can rename this attribute to be called Drivetime.

22. Select the Minutes row, click Rename, then type "Drivetime".



The Meters and Drivetime attributes have a yellow warning symbol that represents a potential problem with the evaluators.

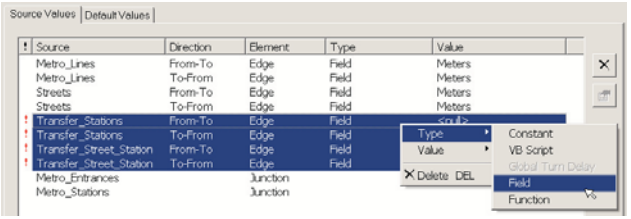
23. Select Meters and click Evaluators to inspect values for the Meters attribute for each source in the network.



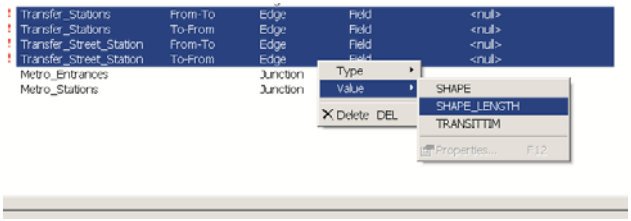
ArcGIS Network Analyst inspects all sources and tries to automatically assign values for the Meters attribute. The Metro_Lines source and the Streets source have a field called Meters; therefore, this field is automatically assigned to the sources.

For each edge source in the network, attributes need to be assigned for each direction of travel. Since the length does not depend on direction of travel, the same values are assigned for both directions of a source. Network Analyst attempts to assign values for each cost attribute for each edge source that participates in the network. In this case, Network Analyst was unable to find values for Transfer_Stations and Transfer_Street_Station sources. Hence a warning symbol is present to indicate that there is a problem.

24. Select all four rows with the yellow warning symbol (two sources in both directions), right-click, choose Type, and click Field. The yellow warning sign changes to a red exclamation mark indicating an incomplete assignment of values.



25. The four rows, now with the red exclamation mark, should still be selected. Right-click the selected rows, choose Value, and click SHAPE_LENGTH. This will assign values for the Meters attribute for the selected sources from the their SHAPE_LENGTH field.



26. Click Apply.

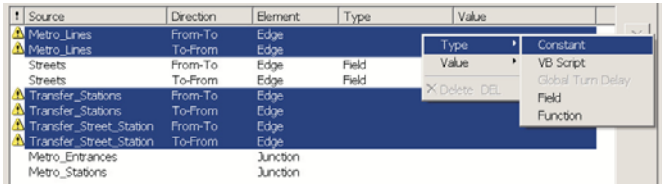
27. From the Attributes drop-down box, select Oneway. The attribute Oneway has been assigned values automatically by the ArcGIS Network Analyst for the Streets source. Since all other sources are related to the metro system, they have no oneway restrictions.

28. From the Attributes drop-down box, select Drivetime.

The values for the Streets source are populated automatically by Network Analyst. Other edge sources have no values assigned and have the warning symbol.

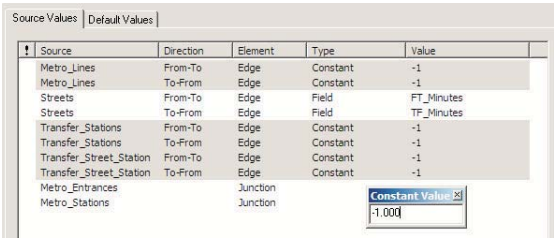
The attribute Drivetime will be used to model the travel time using automobiles. Since automobiles travel on streets only (and not on Metro_Lines or transfers between stations), a valid value of Drivetime can exist only for streets (which has been automatically set up).

29. Select all the other edge sources that belong to the metro system (Metro_Lines, Transfer_Station, and Transfer_Street_Station). You can use the CTRL key and select each of them. Click on the column heading named Type and select Constant.



30. The same rows should still be selected. Hit the F12 key on the keyboard to bring up the Constant Value Input box. (Alternately, you can also right-click the selected rows, point to Value and select Properties to bring up the same input box.) Type -1 and press Enter.

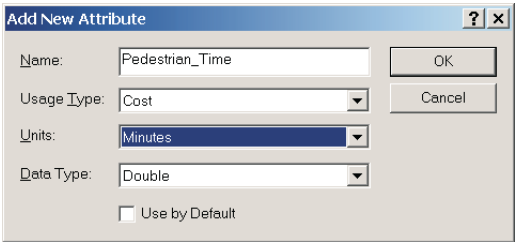
    By assigning a constant of -1, the system will treat the sources as restricted when the attribute Drivetime is used as an impedance.



31. Click OK to return to the New Network Dataset Wizard.

32. Click Add to add a new attribute.

33. In the Add New Attribute dialog box, type "Pedestrian_Time" for the Name. Set the Usage Type as Cost, the Units as Minutes, and the Data Type as Double.

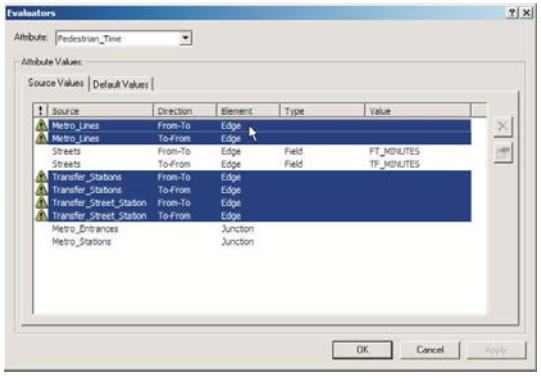


34. Click OK.

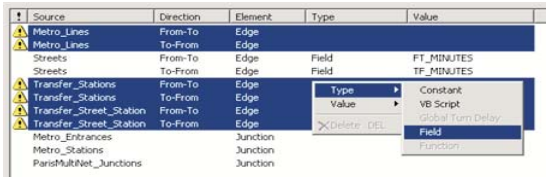
35. Select Pedestrian_Time and click Evaluators.

    The Pedestrian_Time attribute in the network represents the time a pedestrian takes on the network. In this case it has two components because a pedestrian can utilize the metro system in addition to walking on the street network. In the Evaluators dialog, the following six sources should already be selected. Metro_Lines (in

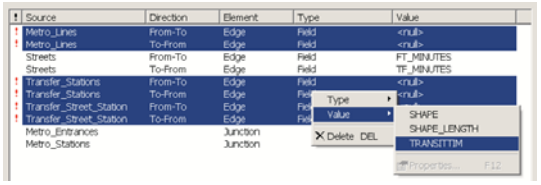
each direction), Transfer_Stations (in each direction) and Transfer_Street_Station (in each direction). If not, you can use the CTRL key and select each of them.



36. Right-click, choose Type, and click Field.

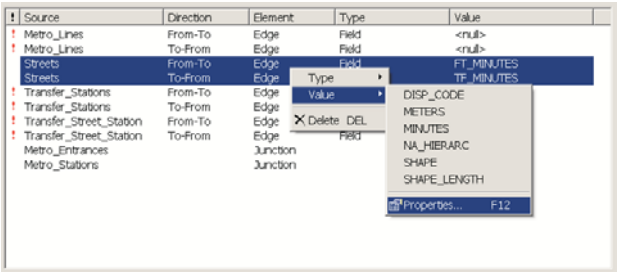


37. The same rows should still be selected. Right-click, choose Value, and click TRANSITTIM.



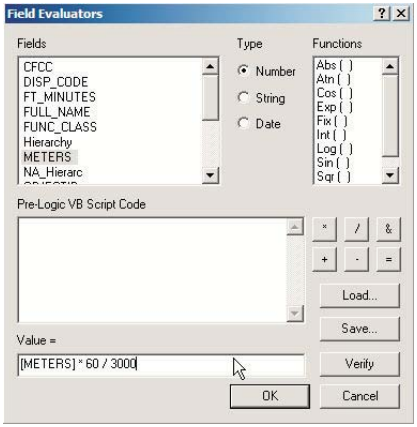
38. To set up the Pedestrian_Time for Streets, click the row for Streets in the From-To direction. Hold the CTRL key and click the row for Streets in the To-From direction, to select both rows for the Streets source.

39. Right-click on the selected sources, point to Value, and click Properties to bring up the Field Evaluators dialog box.

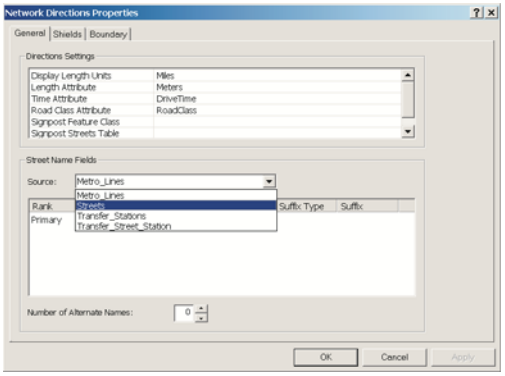


On the street network a pedestrian can walk. Hence for the Streets source, the value of Pedestrian_Time is the walk time for a pedestrian. Assuming that a pedestrian walks at 3 km/h, walk time in minutes will then be [Meters] * 60 / 3000 where [Meters] is the attribute containing length of the edge in meters.

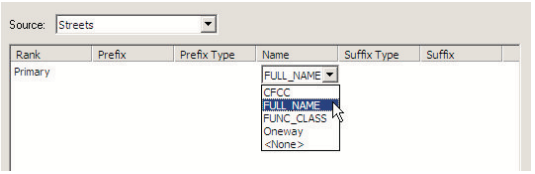
40. Double-click on the METERS field to move it into the "Value =" location and finish typing the expression as [METERS] * 60 / 3000 in the Field Evaluators Dialog as shown below. Click Verify to verify that the expression is correct and fix, if necessary.



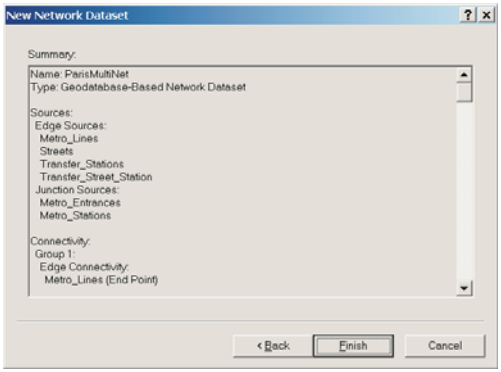
41. Click OK to close the dialog box and return to the Evaluators dialog box.
42. Click OK to save the attribute assignment.
43. Click Next.
44. Click Yes to set up directions. Click Directions to open the Directions Properties Page.
45. On the General tab, click the Source drop-down arrow and click Streets.



46. Click on Primary in the Street Name Fields list.
47. Click under the Name field and click FULL_NAME from the drop-down list.

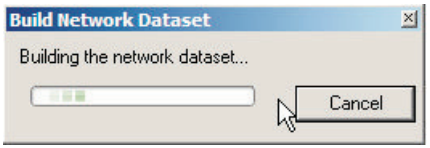


48. Click OK.
49. Click Next to see a summary of the settings defined.

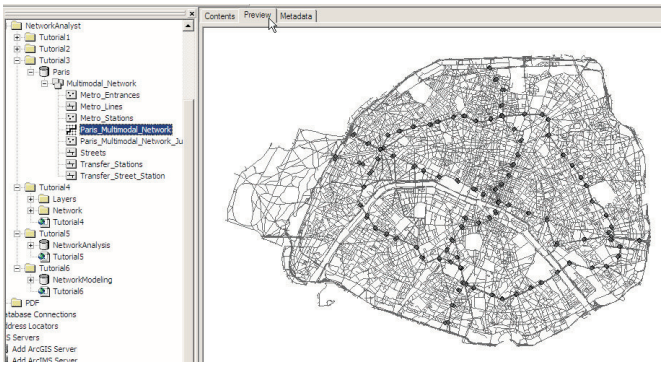


50. Click Finish to create the new network dataset.

51. Click Yes to build the network dataset.



Once the network dataset is built, you should see a new network dataset called ParisMultiNet along with the system junctions feature class ParisMultiNet_Junctions. Preview the network dataset by selecting it and clicking on Preview.



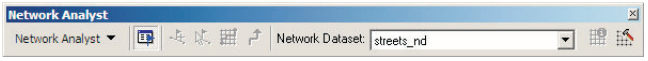
52. Close ArcCatalog.

Exercise 4: Finding the best route using a network dataset

In this Exercise you will find the best route for the given order of stops based on travel time.

Preparing your display

1. If you have Exercise4.mxd open in ArcMap, skip steps 2 to 5.
2. Start ArcMap by either double-clicking a shortcut installed on your desktop or using the programs list in your Start menu. Choose Ok to start ArcMap with a new empty map.
3. Click File on the Main menu and click Open.
4. In the Open dialog box, navigate to C:\arcgis\ArcTutor\Network_Analyst\Exercise4. (This is the default install location for this data.)
5. Double-click Exercise4.mxd.
6. If the Network Analyst Extension is not enabled, on the Tools menu, click Extensions, and in the Extensions dialog, click Network Analyst and then close the dialog.
7. If the Network Analyst toolbar is not already present, on the Main menu, click View, point to Toolbars, and click Network Analyst.

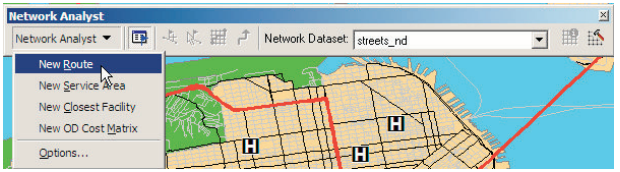


8. If the Network Analyst Window is not already open, click the Network Analyst Window button on the Network Analyst toolbar.

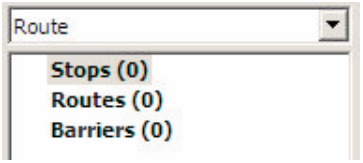
This is a dockable window which you can dock within the ArcMap window or leave undocked. In this Exercise the window is docked below the Table of Contents.

Creating the Route analysis layer

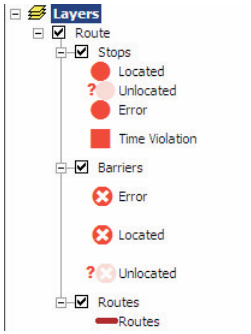
1. On the Network Analyst toolbar, click the Network Analyst drop-down menu, and click New Route.



The Network Analyst Window now contains empty lists of Stops, Routes, and Barriers categories.



Additionally, the table of contents contains a new Route Analysis Layer.



Adding a stop

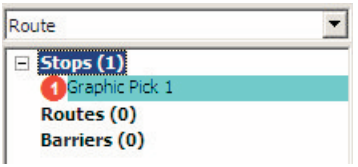
Next, you will add the stops between which you will be creating the best route.

1. Click Stops(0) on the Network Analyst Window.
2. On the Network Analyst Toolbar, click the Create Network Location tool .
3. Click anywhere on the street network in the map to define a new stop location.

   The program then calculates the nearest network location and symbolizes the stop with the located symbol. The stop will remain selected until another stop is placed or until it is unselected.

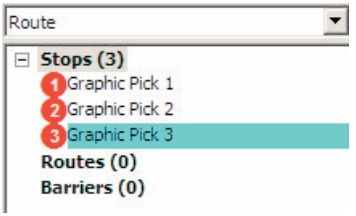
The located stop also displays the number 1. The number represents the order in which the stops will be visited by the calculated route.

You will also notice that the Stops category on the Network Analyst Window now lists 1 stop. Expand the Stops category to see the Graphic Pick 1 listed there.



4. Add two more stops on the map. The stops are numbered 2 and 3. The order of stops can be changed on the Network Analyst Window.

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



If a stop is not located on the network, it will appear with an unlocated symbol.

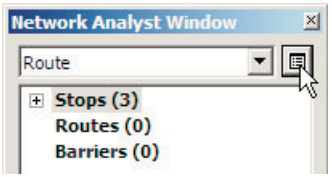
An unlocated stop can be located on the network by moving it closer to any edge that belongs to the network. On the Network Analyst Toolbar, click Select/Move Network Location tool .

Using the Select/Move Network Location tool , click and drag the unlocated stop closer to an edge on the network.

Setting up the parameters for the analysis

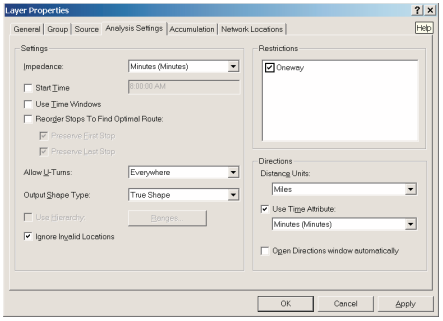
Next, you will specify that your route will be calculated based on time (minutes), that U-turns are allowed everywhere, and that one-way restrictions must be followed.

1. Click the Analysis Layer Properties button next to Route layer on the Network Analyst Window to bring up the Layer Properties dialog box for Route.



2. In the Layer Properties dialog box, click the Analysis Settings tab. Make sure the impedance selected is Minutes (Minutes).
3. Do not use time windows. (Leave the box unchecked.) Time windows are used when certain stops can only be visited at certain times.
4. Do not reorder stops. (Leave the box unchecked.) This preserves the order of stops as decided by you, when you created the stops.
5. Choose Everywhere from the Allow U-turns drop-down box.
6. Choose True Shape from the Output Shape Type drop-down box.
7. Check the box labeled Ignore Invalid Locations. This will let you find the best route using located stops. Stops that were not located on the network will be ignored.

8. Check Oneway in the Restrictions list.

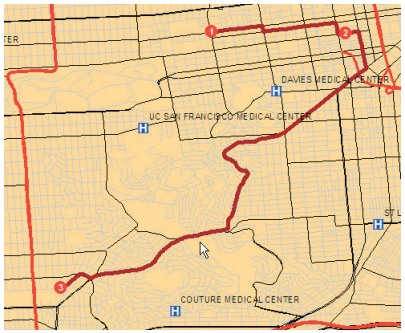


9. Find the Directions section.
10. Make sure the Distance Units are set to Miles, the Use Time Attribute box is checked and the time attribute is set to Minutes.
11. Click OK.

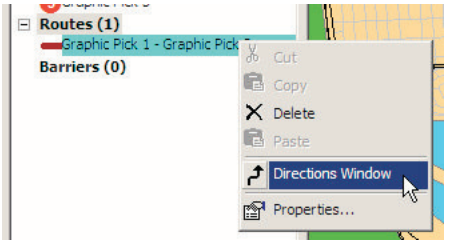
Run the process to compute the best route

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

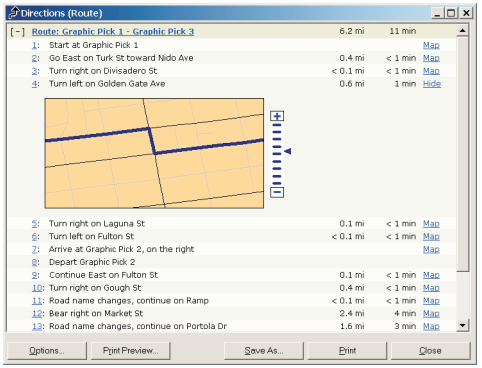
   The route polyline appears in the map and in the Route category of the Network Analyst Window.



2. Click the plus (+) sign next to Routes on the Network Analyst Window to show the Route.
3. Right-click the new route called 'Graphic Pick 1 - Graphic Pick 3' and click Directions Window to display driving directions.



4. The Directions Window can also be displayed with turn-by-turn maps that can be shown by clicking on the Map link.



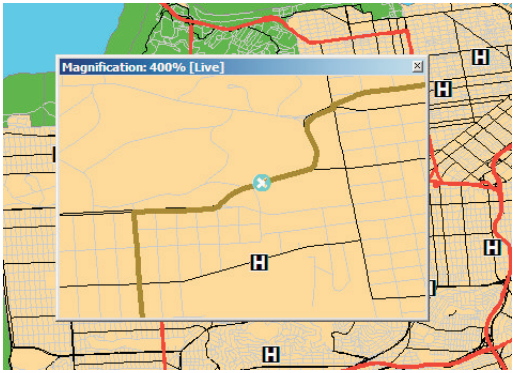
5. Close the Directions Window.

Adding a barrier

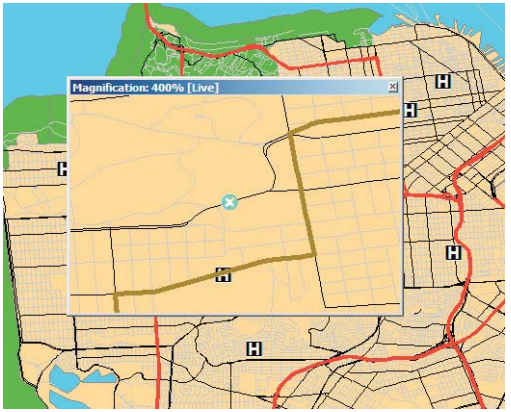
In this section, you will add a barrier on the route, that represents a road block and will find an alternate route to the destination, avoiding the road block.

1. In the Window menu, click Magnifier to bring up the Magnifier window.
2. Click on the title bar of the Magnifier window and drag to reposition the Magnifier window.
3. Move the Magnifier window over the route, to a point where you want to add a barrier. The Magnifier window shows a part of the map where you can add a barrier at a zoom of 400 percent.

4. On the Network Analyst Window, click Barriers (0).
5. On the Network Analyst Toolbar, click the Create Network Location tool .
6. In the Magnifier window, click anywhere on the route, to place a barrier.



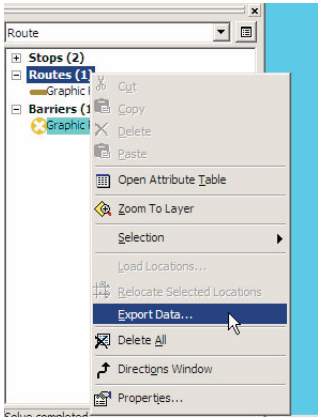
7. Click the Solve button on the Network Analyst toolbar. A new alternative route is computed, avoiding the barrier.



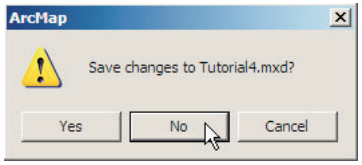
8. Close the Magnifier Window.

Saving the best route

1. Right-click Routes (1) on the Network Analyst Window and click Export Data.



2. Type in a location and shapefile name to save the results, such as C:\Data\Exercise4_Route.shp, in the Output shapefile or feature class field.
3. Click OK. The best route generated is saved to the specified shapefile.
4. Click NO when prompted to add the exported data to the map as a layer.
5. If you do not plan to work on any other Exercise, close ArcMap. Click No to discard all changes.



6. If you do plan to work on other Exercise, then do a File New in ArcMap and Click No to discard all changes to the current map document.

Exercise 5: Finding the closest fire stations

In this Exercise you will find the closest four fire stations that can respond to a fire at a given address. You will also generate the fastest route from each of these fire stations provided to each driver of the fire engine.

Preparing your display

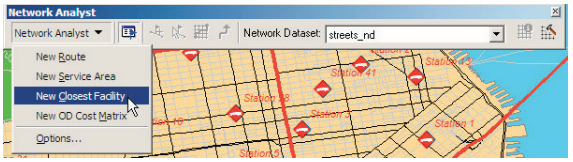
1. If you have Exercise5.mxd open in ArcMap, skip steps 2 to 5.
2. Start ArcMap by either double-clicking a shortcut installed on your desktop or using the programs list in your Start menu. Choose Ok to start ArcMap with a new empty map.
3. Click File on the Main menu and click Open.
4. In the Open dialog box, navigate to C:\arcgis\ArcTutor\Network_Analyst\Exercise5\Exercise5.mxd. (This is the default install location for this data.)
5. Double-click Exercise5.mxd.
6. If the Network Analyst Extension is not enabled, on the Tools menu, click Extensions, and in the Extensions dialog box, click Network Analyst and close the Extensions dialog box.
7. If the Network Analyst toolbar is not already present, on the Main menu, click View, point to Toolbars, and click Network Analyst.

8. If the Network Analyst Window is not already open, click the Network Analyst Window button on the Network Analyst toolbar.

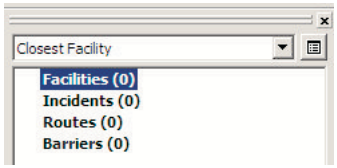
   This is a dockable window which you can dock within the ArcMap window or leave undocked. In this Exercise, the window is docked below the Table of Contents.

Creating the Closest Facility analysis layer

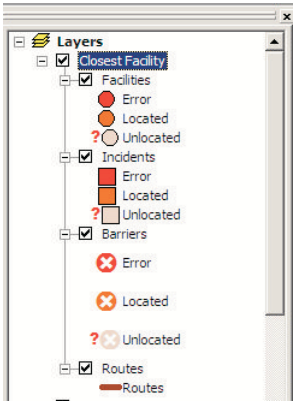
1. On the Network Analyst toolbar, click the Network Analyst drop-down menu and click New Closest Facility.



The Network Analyst Window now contains an empty list of Facilities, Incidents, Routes, and Barriers categories.



Additionally, the Table of Contents contains a new Closest Facility analysis (group) layer.

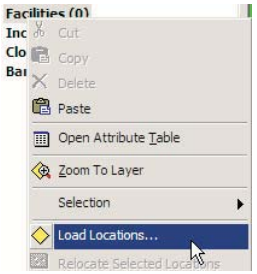


Adding facilities

Next you will add facilities from a point shapefile for which a layer file has been created.

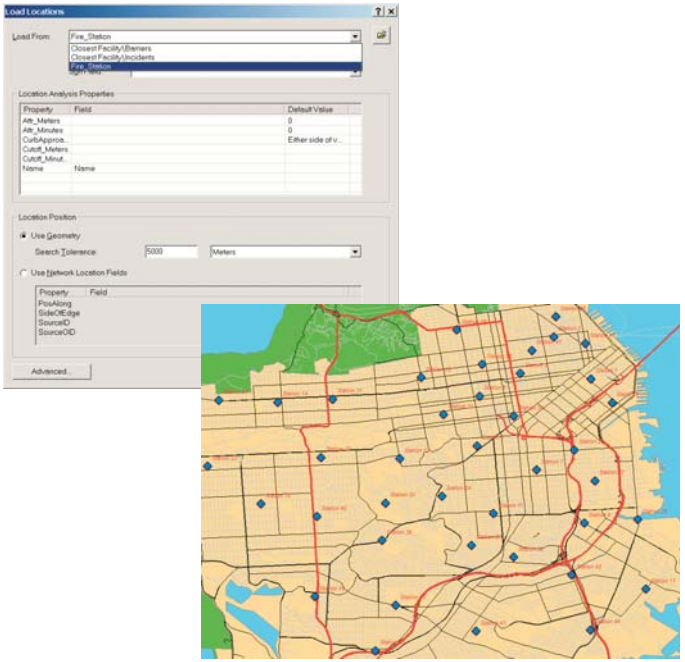
1. Right-click Facilities (0) in the Network Analyst window and click Load Locations.

2. Select Fire_Station from the Load From drop-down list. Keep the default settings.



3. Click OK.

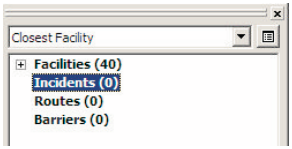
   Forty fire stations are listed in the Network Analysis window and are displayed as facilities on the map.



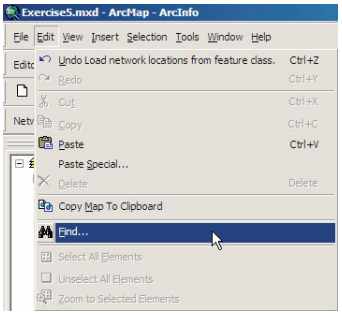
Adding an incident

Next, you will find a street address (1202 Twin Peaks Blvd) and add it as an incident for Closest Facility Analysis.

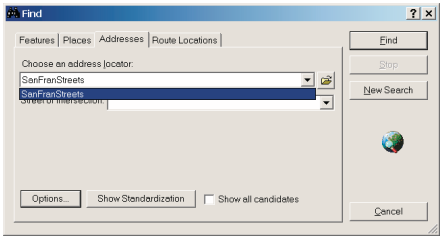
1. Click Incidents(0) on the Network Analyst Window to select it as the feature layer to which you will add the street address as a network location.



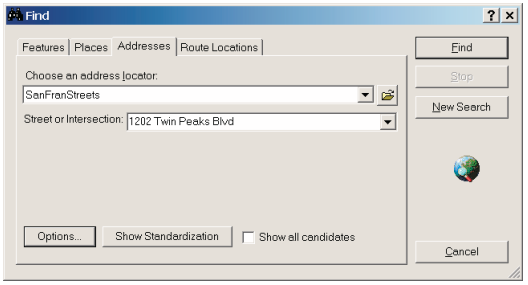
2. Select Find from the Edit menu to bring up the Find dialog box.



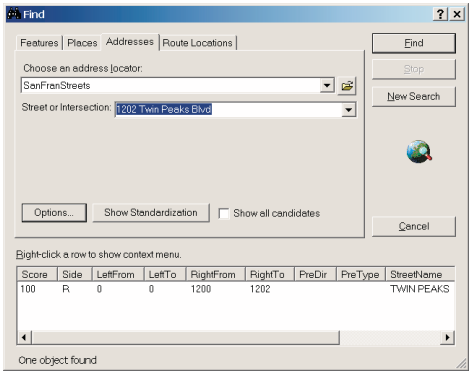
3. In the Addresses tab, Select "SanFranStreets" from the Choose an address locator drop-down list.



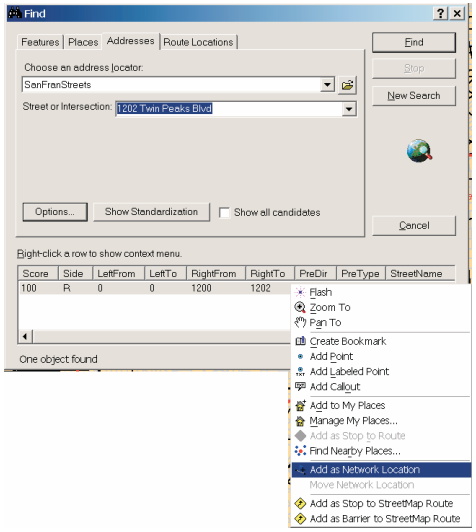
4. Type "1202 Twin Peaks Blvd" in the text box labeled Street or Intersection.

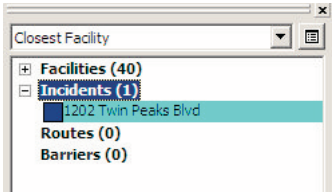


5. Click Find. One location is found with that street address and is listed as a row in the table in the Find dialog box.



6. Right-click the row and click Add as Network Location. This adds the located address as an incident on the Network Analyst Window and on the map.



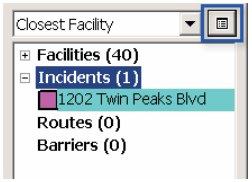


7. Close the Find dialog box.

Setting up the parameters for the analysis

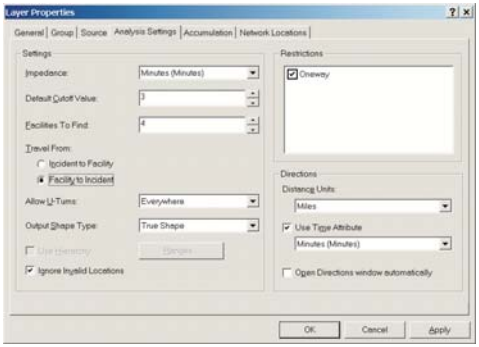
Next, you will specify the parameters for your Closest Facility analysis.

1. Click the Closest Facility Properties Button next to Closest Facility on the Network Analyst Window to bring up the Layer Properties dialog box.



2. In the Layer Properties dialog box, click the Analysis Settings tab.
3. Click the Impedance drop-down arrow and click Minutes (Minutes).
4. Set the Default Cutoff value to 3. ArcGIS will search for fire stations that are within three minutes of the fire. Any fire station outside of three minutes drive time will be ignored.
5. Increase the Facilities to Find from 1 to 4. ArcGIS will attempt to search for four fire stations from the fire site, within the three minute cutoff. If there are only three fire stations within the three minute cutoff, then the fourth fire station will not be found.
6. Under Travel From, select Facility (fire station) to Incident (fire).
7. Select Everywhere from the Allow U-Turns drop-down box.

8. Select True Shape from the Output Shape Type drop-down box.
9. Check the box labeled Ignore Invalid Locations. This will let you find the best route using located stops. Stops that were not located on the network will be ignored.
10. Check Oneway in the Restrictions list.
11. Click OK to save the settings.



Run the process to identify the closest facility

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

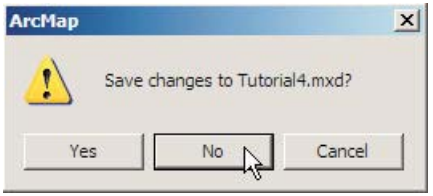
   The routes appear in the Map and in the Route Category on the Network Analyst Window.

Note that only two fire stations were found to be closest to the fire within the three-minute cutoff. You can optionally increase the cutoff value to 4 minutes and see how many fire stations are found.

2. Click the Directions Window button in the Network Analyst Toolbar to generate directions for routes from each fire station.

If you do not plan to work on any other exercise, close ArcMap.

3. Click No to discard all changes.



Exercise 6: Calculating service area and creating a OD Cost Matrix

In this exercise you will create a series of polygons representing 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 area polygons for six warehouses in Paris. You will also find out how many stores lie within each of these service areas. You have to 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 the stores within a 10-minute drive time. Such a matrix is used as an input for logistics, delivery, and routing analyses.

Preparing your display

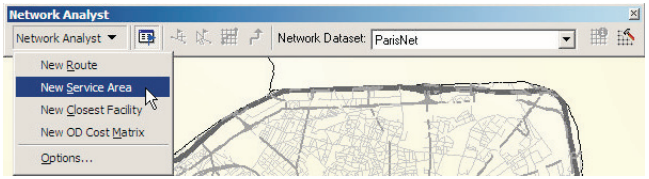
1. If Exercise6.mxd is open in ArcMap, skip steps 2 to 5.
2. Start ArcMap by double-clicking a shortcut installed on your desktop or using the programs list in your Start menu. Click Ok to start ArcMap with a new empty map.
3. Click File on the Main menu and click Open.
4. In the Open dialog box, navigate to C:\arcgis\ArcTutor\Network_Analyst\Exercise6\Exercise6.mxd. (This is the default install location for this data.)
5. Double-click Exercise6.mxd.
6. If the Network Analyst Extension is not enabled, on the Tools menu, click Extensions, and in the Extensions dialog box, click Network Analyst and close the Extensions dialog box.
7. If the Network Analyst toolbar is not already present, on the Main menu, click View, point to Toolbars, and click Network Analyst.

8. If the Network Analyst Window is not already open, click the Show/Hide Network Analyst Window button on the Network Analyst toolbar.

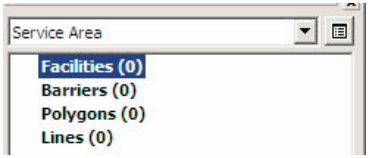
   This is a dockable window which you can dock within the ArcMap window or leave undocked. In this Exercise the window is docked below the Table of Contents.

Creating the Service Area analysis layer

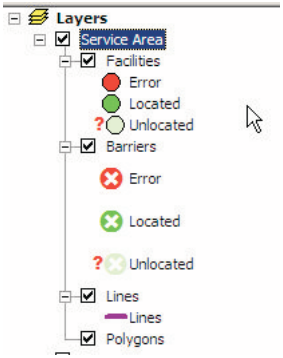
1. On the Network Analyst toolbar, click the Network Analyst drop-down menu and click New Service Area.



The Network Analyst Window now contains an empty list of Facilities, Barriers, Lines, and Polygons categories.



Additionally, the table of contents contains a new Service Area analysis layer.

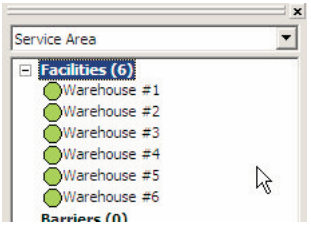


Adding facilities

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

1. Right-click Facilities (0) on the Network Analyst Window and select Load Locations. Select Warehouses in the Load From drop-down list and click OK.

Click the plus (+) sign next to Facilities (6) in the Network Analyst Window to show the list of six facilities. The facilities are also visible on the map.

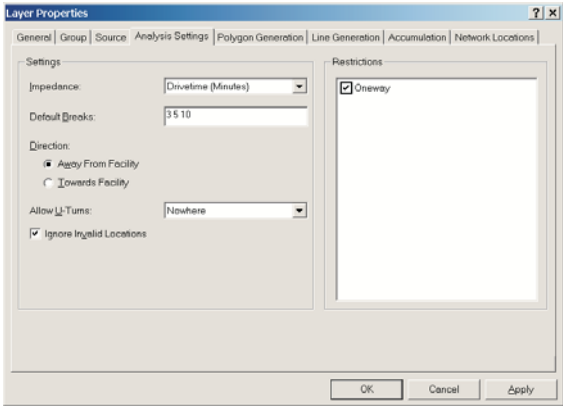


Setting up the parameters for the analysis

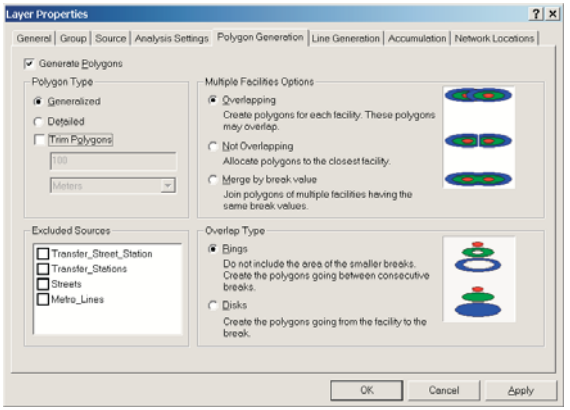
Next, you will specify that your service area will be calculated based on Drivetime (minutes). Three service area polygons will be calculated for each facility, one at 3 minutes, one at 5 minutes, and another at 10 minutes. You will specify that the direction of travel will be from the

facility–not towards the facility–that no U-turns are allowed, and that one-way restrictions must be followed.

1. In the Network Analyst Window, click the Service Area Properties Button to bring up the Layer Properties dialog box.
2. Click the Analysis Settings tab.
3. Click the Impedance drop-down list and select Drivetime (Minutes).
4. Type "3 5 10" in the Default breaks text box. (Enter this as 3 5 10; the three numbers are separated by a space, without the quotes.)
5. Under Direction, click Away from facility.
6. Click Nowhere from the Allow U-turns drop-down list.
7. Check Oneway in the Restrictions list to honor one-way restrictions.
8. Check the Ignore Invalid Locations checkbox.

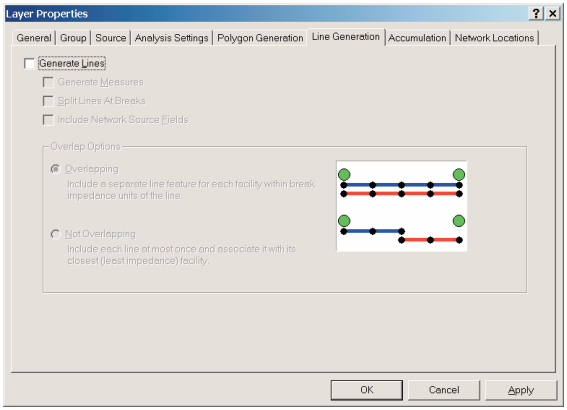


9. Click the Polygon Generation tab.
10. Make sure that Generate Polygons is checked.
11. Click Generalized for Polygon Type. This results in faster analysis. Detailed polygons are much more accurate, but need more time to be generated.
12. Uncheck the Trim Polygon option. This is post-process that trims the outside polygon to remove spikes but takes a little longer to run.
13. Click Overlapping Multiple Facilities Options. This results in individual polygons per facility that may or may not overlap.
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 the box labeled Generate Lines unchecked.



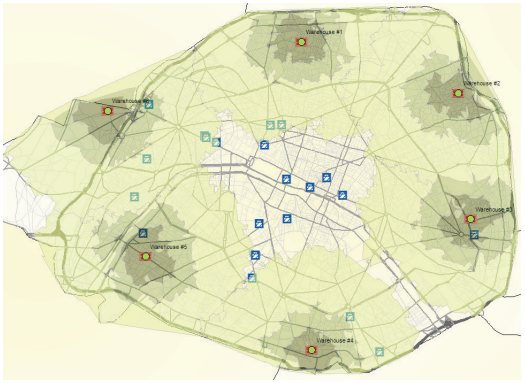
18. Click OK to save your settings.

Run the process to compute the Service Area

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

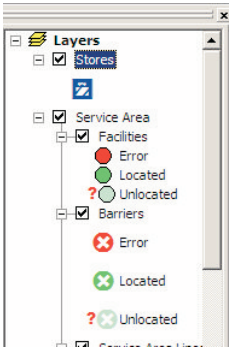
   The service area polygons appear on the map and on the Network Analyst Window.

   There is a transparency set by default for the Polygons layer. This shows the underlying layers and gives an idea of the area under the polygons with respect to the street network.

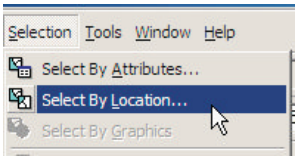


Identifying stores that do not lie within any polygon

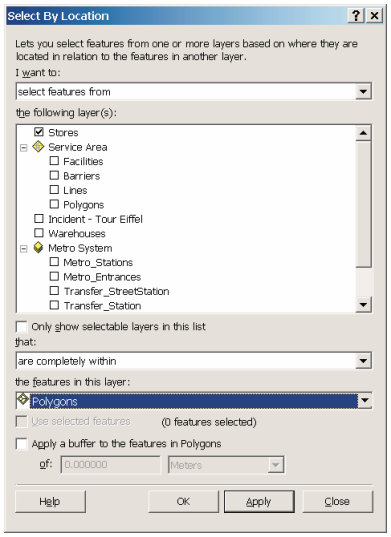
1. In the table of contents select and move the Stores feature layer to the top to improve visibility.



2. Choose Select by Location from the Selection menu.

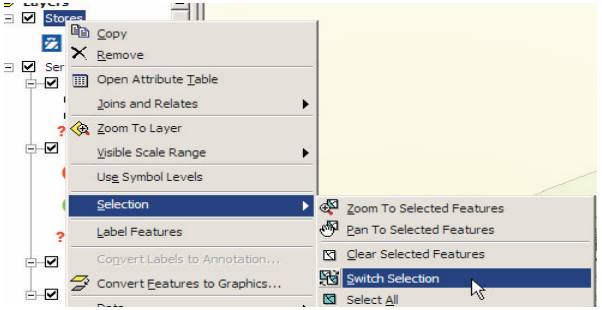


3. Create the selection query in the Select by Location to select features from Stores that are completely within Polygons, as shown below.



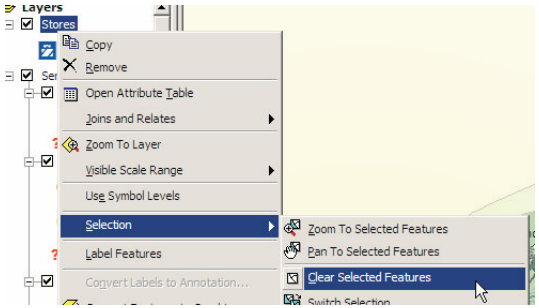
4. Click Apply. This will select all stores that lie within service area polygons.
5. Click Close.

   You want to select stores that are not within the service area polygons, which is the inverse of the current selection. To get the selection of stores that are not within the service area polygons, you can switch the selection.
6. Right-click Stores in the Table of Contents, point to Selection and choose Switch Selection.



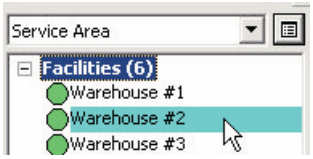
7. The selection now shows the distribution of stores not contained in any service area polygon. You use this selection to identify the area to which you will relocate a warehouse. This area appears to be in the center of the map.

8. Right-click Stores in the Table of Contents, point to Selection and click Clear Selected Features.

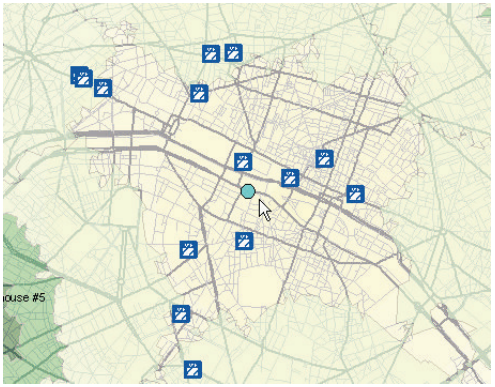


Relocating the least accessible warehouse

1. Look at the service area polygons of Warehouse #2. There are no stores that lie within the 3-, 5- or 10-minute service areas of Warehouse #2. Hence, you will relocate Warehouse #2 to better service the stores.
2. On the Network Analyst Window, select Warehouse #2 under Facilities (6).



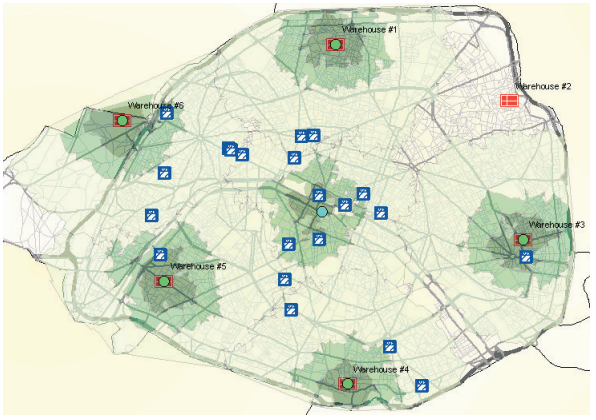
3. Use the Select/Move Network Location Tool to move Warehouse #2 to the center of the map, as shown in the figure below.



Run the process to compute the Service Area

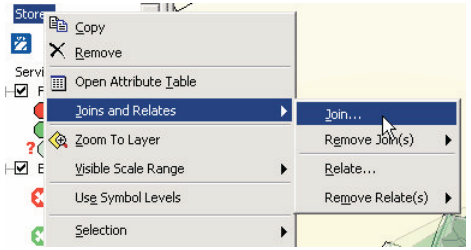
1. Click the Solve button on the Network Analyst toolbar.

   The service area polygons appear on the map and on the Network Analyst Window.

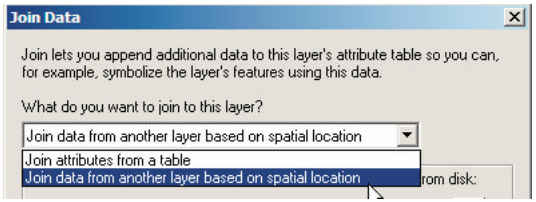


Identifying the service area polygon that each store lies within

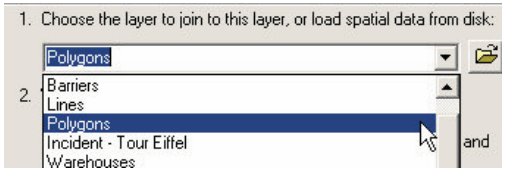
1. In the table of contents, right-click Stores feature layer, point to Joins and Relates and select Join.



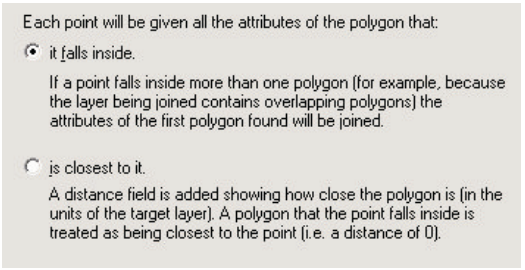
2. Choose Join data from another layer based on spatial location.



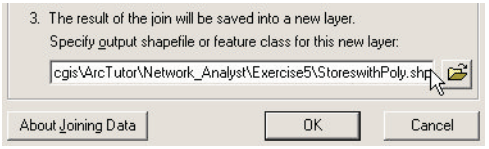
3. Select Polygons as the layer to join to this layer.



4. Select the first radio button labeled "it falls inside" to add the attributes of polygon to all points that fall inside the polygon.

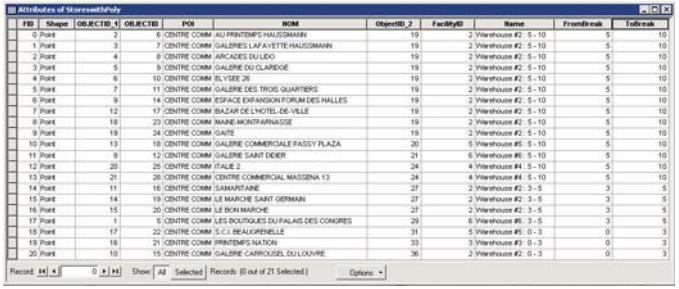


5. Specify the output shapefile to save the result of the join as StoreswithPoly.shp.



6. Click OK to perform the join.

7. Right-click the newly added StoreswithPoly feature layer and select Open Attribute Table. Each row 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 0–3 minute service area of warehouses.



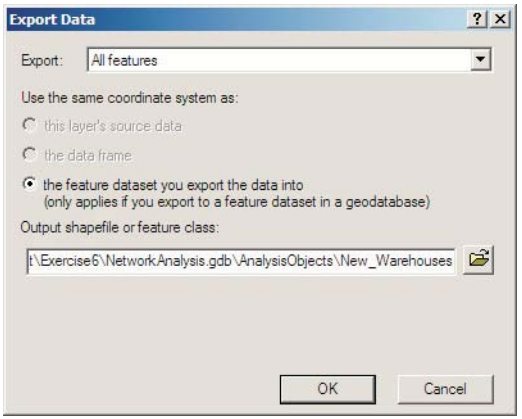
8. Close the attribute table.

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

9. Right-click Facilities (6) on the Network Analyst Window and click Export Data.

10. In the Export drop-down list, click All features.

11. Type "C:\arcgis\ArcTutor\Network_Analyst\Exercise6\NetworkAnalysis.gdb\AnalysisObjects\New_Warehouses" as the output feature class. You can choose another location and name for the output if you do not want to write to the input database.



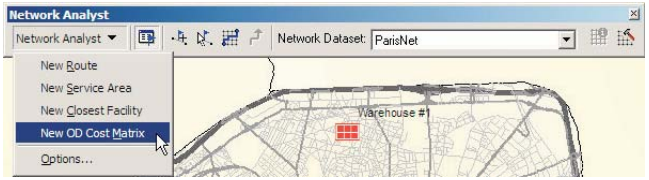
12. Click OK.

13. Choose No when prompted to add the feature class to the map. You will not be using this feature class for the remaining exercise.

    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 the stores that will be serviced by each warehouse within a 10-minute drive time. Also, you would like to find the total drive time from each warehouse to its stores.

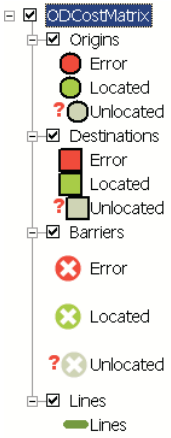
Creating the OD Cost Matrix analysis layer

1. In the table of contents, uncheck Service Area analysis layer and StoreswithPoly to improve readability of the map.
2. On the Network Analyst toolbar, click the Network Analyst drop-down menu and click New OD Cost Matrix.



The Network Analyst Window now contains an empty list of Origins, Destinations, Lines, and Barriers categories.

Additionally, the table of contents contains a new OD Cost Matrix analysis layer.

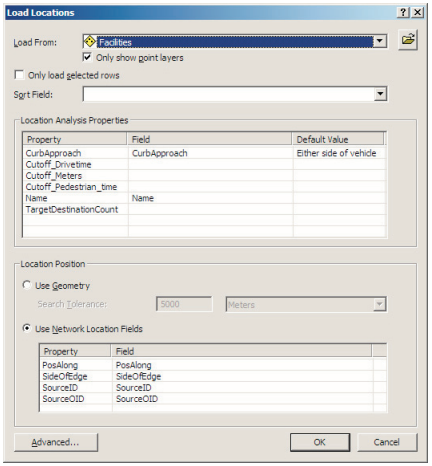


Adding origins

You can use the facilities from Service Area Analysis (in the previous section) as origins. If you have not completed the section on Service Area Analysis, you can alternately use the Warehouses feature layer.

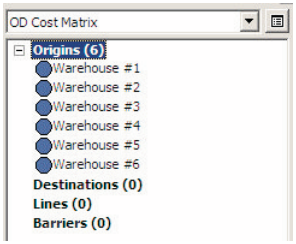
1. Right-click Origins (0) on the Network Analyst Window and click Load Locations.
2. Select ServiceArea\Facilities in the Load From drop-down list. (If you did not complete the previous section on service area analysis, you can use Warehouses instead. Note that your results will not resemble the results in this exercise.)
3. Uncheck the Only load selected rows checkbox.

4. Click Use Network Location Fields radio button under Location Position. Using network location fields will allow ArcGIS to use the located position of Service Area facilities to locate the origins again. This is much faster than using search tolerance to locate them again. (If you are loading Warehouses, you will need to click the use Geometry radio button and set the Search Tolerance to 50 meters.)



5. Click OK.

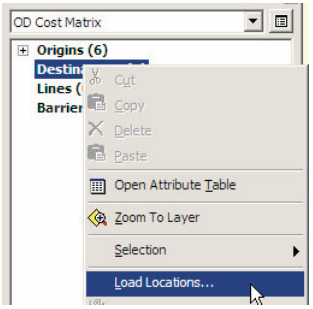
   The Network Analyst Window now shows six origins under the Origins list and on the map.



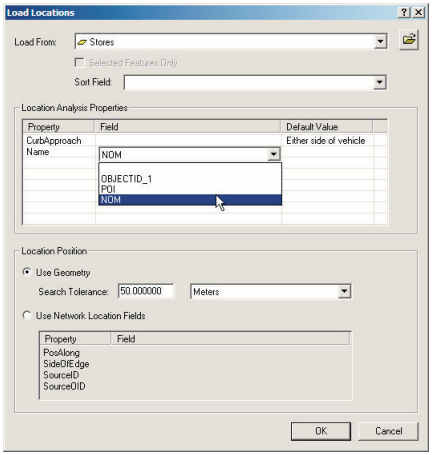
Adding destinations

Next you will add the stores as destinations.

1. Right-click Destinations (0) on the Network Analyst Window and click Load Locations.

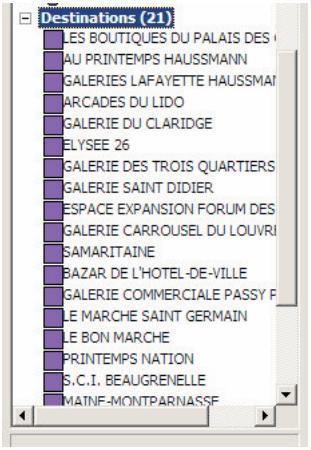


2. Choose Stores in the Load From drop-down list.
3. Under Location Analysis Properties, for the property Name, select the field "NOM" from the drop-down list. Since the field name is in French, ArcGIS Network Analyst was unable to map the field name automatically.

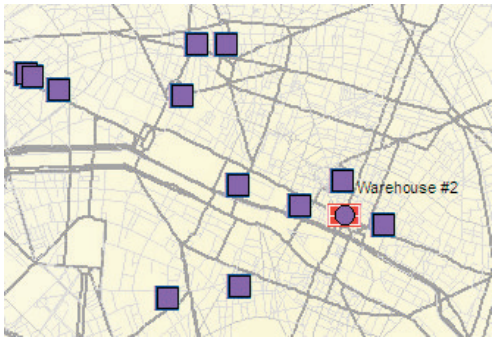


4. Click OK.

   The Network Analyst Window now lists 21 destinations under the Destinations list.



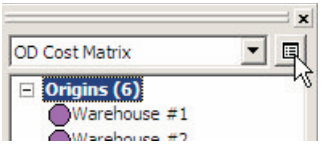
   These destinations are also displayed on the map.



Setting up the parameters for the analysis

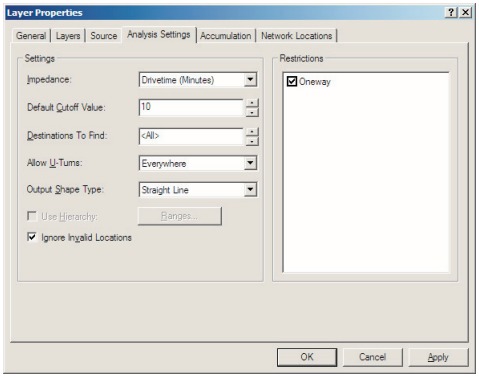
Next, you will specify that your OD Cost Matrix will be calculated based on time (Drivetime).You will set a default cutoff value of 10 minutes and will ensure that all destinations are found within the specified cut off. Additionally, you will specify that U-turns are allowed everywhere and the output 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.

1. Click the ODCostMatrix Properties Button next to ODCostMatrix on the Network Analyst Window.



2. Click the Analysis Settings tab.
3. Click the Impedance drop-down list and click Drivetime (Minutes).
4. Type “10” in the Default Cutoff Value drop-down list. This will create origin–destination paths from each warehouse to all stores that can be reached within 10 minutes.
5. Select <All> from the Destinations to Find drop-down list.
6. Select Everywhere from the Allow U-turns drop-down list.
7. Select Straight Line from the Output Shape Type drop-down list.

8. Check Oneway in the Restrictions list.
9. Check Ignore Invalid Locations.
10. Click OK to save the parameters.

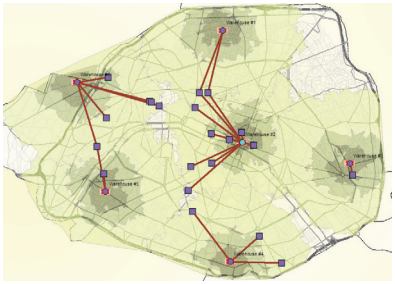


Run the process to create the OD Cost Matrix

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

   The OD lines appear on the map. The number of lines in this tutorial are 24. These may be different for you, depending on where you relocated Warehouse #2.

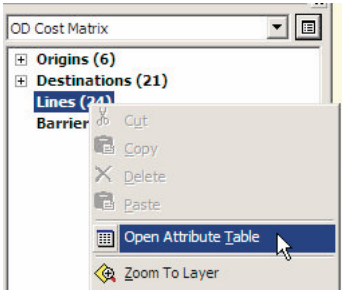
2. Turn on the Service Area Layer, and display the Lines on top of the service areas of the warehouses.



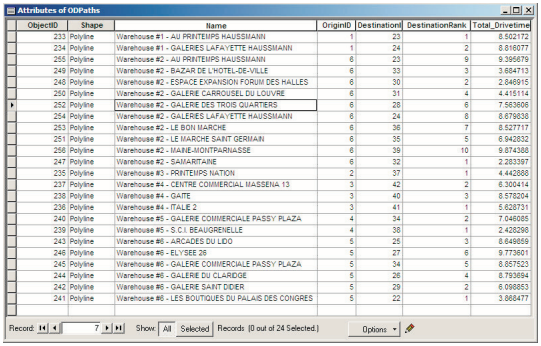
Allocating stores to warehouses

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

1. Right-click on Lines (24) on the Network Analyst Window and click on Open Attribute Table to open the OD cost matrix.



2. The Attributes of Lines represents the origin destination cost matrix from each warehouse to stores within a 10 minute drive time in Paris. 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 23 has a rank of 1 and DestinationID 24 has a rank of 2. This is because it takes less time to go from Warehouse #1 to DestinationID 23. (This may be different for you, as your analysis results are dependent on the source feature class of the origins and destinations.)



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.

3. Exit ArcMap and do not save any changes to the Exercise6.mxd.

Exercise 7: Creating a model for route analysis

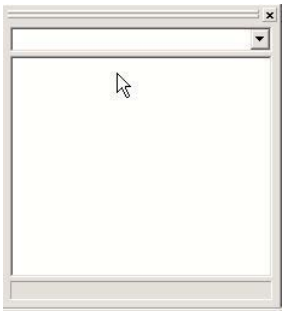
In this Exercise you will create a model for finding the fastest delivery route connecting 21 stores in Paris.

Preparing your display

1. If you have Exercise7.mxd open in ArcMap, skip steps 2 to 7.
2. Start ArcMap by either double-clicking a shortcut installed on your desktop or using the programs list in your Start menu.

   If the Network Analyst Extension is not enabled, on the Tools menu, click Extensions, and in the Extensions dialog box, click Network Analyst and close the Extensions dialog box.
3. Click File on the Main menu and click Open.
4. In the Open dialog box, navigate to C:\arcgis\ArcTutor\Network_Analyst\Exercise7. (This is the default install location for this data.)
5. Double-click Exercise7.mxd.
6. If the Network Analyst toolbar is not already present, on the Main menu, click View, point to Toolbars, and click Network Analyst.

7. If the Network Analyst Window is not already open, click the Network Analyst Window button on the Network Analyst toolbar.

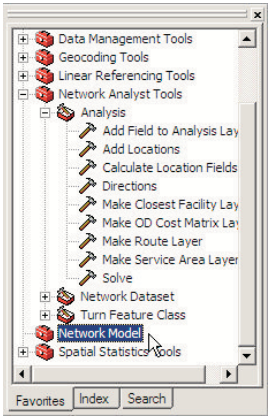


This is a dockable window which you can dock within the ArcMap window or leave undocked. In this exercise, the window is docked below the table of contents.

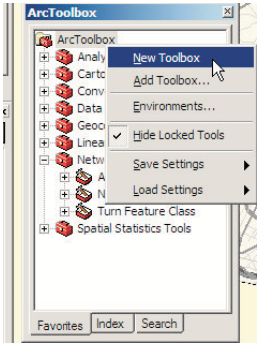
8. In the table of contents, check the check box by the Stores layer to show it on the map.
9. In the table of contents, uncheck the check box by the Metro System group layer to hide it on the map.

Creating the Model

1. On the Standard toolbar, click the Show/Hide ArcToolbox Window Button to show the ArcToolbox window.

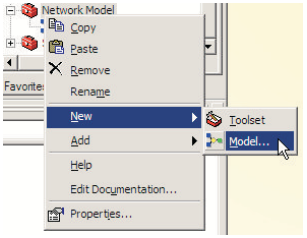


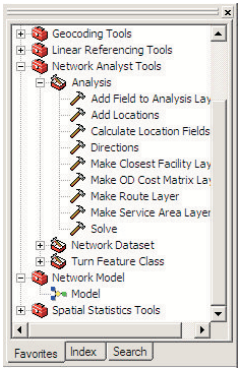
2. Right-click ArcToolbox in the ArcToolbox window and select New Toolbox.

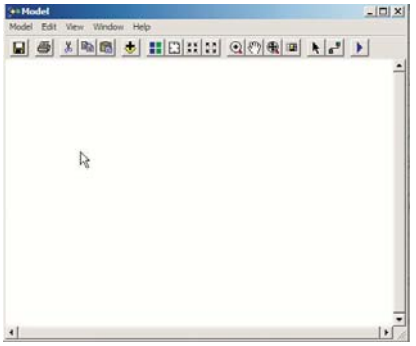


3. Type “NetworkModel” to name the newly added toolbox.

4. Right-click on NetworkModel toolbox, select New and then Model. A new model appears in the NetworkModel toolbox and in the map window.



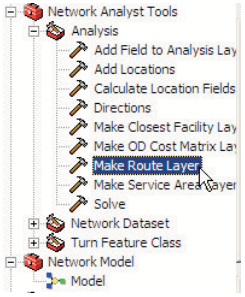


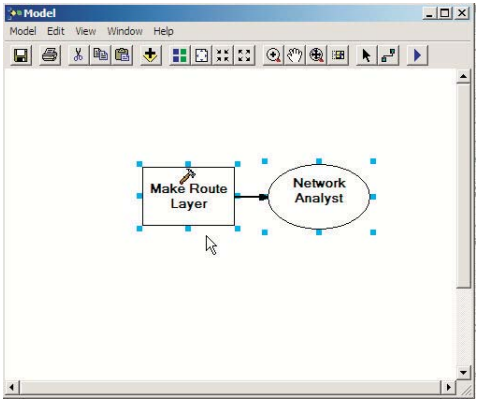


Creating the Route Layer in the model

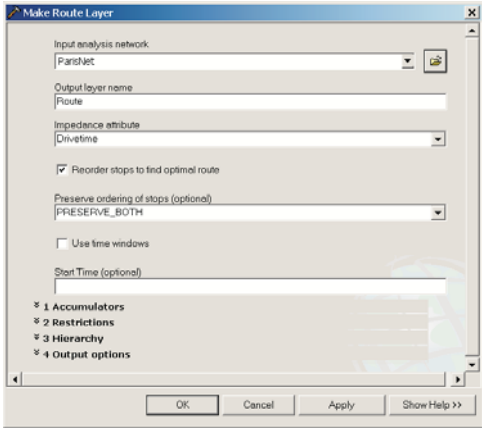
Next you will create the route layer within the model. The workflow for using Network Analyst in a model is the same as the workflow for using Network Analyst in ArcMap. First, you create a route layer and set properties. Next, you add the network locations (stops) to be used as inputs. Last, you solve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

1. Select the Make Route Layer tool in the Analysis Toolset of the Network Analyst Tools toolbox and drag it into the model.





2. Double-click the Make Route Layer Tool in the model, to set its properties.
3. Click the ParisNet as the Input Analysis Network in the drop-down list.
4. In the Impedance attribute drop-down list, click Drivetime.
5. Check the Reorder stops to find optimal route checkbox.
6. In the Preserve ordering of stops drop-down list, click PRESERVE_BOTH.

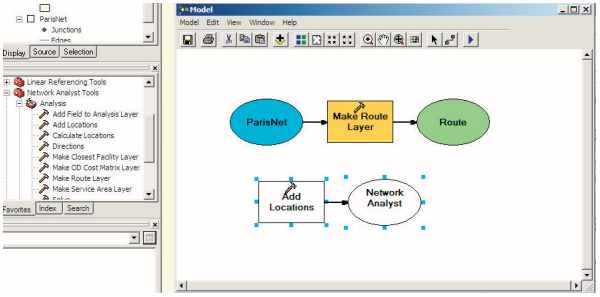


7. Click OK to continue. The Input analysis network is now added to the model. The Make Route Layer tool becomes yellow in color and the output layer becomes green. Click the Full Extent button to view the entire model.

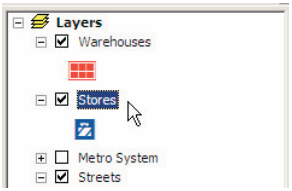
Adding stops in the model

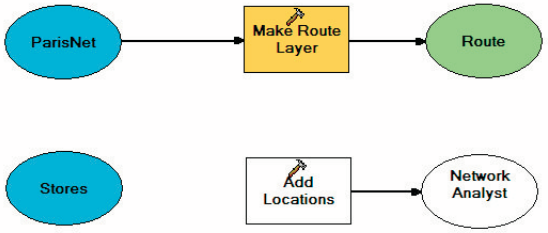
Next you will add the stores as stops by using the Add Locations tool.

1. Select the Add Locations tool in the Analysis toolset of the Network Analysis toolbox and drag it into the model.

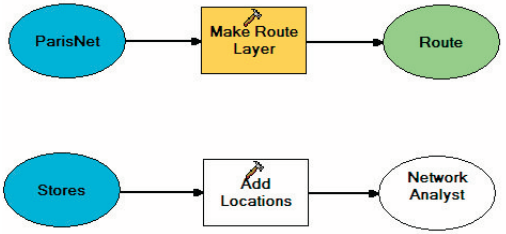


2. Select the Stores feature layer in the table of contents and drag it into the model to the left of the Add Locations tool.



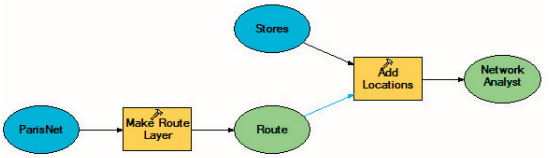


3. Select the Add Connection Tool and connect Stores to the Add Locations tool.



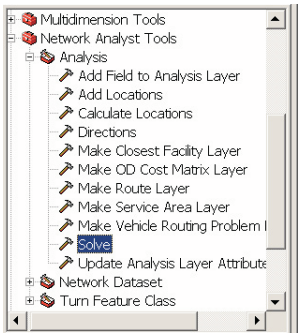
4. Using the Add Connection tool, connect the output layer called Route to the Add Locations tool. The Add Locations tool becomes yellow in color.

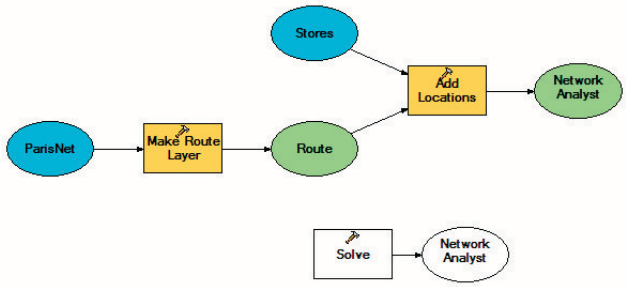
   Click the AutoLayout button to arrange the model. Click the Full Extent button to view the entire model.



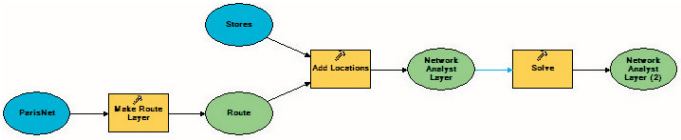
Adding the solve function and finding the best route

1. Select the Solve tool in the Analysis toolset in the Network Analyst toolbox and drag it into the model.

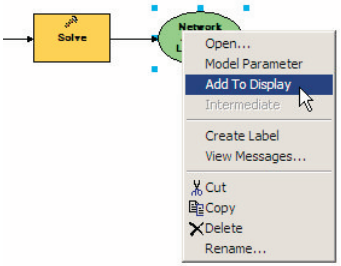




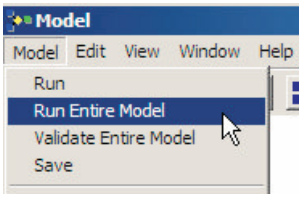
2. Using the Add Connection tool, connect the output layer called Network Analyst Layer to the Solve tool. The Solve tool becomes yellow in color and the output layer becomes green. Click the AutoLayout button to arrange the model. Also click the Full Extent button to view the entire model.



3. Using the Select tool right-click on the output layer of the Solve tool (Network Analyst Layer) and click Add To Display. This will add the final output to the map.

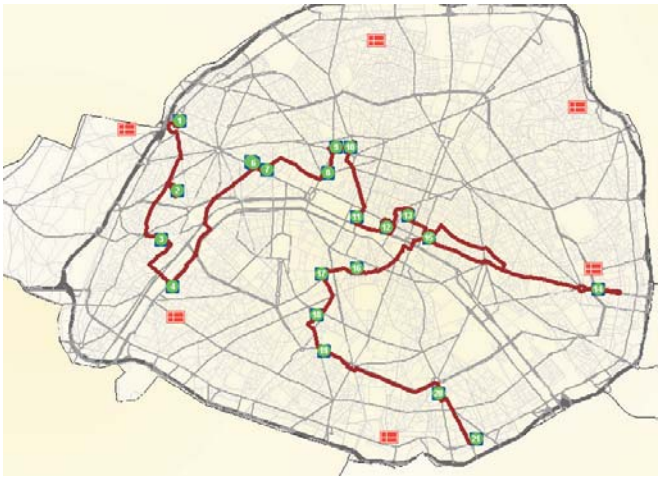


4. Click on the Save button to save the model.
5. From the Model menu, choose Run Entire Model to perform the analysis.

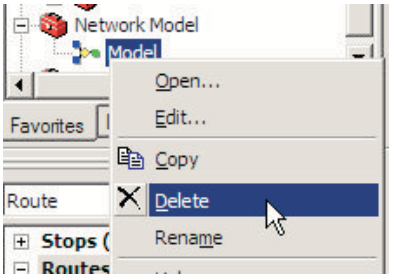


6. Close the model to inspect the results. Click Yes, when prompted to save the model.

A new Route layer is added to the map, the Network Analysis window has all the stops and the resultant route. The route is also displayed on the map.



7. In the ArcToolbox window, expand the NetworkModel toolbox, right-click Model, and click Edit.
8. To access the shortest path feature class for further analysis, link the output of the model to a Select Data tool found in the Data Management\General toolbox. Double-click the Select Data tool to set its properties. Once the form comes up, change the Child Data Element to Routes.
9. Link the output of the Select Data tool to a CopyFeatures tool from Data Management\Features toolbox. Double-Click on the Copy Features tool and type C:\arcgis\ArcTutor\Network_Analyst\Exercise7\path.shp and close the form. Now running the entire model will solve the path, select the route sublayer and export it out as a shapefile.
10. Right-click the Model in the NetworkModel toolbox and select Delete. Click Yes to verify the deletion.



11. Exit ArcMap and do not save any changes to the Exercise7.mxd.

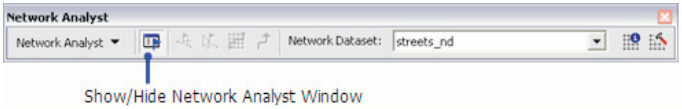
Exercise 8: Servicing a set of orders with a fleet of vehicles

In this exercise you will find the best routes for a fleet of vehicles, which is operated by a distribution company, to deliver goods from a main 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.

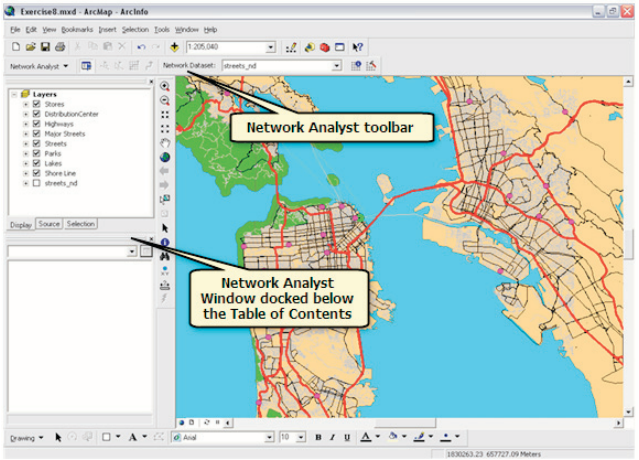
This can be achieved by solving a vehicle routing problem (VRP). Once the delivery sequence is determined, you will generate the turn by turn directions for the resulting routes which can be printed and given to the drivers to make the deliveries.

Preparing your display

1. If you have Exercise8.mxd open in ArcMap, skip steps 2 to 5.
2. Start ArcMap by double-clicking a shortcut installed on your desktop or using the programs list in your Start menu. Choose OK to start ArcMap with a new, empty map.
3. Click File on the Main menu and click Open.
4. In the Open dialog box, navigate to C:\arcgis\ArcTutor\Network_Analyst\Exercise8\Exercise8.mxd. (This is the default install location for this data.)
5. Double-click Exercise8.mxd.
6. If the Network Analyst extension is not enabled, on the Tools menu, click Extensions, and in the Extensions dialog box, click Network Analyst and close the Extensions dialog.
7. If the Network Analyst toolbar is not already present, on the Main menu, click View, point to Toolbars, and click Network Analyst.

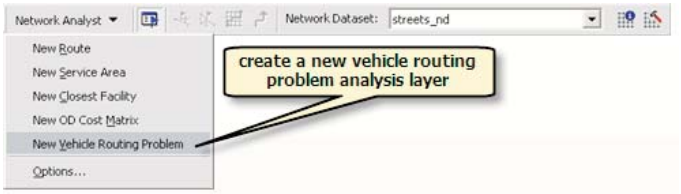


8. If the Network Analyst Window is not already open, click the Network Analyst Window button on the Network Analyst toolbar. The Network Analyst Window is a window that you can dock within ArcMap or leave undocked. In this exercise, the window is shown docked below the Table of Contents but you can place it wherever you like.



Creating the Vehicle Routing Problem analysis layer

1. On the Network Analyst toolbar, click the Network Analyst drop-down menu and click New Vehicle Routing Problem.



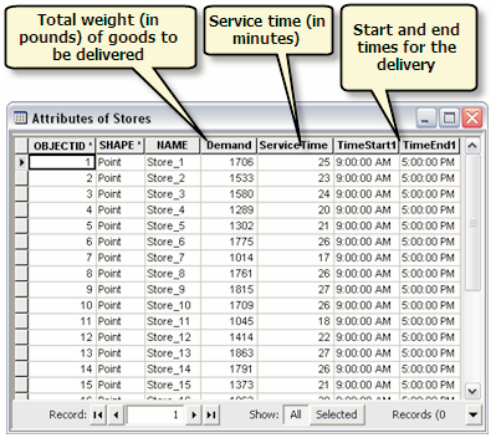
The Network Analyst Window now contains an empty list of Orders, Depots, Routes, Depot Visits, Breaks, Route Zones, Route Seed Points, Route Renewals, Specialties, Order Pairs, and Barriers network analysis classes.

The Table of Contents contains a new Vehicle Routing Problem analysis (group) layer.

Adding Orders

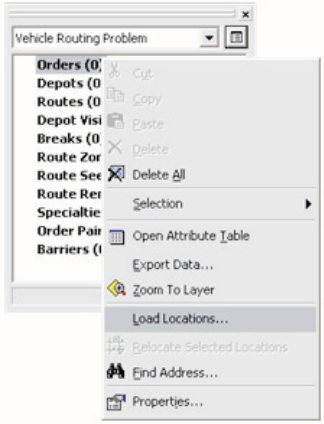
You will add the grocery store locations to the network analysis class called Orders. These are like "orders to be filled" since each grocery store has requested goods to be delivered to it from the distribution center. Members of the Orders class will eventually become stops along the vehicles' routes.

The grocery store locations are already added as a layer named 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 park the vehicle and unload the goods.

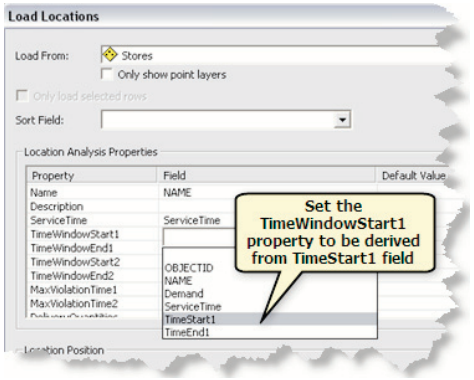


You will add these stores point features as orders.

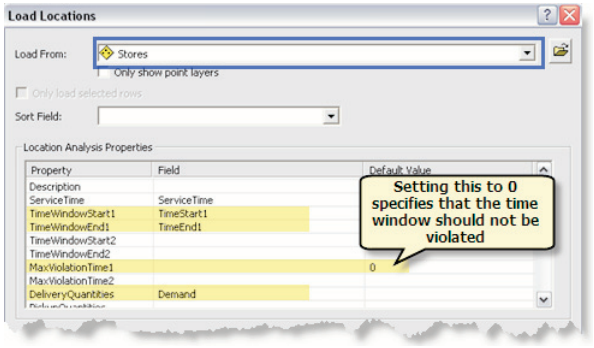
1. Right-click Orders (0) in the Network Analyst Window and click Load Locations.



2. Select Stores in the Load From drop-down list.
3. The Location Analysis Properties section on the Load Locations dialog box lets you specify which attributes of the Stores features class contain the values that Network Analyst will use to solve this vehicle routing problem. In the Location Analysis Properties section, make sure 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 (usually located in C:\Program Files\ArcGIS\NetworkAnalyst\NetworkConfiguration\NASolverConfiguration.xml)
4. Click in the field column beside the TimeWindowStart1 property and select TimeStart1 field from the drop-down list. Similarly, set the TimeWindowEnd1 property to be derived from TimeEnd1 field and set DeliveryQuantities to read from the Demand field.

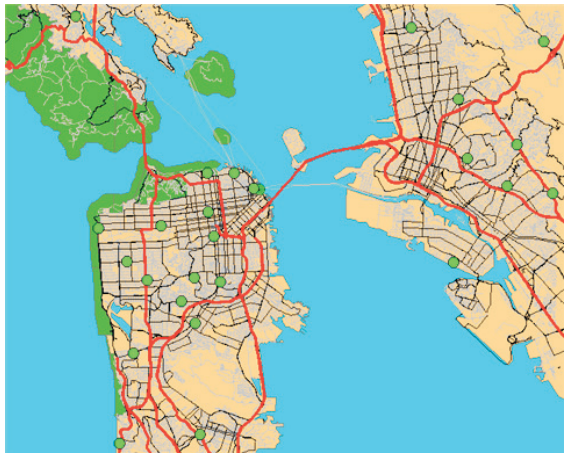


5. Type 0 (zero) under Default Value for the MaxViolationTime1 property. Setting this property to 0 specifies that the time window should not be violated. Leave default settings for the other properties.



6. Click OK

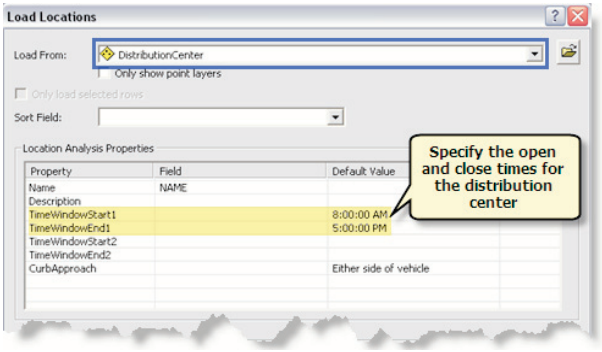
   Now 25 stores are listed in the Network Analyst Window under the Orders network analysis class and are displayed as Orders on the map in the Vehicle Routing Problem layer.



Adding Depots

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

1. Right-click Depots (0) in the Network Analyst Window and click Load Locations.
2. Select DistributionCenter in the Load From drop-down list.
3. In the Location Analysis Properties section, make sure the Name property is automatically matched to the NAME field.
4. Type “8 AM” under Default Value for the TimeWindowStart1 property and “5 PM” under default value for the TimeWindowEnd1 property. Leave the default settings for the other properties.



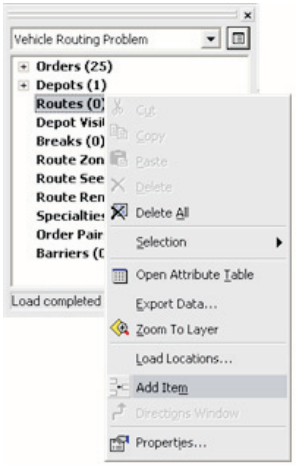
5. Click Ok

One distribution center is listed in the Network Analyst Window under the Depots network analysis class and is displayed as Depot on the map in the Vehicle Routing Problem layer.

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.

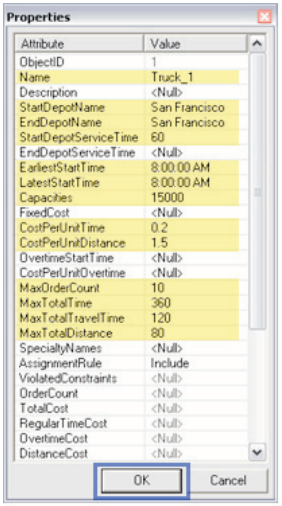
1. Right-click Routes (0) in the Network Analyst Window and click Add Item.



   A new route named Item1 is added under the Routes class in the Network Analyst Window and the Properties window for the newly created route opens.

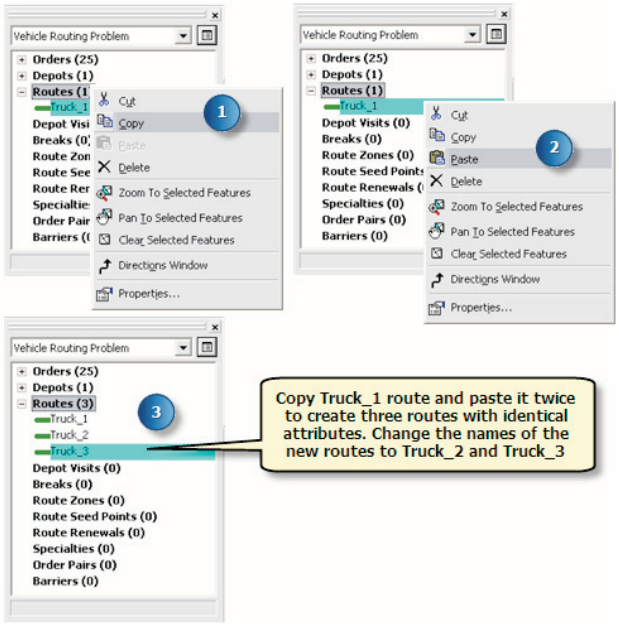
2. In the Properties window, specify the attributes for the route as shown in the table below. Leave default values for other attributes. The description column in the table explains the use of particular values.

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 has to 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	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	In order 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	In order to balance daily fuel and maintenance costs among the fleet, any one truck should not travel more than 80 miles on its route.



For the Capacities attribute make sure the value 15000 is not entered as 15,000.

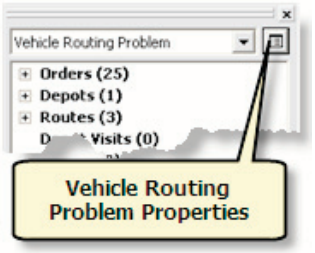
3. Click OK. A new route called Truck_1 is listed in the Network Analyst Window.
4. Since the three trucks at the distribution center are the same, you can make two copies of the first truck you entered and rename them. Right-click the existing Truck_1 route object, select copy and then select paste twice so you have three routes listed under the Routes network analysis class in the Network Analyst Window. Double-click each of the two new routes to open their properties windows and modify their Name attributes to Truck_2 and Truck_3.



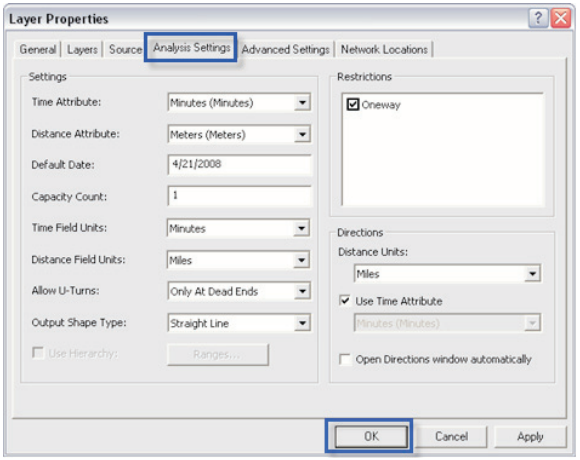
Setting up the properties for analysis

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

1. Click the Vehicle Routing Problem Properties button next to the drop-down list in the Network Analyst Window to bring up the Layer Properties dialog box.



2. In the Layer Properties dialog box click the Analysis Settings tab.
3. Click the Time Attribute drop-down list and click Minutes. This network attribute will be used by the VRP solver to calculate time-based impedance between orders and the depot.
4. Click the Distance Attribute drop-down list and click Meters. This network attribute is used only to specify travel distances between orders and the depot; the VRP solver minimizes time.
5. Leave the default date as the current date.
6. Since the goods are measured in pounds, make sure that the Capacity Count is set to 1. This says that the goods being delivered have only one measurement: weight. 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 Minutes is selected for Time Field Units. This specifies that all time-based attributes, such as ServiceTime, MaxViolationTime1 for Orders and MaxTotalTime, MaxTotalTravelTime, CostPerUnitTime for Routes, are in minutes.
8. Make sure Miles is selected for Distance Field Units. This specifies that all distance-based attributes, such as MaxTotalDistance, CostPerUnitDistance for Routes, are in miles.
9. Since it is difficult to make U-Turns with delivery trucks, select Only At Dead Ends from the Allow U-Turns drop-down list.
10. Select Straight Line in the Output Shape Type drop-down list. Optionally, you can select True Shape or True Shape (No Measure) option if you want the route shapes to follow the streets; this option only affects the display of the routes, not the results determined by the VRP solver.
11. Check Oneway in the Restrictions list.
12. Leave the options under the Directions group to their default values.
13. Click OK to apply and save the settings.

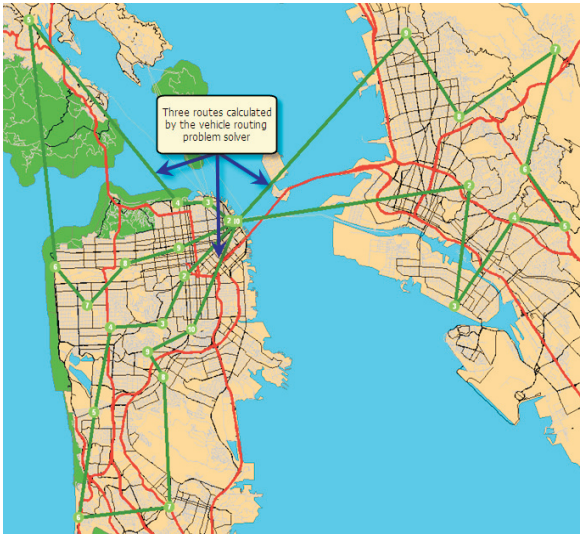


Run the process to determine the best route assignment and order sequence

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

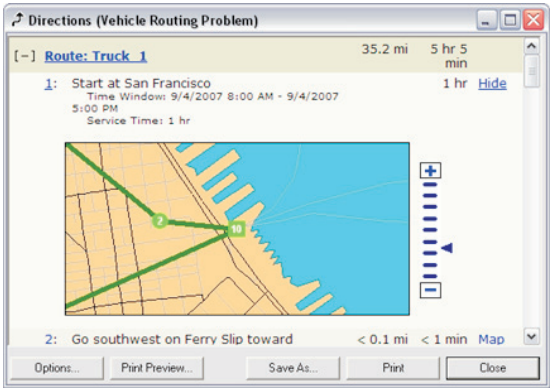
The VRP solver calculates the three routes required to service the orders and draws lines connecting the orders. Each route begins and ends at the distribution center and serves a set of orders along the way.

If there are error messages, make sure that the value of the Capacities attribute for the routes is specified as 15000 instead of 15,000 and each route has a unique name.



Determine turn-by-turn directions for the routes

1. Right-click the Routes (3) in the Network Analyst Window and click Selection and Clear Selected Features.
2. Click the Directions Window button on the Network Analyst toolbar to generate directions for all the routes.



3. You can optionally export the Vehicle Routing Problem layer as a layer file (<filename>.lyr) on disk so that you can load it in a different map document.
4. If you wish to continue working with the advanced tutorial scenario, close the directions window. Otherwise, exit ArcMap and do not save any changes to Exercise8.mxd.

Make changes to the existing solution to solve a different scenario

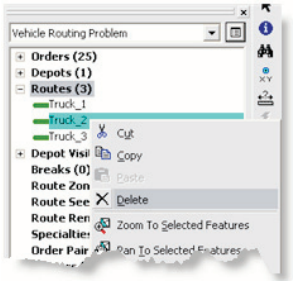
The vehicle routing problem solution obtained earlier worked well for the company. But after a few weeks, the driver assigned to Truck_2 quit the job. So now the distribution company has to service the same stores but with just two trucks. To accommodate the extra workload, the company decided to pay 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 truck load while making their deliveries instead of returning back 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

In this step, you will delete the Truck_2 route.

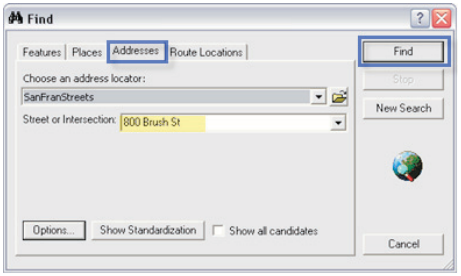
1. In the Network Analyst Window, right-click the Truck_2 object in the Routes network analysis class and click Delete.



Adding route renewals

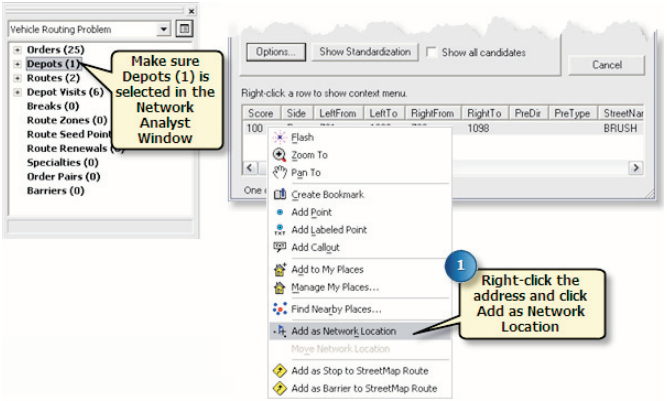
The two satellite distribution centers that the company acquired are at 800 Brush St and 100 Old County Rd and they can act as renewal locations for the trucks. The trucks can refill their cargo by visiting these renewal locations and thus save time by not returning to the starting depot for renewal. The renewal locations are added as 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.

1. In the Network Analyst Window, select Depots(1).
2. On the Tools toolbar, click the Find button .
3. In the Find dialog box, select the Addresses tab.
4. Select SanFranStreets from the Choose an address locator drop-down list.
5. In the Street or Intersection combo box, type “800 Brush St” and click Find.



The SanFranStreets address locator finds the address and shows the result at the bottom of the Find dialog box.

6. Right-click the row, click Add as Network Location.

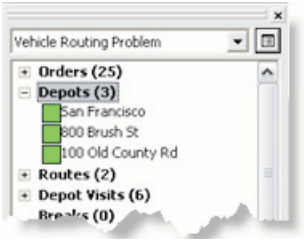


This will add the located address as a depot object in the Depots network analysis class.

The depot location is also shown in the map display.

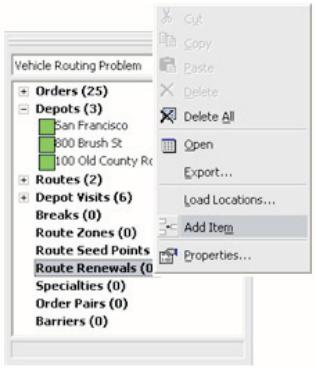
7. In the Street or Intersection combo box, type "100 Old County Rd" and click Find.
8. Right-click the row and click Add as Network Location and close the Find dialog box.

   The Depots network analysis class now has three depots.



Since each truck can possibly renew at both locations, you will associate each truck with the two renewal locations. The VRP solver will figure out the best renewal location for each truck.

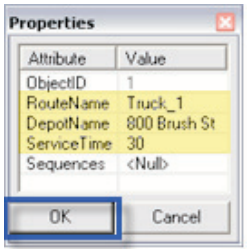
9. In the Network Analyst Window, right-click Route Renewals (0) and click Add Item.



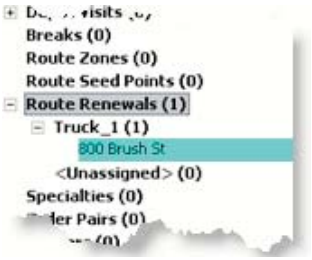
A new route renewal object named Item1 is added under the Route Renewals class in the Network Analyst Window and the Properties window for Item1 opens.

10. In the Properties window, specify the attributes for the route renewal as shown in the table below.

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

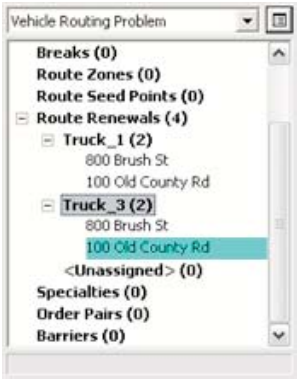


11. Click OK. A new route renewal object called 800 Brush St is listed within the Truck_1 item in the Network Analyst Window.



12. Follow steps 9–11 and add three more route renewal objects such that each truck (Truck_1 and Truck_3) can renew 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 item, respectively.

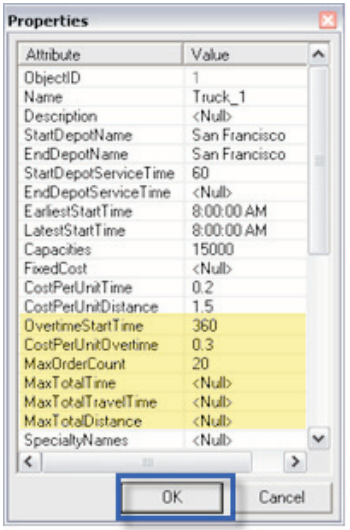


Modifying routes to include overtime

In order to accommodate the extra workload, the company has decided not to have any maximum time, maximum travel time, or 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.

1. In the Network Analyst Window, under the Routes network analysis class, double-click the Truck_1 object to open the Properties window for Truck_1.
2. In the Properties window, make changes to the attributes of the route so they reflect the values in the table below.

Attribute	Value	Description
OvertimeStartTime	360	The driver is paid overtime if he/she works for more than 6 hours (360 minutes).
CostPerUnitOvertime	0.3	The truck driver is paid 18 dollars 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/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.



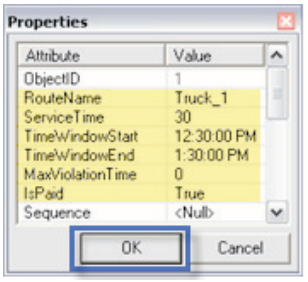
3. Click OK.
4. Repeat steps 1–3 above for Truck_3.

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.

1. In the Network Analyst Window, right-click the Breaks (0) and click Add Item.
2. In the Properties window, specify the attributes for the break as shown in the table below and click OK. Leave the default values for the other attributes.

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



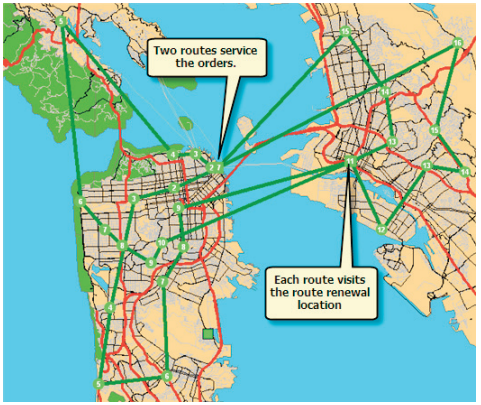
3. Repeat steps 1–2 above for Truck_3.

   The Network Analyst Window should now have two breaks objects listed under the Breaks class.

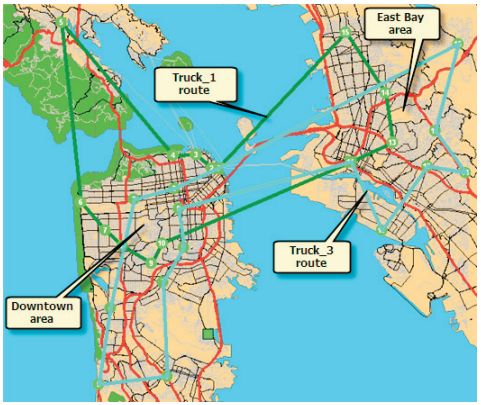
Determine the solution

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 renew the truck load, continues to service the remaining orders, and finally returns to the distribution center.



This solution meets all of 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 route for Truck_1 services the orders that are downtown and the route for Truck_3 services the orders within the East Bay area. In the next steps you will add route seed points to incorporate these driver preferences.

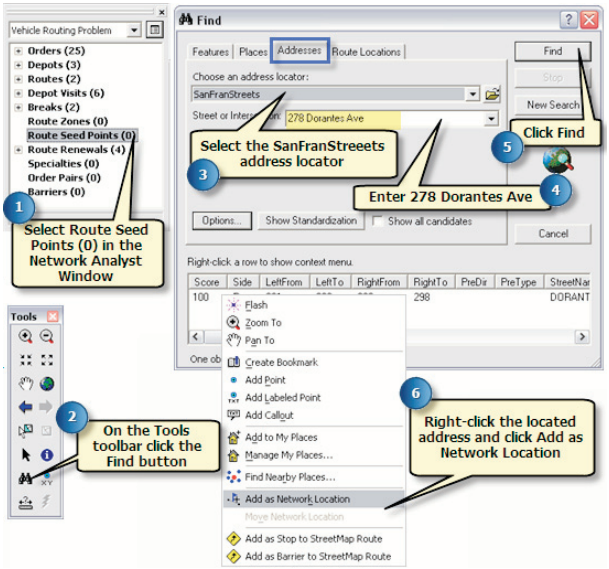


Adding route seed points

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.

1. In the Network Analyst Window, select Route Seed Points (0).
2. On the Tools toolbar, click the Find button .
3. In the Find dialog box, select the Addresses tab.
4. Select SanFranStreets from the Choose an address locator drop-down list.
5. In the Street or Intersection combo box, type “278 Dorantes Ave” and click Find.

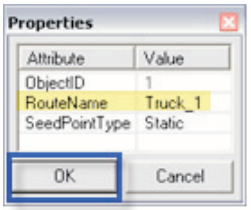
   The SanFranStreets address locator finds the address and shows the result at the bottom of the Find dialog box.
6. Right-click the row, click Add as Network Location, and close the Find dialog box.



This will add the located address as a route seed point object in the Route Seed Points network analysis class. The route seed point location is also shown in the map display.

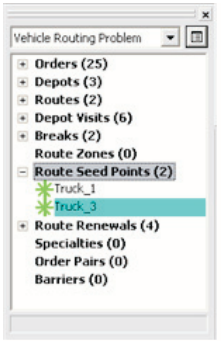
7. In the Network Analyst Window, double-click the newly added route seed point object (labeled as 278 Dorantes Ave) to open the Properties window for this object.
8. In the Properties window, specify the attributes for the route seed point as shown in the table below.

Attribute	Value	Description
RouteName	Truck_1	The name of the route to which this seed point applies.
SeedPointType	Static	The will cause the orders that are clustered around the specified seed point to be most likely assigned to Truck_1.



9. Click OK.
10. Repeat steps 1–6 above to add another route seed point at the address 1888 Peralta St.
11. Repeat steps 7–9 above to change the RouteName attribute to Truck_3 for this route seed point.

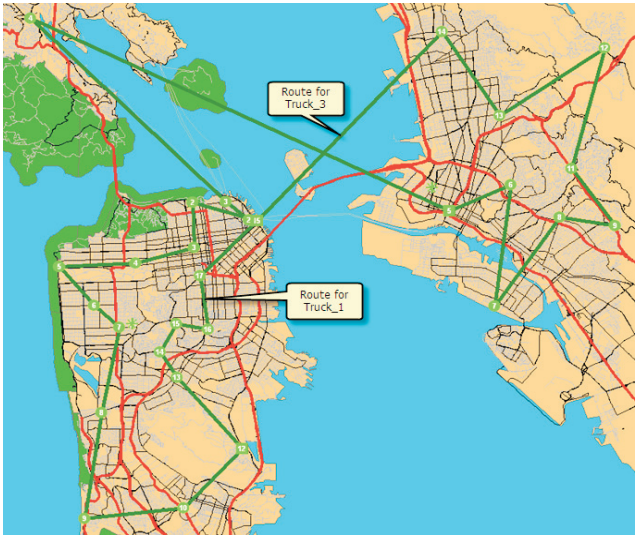
    The Route Seed Points network analysis class now has two route seed points.



Determine the solution

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, services a set of orders along the way, visits a renewal location to reload the truck, continues to service remaining orders, and finally returns to the distribution center. The route for Truck_1 includes orders in the downtown region only.



2. You can optionally export the vehicle routing problem layer as layer file (<filename>.lyr) on disk so that you can load it in a different map document.
3. Exit ArcMap and click No to discard all changes.

Exercise 9: Finding best routes to service a set of paired orders

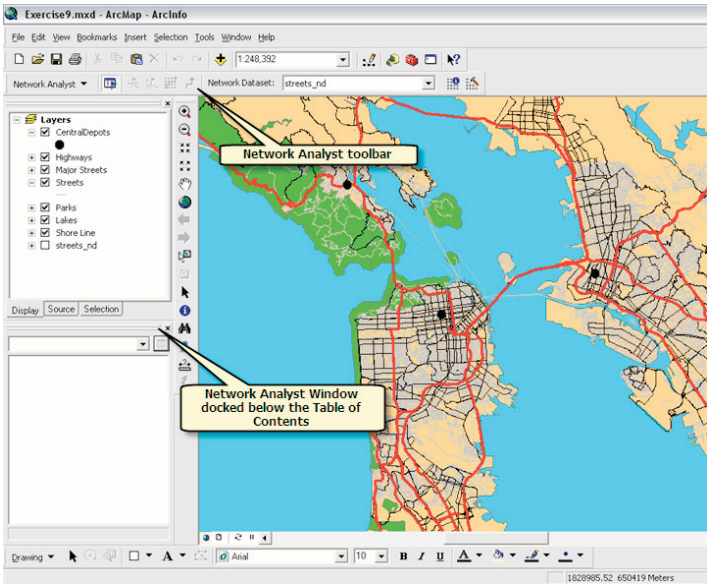
In this exercise you will find the best routes for a fleet of vans, which are operated by a logistics company, to transport people from their homes to hospitals. The dispatcher at the company has received a list of people who need to visit their doctors and require transportation services provided by the logistics company. The people can't spend more than a specified time on the van during transit due to their health conditions. They have to be picked up within time windows that are assigned according to their appointments at the hospitals. Some people require wheelchairs. The main objective is to assign people-hospital pairs to the vans in the fleet and to sequence the assignments in a way that minimizes the total travel time.

This can be achieved by solving a vehicle routing problem (VRP) that uses order pairs. Once the routes are determined, you will generate turn-by-turn directions for the resulting routes which can be printed and given to the drivers.

Preparing your display

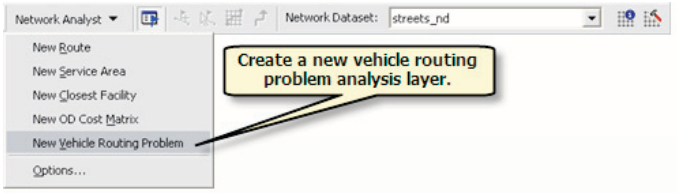
1. If you have Exercise9.mxd open in ArcMap, skip steps 2 to 5.
2. Start ArcMap by either double-clicking a shortcut installed on your desktop or using the programs list in your Start menu. Choose OK to start ArcMap with a new, empty map.
3. Click File on the Main menu and click Open.
4. In the Open dialog box, navigate to C:\arcgis\ArcTutor\Network_Analyst\Exercise9\Exercise9.mxd. (This is the default install location for this data.)
5. Double-click Exercise9.mxd.
6. If the Network Analyst extension is not enabled, on the Tools menu, click Extensions, and in the Extensions dialog box, click Network Analyst, then close the Extensions dialog box.
7. If the Network Analyst toolbar is not already present, on the Main menu, click View, point to Toolbars, and click Network Analyst.

8. If the Network Analyst Window is not already open, click the Network Analyst Window button on the Network Analyst toolbar. The Network Analyst Window is a window that you can dock within ArcMap or leave undocked. In this exercise, the window is shown docked below the Table of Contents, but you can place it wherever you like.



Creating the Vehicle Routing Problem analysis layer

1. On the Network Analyst toolbar, click the Network Analyst drop-down menu and click New Vehicle Routing Problem.



The Network Analyst Window now contains an empty list of Orders, Depots, Routes, Depot Visits, Breaks, Route Zones, Route Seed Points, Route Renewals, Specialties, Order Pairs, and Barriers network analysis classes.

The Table of Contents contains a new Vehicle Routing Problem analysis (group) layer.

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 the wheelchair as a specialty so that the orders that require this specialty can be assigned to the routes that support the specialty.

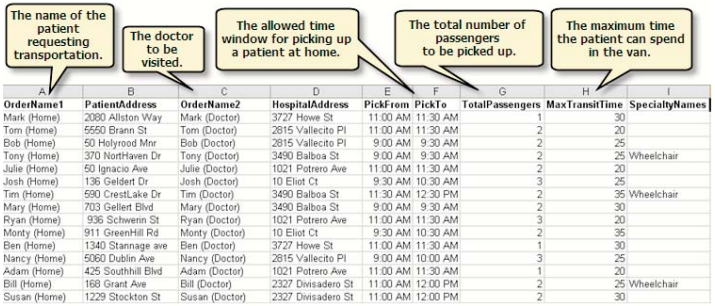
1. Right-click Specialties (0) in the Network Analyst Window and click Add Item.

A new speciality named Item1 is added under the Specialties class in the Network Analyst Window and Properties window for the new specialty opens.

2. In the Properties window, change the value of the Name attribute to Wheelchair and click OK.

Adding Orders

The people and the hospital addresses are stored in a spreadsheet that is provided to the dispatcher. The spreadsheet contains information about each patient, including their name and home address; the name and the address of the hospital they must be delivered to; the time window within which the patient has to be picked up; the total number of passengers, including the patient, that are riding together; the maximum time that the patients can spend in transit; the special requirements of the passengers such as a wheelchair ramp.

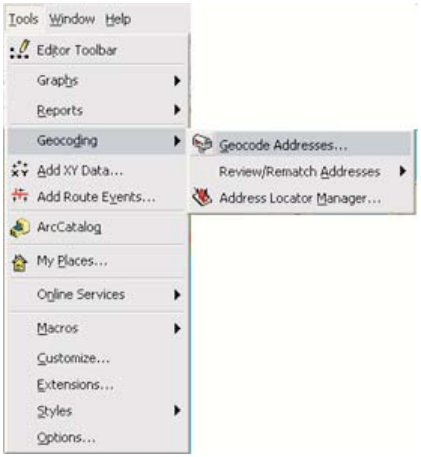


	A	B	C	D	E	F	G	H	I
	OrderName1	PatientAddress	OrderName2	HospitalAddress	PickFrom	PickTo	TotalPassengers	MaxTransitTime	SpecialtyNames
	Mark (Home)	2080 Allston Way	Mark (Doctor)	3727 Howe St	11:00 AM	11:30 AM	1	30	
	Tom (Home)	5550 Brann St	Tom (Doctor)	2815 Vallecito Pl	11:00 AM	11:30 AM	2	20	
	Bob (Home)	50 Holyrood Mnr	Bob (Doctor)	2815 Vallecito Pl	9:00 AM	9:30 AM	2	25	
	Tony (Home)	370 NortHaven Dr	Tony (Doctor)	3490 Balboa St	9:00 AM	9:30 AM	2	25	Wheelchair
	Julie (Home)	50 Ignacio Ave	Julie (Doctor)	1021 Potrero Ave	11:00 AM	11:30 AM	2	20	
	Josh (Home)	136 Geldert Dr	Josh (Doctor)	10 Eliot Ct	9:30 AM	10:30 AM	3	25	
	Tim (Home)	590 CrestLake Dr	Tim (Doctor)	3490 Balboa St	11:30 AM	12:30 PM	2	35	Wheelchair
	Mary (Home)	703 Gellert Blvd	Mary (Doctor)	3490 Balboa St	9:00 AM	9:30 AM	2	30	
	Ryan (Home)	936 Schwerin St	Ryan (Doctor)	1021 Potrero Ave	11:00 AM	11:30 AM	3	20	
	Monty (Home)	911 GreenHill Rd	Monty (Doctor)	10 Eliot Ct	9:30 AM	10:30 AM	2	35	
	Ben (Home)	1340 Stannage ave	Ben (Doctor)	3727 Howe St	11:00 AM	11:30 AM	1	30	
	Nancy (Home)	5960 Dublin Ave	Nancy (Doctor)	2815 Vallecito Pl	9:00 AM	10:00 AM	3	25	
	Adam (Home)	425 Southhill Blvd	Adam (Doctor)	1021 Potrero Ave	11:00 AM	11:30 AM	1	20	
	Bill (Home)	168 Grant Ave	Bill (Doctor)	2327 Divisadero St	11:00 AM	12:00 PM	2	25	Wheelchair
	Susan (Home)	1229 Stockton St	Susan (Doctor)	2327 Divisadero St	11:00 AM	12:00 PM	2	30	

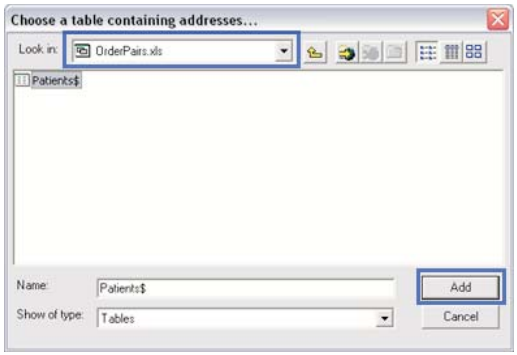
In this case, the passengers and hospital visits are related to each other since each passenger has to visit a prespecified hospital. you can model this situation as order pairs by loading both patient and hospital locations as Orders and then relating them with Order Pairs.

In this step, you will geocode the patient and hospital addresses and load them as orders.

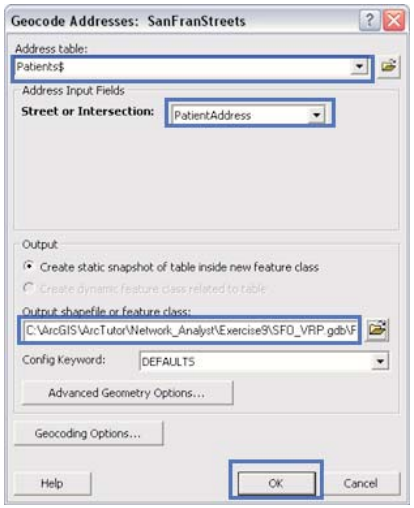
1. Click Geocoding and Geocode Addresses from the Tools menu.



2. In the Choose an Address Locator to use dialog box, make sure SanFranStreets is selected and click OK.
3. In the Geocode Addresses dialog box, for the Address Table, click the browse button and navigate to C:\arcgis\ArcTutor\Network_Analyst\Exercise9 folder (this is the default install location for the tutorial data). Double-click OrderPairs.xls, select Patients$ table, and click Add.

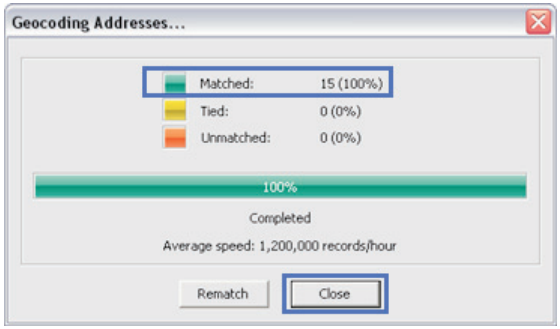


4. In the Geocode Addresses dialog box, select PatientAddress from the Street or Intersection drop-down list.
5. In the Geocode Addresses dialog box, for Output shapefile or feature class, click the browse button. Change Save as type to File and Personal Geodatabase feature class, and navigate to SFO_VRP.gdb file geodatabase within the Exercise9 folder.
6. In the Saving Data dialog box, type “Patients” in the Name text box and click Save.
7. In the Geocode Addresses dialog box, click OK.

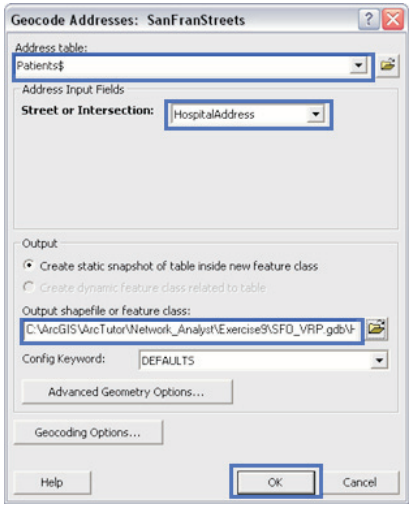


8. In the Geocoding Addresses dialog box, make sure the Matched label shows 15 (100%) and click Close.

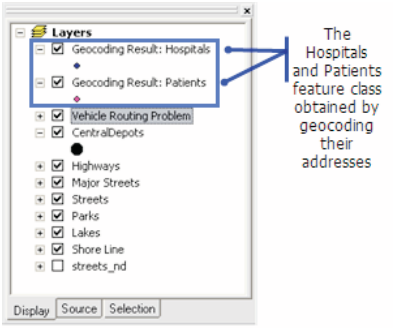
   Fifteen addresses are geocoded from the OrderPairs spreadsheet and the output feature class is added to the Table of Contents in ArcMap.



9. Repeat steps 1–8 above using the HosptialAddress field in the OrderPairs spreadsheet to geocode hospital addresses as a point feature class called Hospitals.



The ArcMap Table of Contents should now have two feature layers called Geocoding Results: Hospitals and Geocoding Results: Patients.



10. In the Table of Contents, uncheck the check boxes next to the Geocoding Results: Hospitals and Geocoding Results: Patients layers so that they are not visible on the ArcMap display.

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

11. In the Network Analyst Window, right-click Orders (0) and click Load Locations.

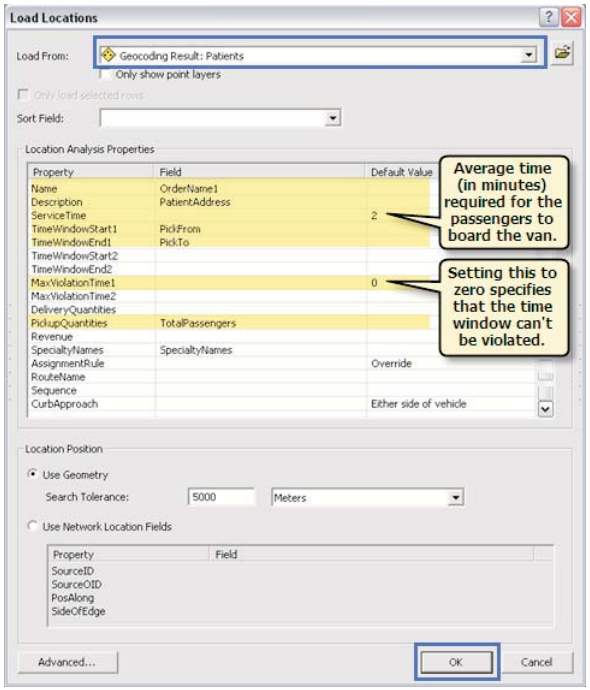
12. Select Geocoding Results: Patients in the Load From drop-down list.

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 use to solve this vehicle routing problem.

13. In the Location Analysis Properties section, click in the field column beside the Name property and select OrderName1. Similarly, set the Description property to be derived from the PatientAddress field, the TimeWindowStart1 property to be derived from PickFrom field, the TimeWindowEnd1 property to be

derived from PickTo field, and the PickupQuantities to be derived from TotalPassengers field.

14. Make sure the SpecialtyNames property is automatically matched to the SpecialtyNames field.
15. Type 2 under Default Value for the Service Time property and 0 under Default Value for the MaxViolationTime1 property. Leave the default settings for the other properties.
16. Click OK.



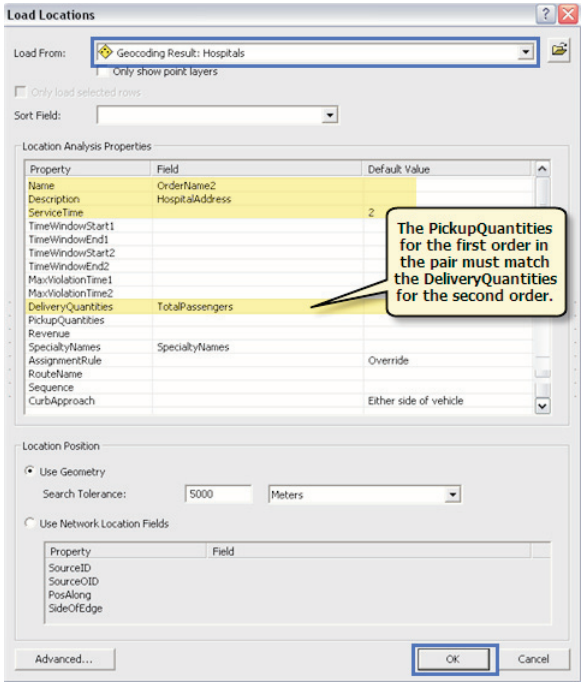
Now fifteen orders are listed in the Network Analyst Window under the orders network analysis class and are displayed as orders on the map in the Vehicle Routing Problem layer.

In the next steps, you will load hospital locations as orders.

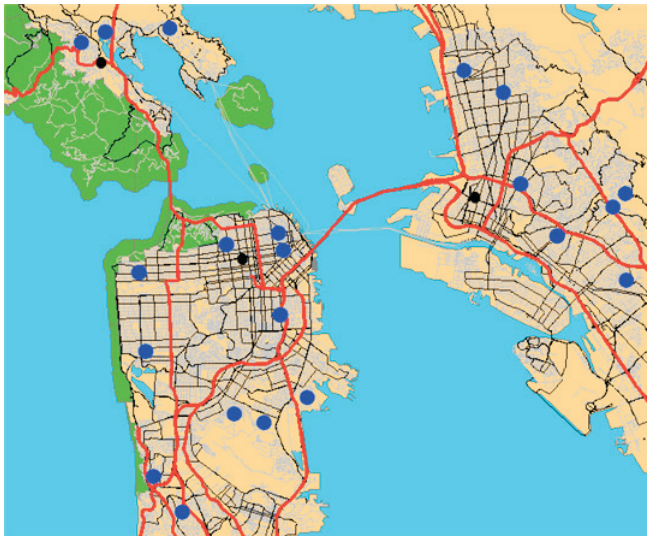
17. In the Network Analyst Window, right-click Orders (15) and click Load Locations.
18. Select Geocoding Results: Hospitals in the Load from drop-down list.
19. In the Location Analysis Properties section, click in the field column beside the Name property and select OrderName2. Similarly, set the Description property to be derived from the HospitalAddress field and DeliveryQuantities to be derived from the TotalPassengers 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 which need to visit the same hospital. So if the hospital addresses are used to derive the value of the Name attribute for Orders, then the VRP solver will return error messages as there will be duplicate values for the Name attribute.

20. Make sure the SpecialtyNames property is automatically matched to the SpecialtyNames field.
21. Type 2 under Default Value for the Service Time property. Leave default settings for the other properties.
22. Click OK.



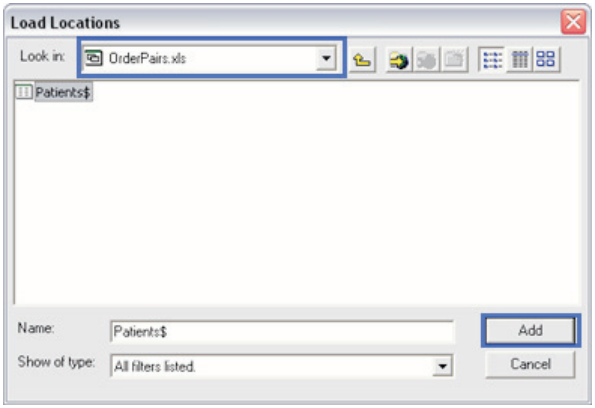
Now, thirty orders are listed in the Network Analyst Window under the orders network analysis class and are displayed as orders on the map in the Vehicle Routing Problem layer.



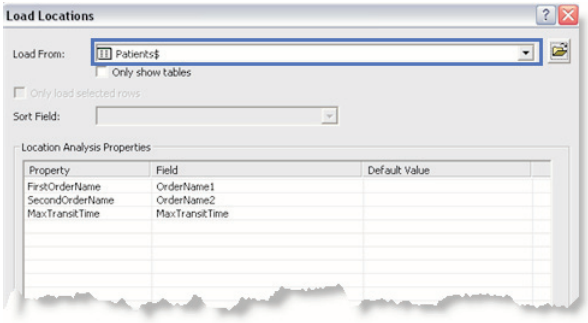
Adding Order Pairs

The passengers have to be taken to a prespecified 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.

1. Right-click Order Pairs (0) in the Network Analyst Window and click Load Locations.
2. In the Load Locations dialog box, click the Browse button and navigate to Exercise9 folder.
3. Double-click OrderPairs.xls, select Patients$ table, and click Add.

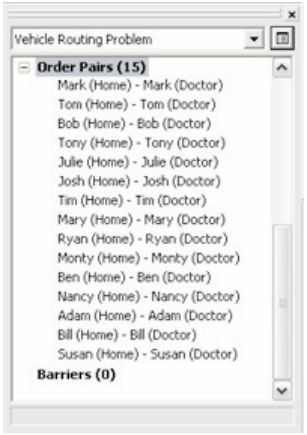


4. In the Load Locations dialog box, make sure the FirstOrderName property is automatically matched to the OrderName1 field, the SecondOrderName property is automatically matched to the OrderName2 field, and the MaxTransitTime property is automatically matched to the MaxTransitTime field.



5. Click OK

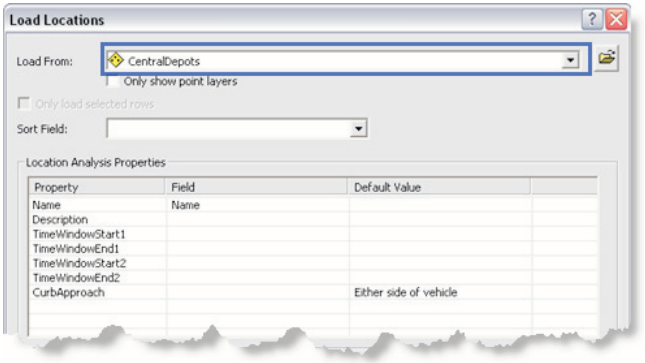
   Fifteen order pairs are listed in the Network Analyst Window under the Order Pairs network analysis class.



Adding Depots

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

1. Right-click Depots (0) in the Network Analyst Window and click Load Locations.
2. In the Load Locations dialog box, select CentralDepots from the Load From drop-down list.
3. In the Location Analysis Properties section, make sure the Name property is automatically matched to the Name field.
4. Click OK.



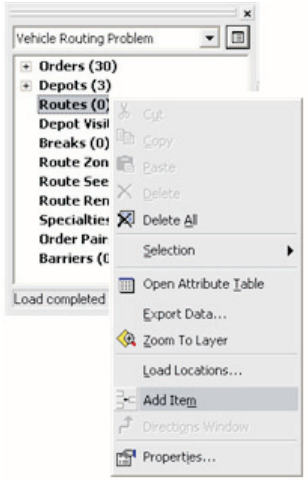
Three depots are listed in the Network Analyst Window under the Depots network analysis class and are displayed as Depots on the map in the Vehicle Routing Problem layer.

Adding Routes

The logistics company has three vans, each with a maximum capacity to carry 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 ramp 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 the wheelchair as a specialty.

1. Right-click Routes (0) in the Network Analyst Window and click Add Item.

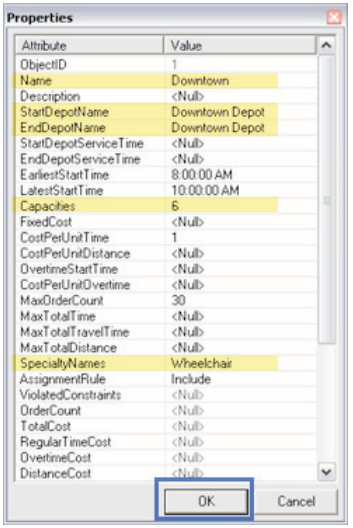


A new route named Item1 is added under the Routes class in the Network Analyst Window and the Properties window for the new route opens.

2. In the Properties window, specify the attributes for the route as shown in the table below. Leave 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 thedowntown area. Make sure this value matches the value for the Name attribute in the Depots network analysis class.
EndDepotName	Downtown Depot	The van returns to the depot in the downtown area at the end of the route. Make sure this value matches the value of the Name attribute in the Depots network analysis class.
Capacities	6	The van can carry a maximum of six passengers at one time.
SpecialtyNames	Wheelchair	The van is equipped to provide access for wheelchairs.

3. Click OK. A new route called 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. These vans are not equipped to allow access for wheelchairs. The following tables list the properties required to be set for these new routes.

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

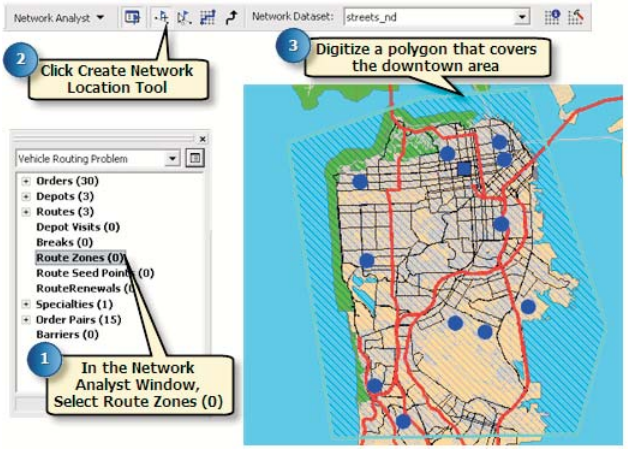
Attribute	Value
Name	East Bay
StartDepotName	East Bay Depot
EndDepotName	East Bay Depot
Capacities	6

The Network Analyst Window should now have three route objects listed within the Routes network analysis class.

Adding Route Zones

The three vans used by the company can operate only in a prespecified area. This means that the vans can't service the orders that are outside the areas assigned to the vans. You will add route zones and associate them with the routes to model this scenario.

1. In the Network Analyst Window, Select Route Zones (0).
2. On the Network Analyst toolbar, click the Create Network Location tool.
3. On the ArcMap display, digitize a polygon that roughly covers the downtown area. Double-click on the screen to complete the polygon.

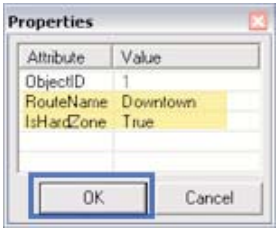


A new route zone named Graphic Pick 1 is added under the Route Zones class in the Network Analyst Window.

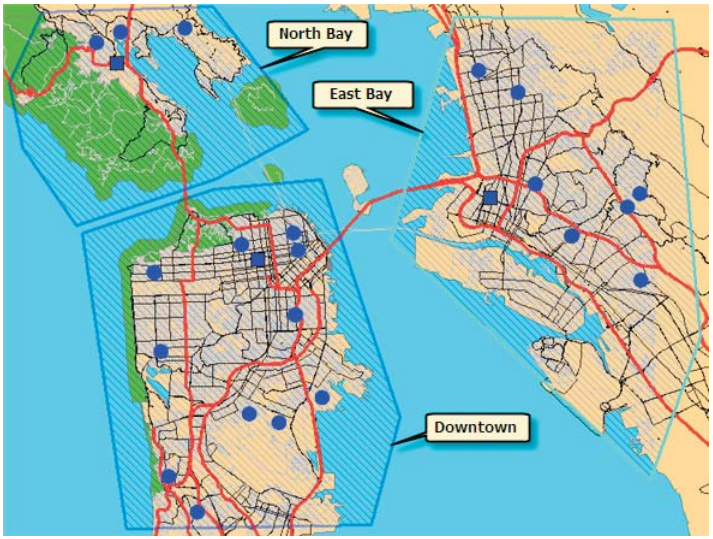
4. In the Network Analyst Window, double-click the new route zone object (named Graphic Pick 1) to open its Properties window.
5. In the Properties window specify the attributes for the route zone as shown in the table below:

Attribute	Value	Description
RouteName	Downtown	Name of the route to which this route zone belongs.
IsHardZone	True	The van can't service orders that are outside the route zone. Setting this value to true ensures that the van is assigned only those orders that are within the route zone.

6. Click OK.



7. Repeat steps 1–6 to add two more route zones that cover North Bay area and East Bay area.

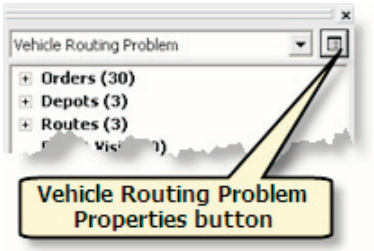


The Network Analyst Window should now have three route zone objects listed within the Route Zones network analysis class.

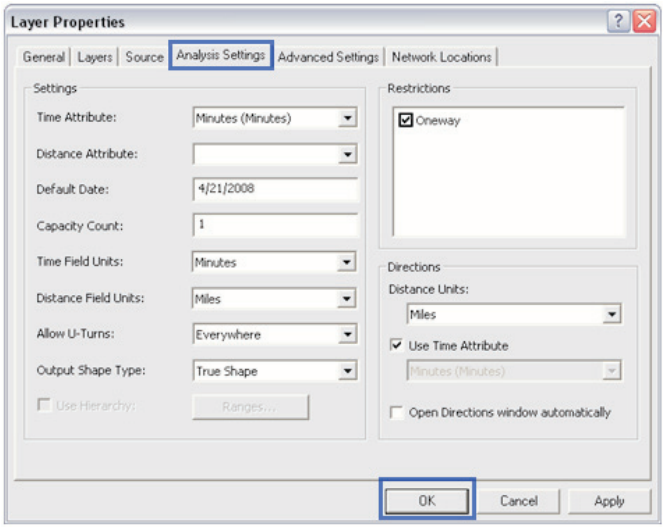
Setting up the properties for analysis

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

1. Click the Vehicle Routing Problem Properties button next to the drop-down list in the Network Analyst Window to bring up the Layer Properties dialog box.



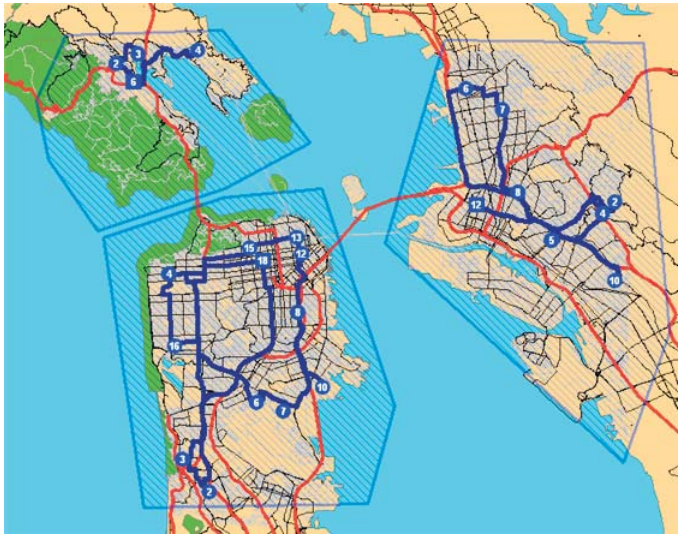
2. In the Layer Properties dialog box click the Analysis Settings tab.
3. Click the Time Attribute drop-down list and click Minutes. This network attribute will be used by the VRP solver to calculate time-based impedance between the orders and the depot.
4. Make sure nothing is selected in the Distance Attribute drop-down list. Since we are not using any distance-based cost parameters, such as CostPerUnitDistance and MaxTotalDistance, the Distance Attribute is not required.
5. Leave the default date as the current date.
6. Since the van capacity is measured only by the total number of passengers that can be accommodated, make sure that the Capacity Count is set to 1. If the capacity were 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. Make sure Minutes is selected for Time Field Units. This specifies that all time-based attributes, such as ServiceTime and MaxViolationTime1 for Orders, CostPerUnitTime for Routes, and MaxTransitTime for Order Pairs are in minutes.
8. Leave the default options for all other properties.
9. Click OK to apply and save the settings.



Run the process to determine the solution

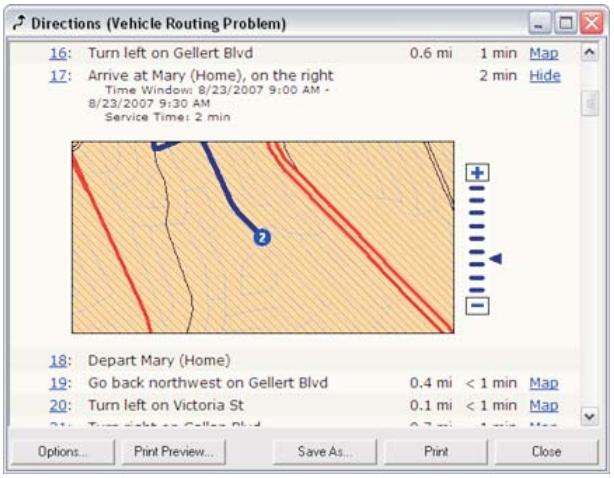
1. Click the Solve button on the Network Analyst toolbar.

The VRP solver calculates the routes for each van. Each route begins at the depot, picks up one or more people if the time they spend on the van is less than the MaxTransitTime specified, 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

1. Click the Directions Window button on the Network Analyst toolbar to generate directions for all the routes.



2. You can optionally export the vehicle routing problem layer as a layer file (<filename>.lyr) on disk so that you can load it in a different map document.
3. Exit ArcMap and click No to discard all changes.