NETWORK ANALYSIS

Tutorial

Network Analysis

with

TNTmips®

Before Getting Started

TNTmips® provides sophisticated network analysis tools that determine the optimal path between two points with any number of stops and route control parameters taken into consideration. A second mode of operation has you locate points, or centers, then identifies the linear components of the network that should feed that center (Allocate In) or that the center should service (Allocate Out). Again, the characteristics of the lines and nodes that comprise the network are used in determining the result.

Prerequisite Skills This booklet assumes you have completed the exercises in the *Getting Started* and *Introduction to the Display Interface* tutorial booklets. The exercises in those booklets provide basic knowledge on how to use the TNT products. Because network analysis is heavily dependent on attributes, you should also complete the *Managing Relational Databases* and *Managing Geoattributes* booklets, which focus on how databases are created and maintained and how attributes are associated with elements in an object. This booklet does not present these basic skills again.

Sample Data The exercises presented in this booklet use sample data distributed with the TNTgis software. If you do not have access to a TNTgis DVD, you can download the data from MicroImages' web site. The exercises in this booklet use the objects in the NETWORK Project File in the NETWORK data collection.

More Documentation This booklet is intended only as an introduction to the features in the Network Analysis process. The tutorial on Vector Analysis Operations is also recommended if you are not familiar with vector structure and topology.

TNTmips® Pro and TNTmips Free TNTmips (the Map and Image Processing System) comes in three versions: the professional version of TNTmips (TNTmips Pro), the low cost TNTmips Basic version, and the TNTmips Free version. All versions run exactly the same code from the TNT products DVD and have nearly all the same features. If you did not purchase the professional version (which requires a software license key) or TNTmips Basic, then TNTmips operates in TNTmips Free mode.

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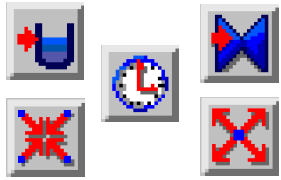
Welcome to Network Analysis

The Network Analysis process in TNTmips provides tools for preparing and analyzing vector objects that represent connected transportation networks. The process provides two modes of analyzing of a properly-prepared vector object: routing and allocation. The routing operation determines the optimal path between the start point, intermediate stops, and end point you designate. In the allocation operation, you indicate the location of centers for influx or distribution; the process then assigns each linear component of the network to one of these centers for most efficient service.

Network Analysis relies on the attributes of nodes and lines to produce meaningful results. The process cannot produce a meaningful route without knowing about one-way streets and impassable intersections. Nor can the process make sensible allocation decisions without knowing the capacity of the centers and the demand along the network lines. Many other attributes such as line length, speed limits, allowed turn directions, average time for turns, stop lights and signs, average time of stop, and so on, allow you to more accurately describe the properties of a road network. The closer the match between the vector attributes and the real-world situation, the more accurate the optimal routing and allocation predictions will be.

Although the input geodata for this booklet is TNTmips Free-sized, once you begin saving database information such as turn impedance, the database tables are too large for TNTmips Free. If you are running Free, you can follow along and view interface components, but after page 10, you won't actually be able to do the steps.



STEPS
☑ launch TNTmips

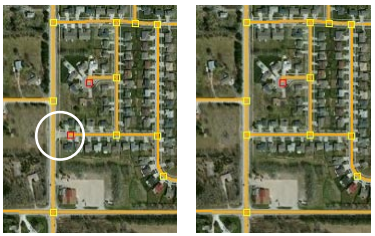
Vocabulary: A **stop**, or **waypoint**, is an intermediate point along a route that must be visited. A **center** is a point within a network to which materials or people are brought or from which materials or services are distributed.

Page 4 discusses the properties of a vector object that is suitable for Network Analysis. Pages 5–7 describe the Routing interface and preferences. Default and attribute based routing solutions are explored on pages 8–9 along with starting a new route on page 10. The exercises on pages 11–15 concern turn and directional impedance. Network node attributes features are discussed on pages 16–18 with the exercise on page 19 moving on to network line attributes. Page 20 presents more information on styles. The remainder of the booklet is devoted to allocation networks.

Prepare the Vector Object

The Network Analysis process operates on vector objects that represent connected transportation networks. In order for network analysis to produce accurate results, the vector object must faithfully represent the actual transportation network. If you acquire or import the network data, be sure to examine the data to make sure that all lines are fully connected and that actual intersections are represented by lines connecting at vector nodes. You can use the Editor to close any gaps and make the necessary connections.

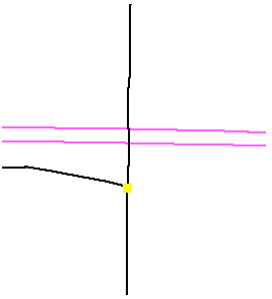
Vector objects with network topology are ideally suited for use in the Network Analysis process. Network topology rules allow a vector object to have nodes wherever the crossing lines actually intersect in the real world, while crossing lines that don't represent a real-world intersection (such as a bridge or highway overpass) are not required to have a node at the crossing point. (Planar and polygonal topology rules require a node wherever two lines meet or cross). When you create or import a new network vector object, be sure to choose network topology for the new vector object to enable non-intersecting crossing lines.



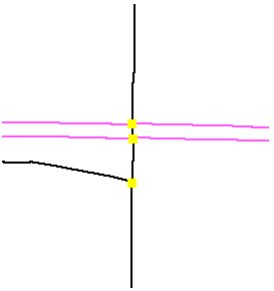
Make sure that lines representing intersecting roads and streets actually connect at vector nodes. Lines can be connected in the Editor if necessary.

If a transportation vector object has nodes at crossing points that do not represent actual intersections (because line elements on either side of the node have different attributes, for example), you can disable turns for those nodes when you set up the node attributes (see page 11).

A local road crosses eastbound and westbound lanes of a limited-access highway and intersects another local road.



A vector object with network topology has a node (yellow square) only at the intersection of the two local roads.



A vector object with planar or polygonal topology requires nodes where the local road crosses the highway lanes.

Network Analysis Routing Interface

Two or three windows open when you launch the Network Analysis process: Network Analysis, Network Analysis View, and Network Analysis Layer Controls. (The latter window opens the first time you use the process and subsequently only if it was open when you last exited the process.) The Manager window provides access to drawing style and DataTip settings. The View window lets you choose display operations and the active tool (zoom, recenter, select, and add stop or center). The majority of the features directly related to network analysis are accessed from the Network Analysis window.

A variety of features built into the Network Analysis process are available by clicking the right mouse button. For example, a right click on a node or line element in the list of all such elements will pan the display if the element is out of the current view.

Vocabulary: Impedance is the opposition to flow along a given line. Impedance can also be thought of as the cost of travelling along a given line. The path chosen by the routing process has the lowest total impedance. A **barrier** is a node that cannot be crossed.

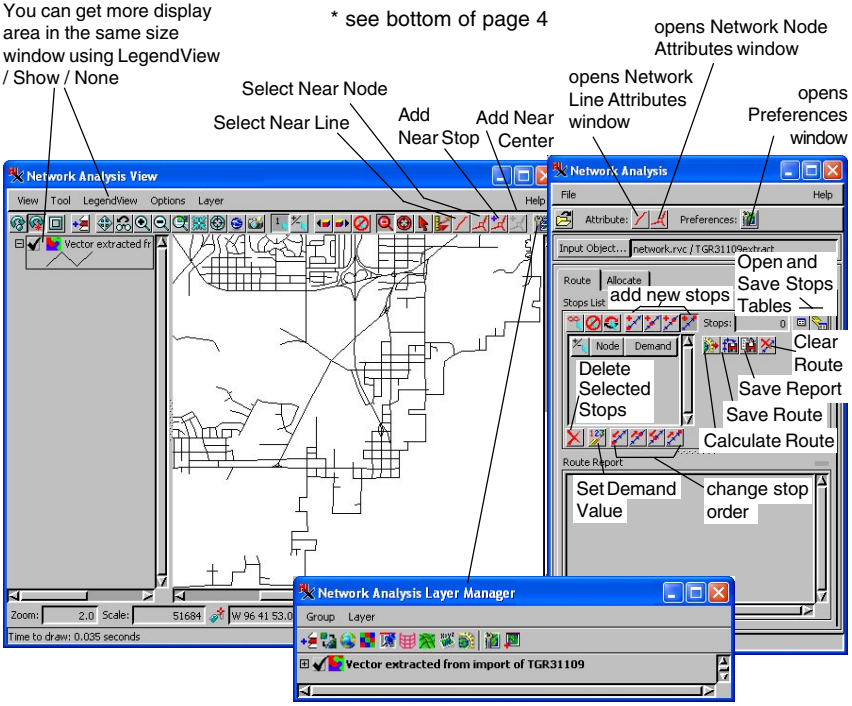
STEPS

☑ choose Geometric / Network Analysis

☑ click on the Open icon or on [Input Object] and select TGR31109 NETWORK you made in the previous exercise* from the NETWORK Project File

You can get more display area in the same size window using LegendView / Show / None

* see bottom of page 4

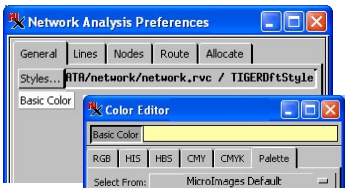


Preferences

STEPS

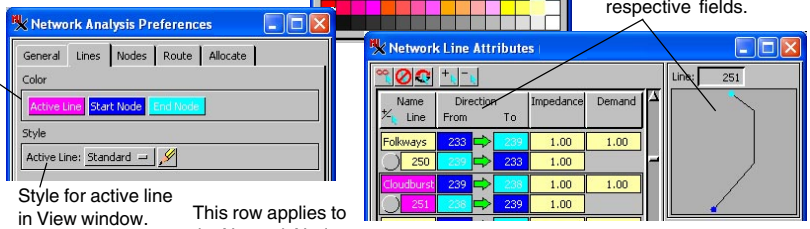
- ☑ click on the Preferences icon near the top of the Network Analysis window
- ☑ click on [Basic Color] on the General tab and select pale yellow or leave the color as white, then click [OK]
- ☑ check that the style sub-object under the vector chosen in the last exercise is selected (select it if not)
- ☑ click on the Lines tab then on one of the color buttons and next on the Style/ Active Line/ Specify button; note the choices
- ☑ click on the Nodes tab and explore the choices available

You can set the color of interface components and the drawing style for network components in the Network Analysis Preferences window. The "Basic Color" in the General panel refers to the background color for all boxes that are not otherwise assigned in the Network Analysis and Network Line and Node Attributes windows. All of the Preferences buttons that assign colors to interface components show the currently selected color. All Style choices apply to the drawing style for network elements in the View window. "Standard" means either solid color or a symbol or line pattern selected from the Style Editor window, which opens when you click on the Specify (pencil) icon. Other choices are None (style specified in Vector Layer Controls is used) and By Script.



These colors apply to the fields in the Network Line Attributes window.

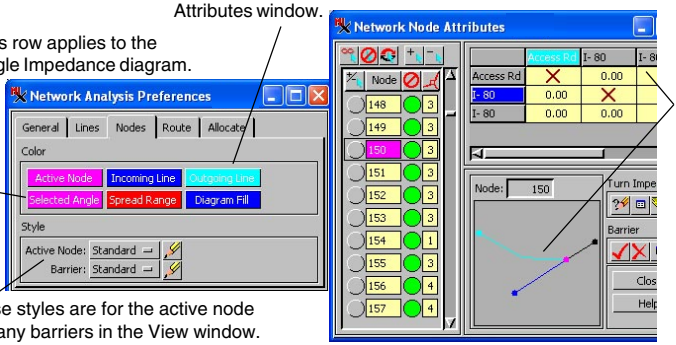
Note the node colors correspond to their respective fields.



Style for active line in View window.

This row applies to the Network Node Attributes window.

This row applies to the Angle Impedance diagram.



Note incoming and outgoing line colors correspond in the turn matrix and graphic.

These styles are for the active node and any barriers in the View window.

Preferences for Routes and Allocation

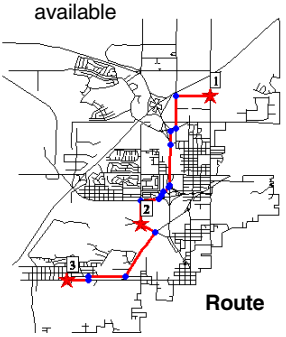
The options in the Route and Allocation Preferences panels relate almost exclusively to the drawing style in the View window. The Color button in each panel changes not only the color for the corresponding box in the Stops or Centers list, but the color assigned to the active stop / center in the View window when the Style is set to Standard. Consult the tutorial booklet entitled *Creating and Using Styles* if you are unfamiliar with designating drawing styles. The methods for assigning styles are described in detail there.

You want to be sure you choose a distinctive style for drawing routes. If the drawing style for the selected vector uses attributes, you do not want to pick a route style that could cause the route to be confused with the style assigned to a particular class of road. If you want symbols or line patterns for allocation networks, you want to choose ones that include the "variable" color. Use of the variable color allows a center and its allocated lines to "match." The color used as variable for each symbol / pattern pair is that assigned to the center when it is added.

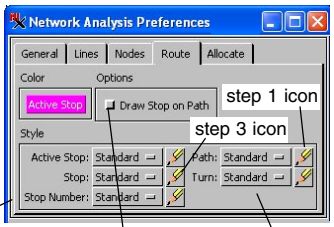
Vocabulary: The **Active Stop** and **Active Center** are selected by clicking on their node number in the Stops or Centers list, respectively—not by selection in the View window.

STEPS

- ☑ click on the Route tab then on the Path Specify icon 
- ☑ click on the red tile in the color palette, enter 3 Screen Pixels for the Line Width, and click [OK]
- ☑ click on the Stop Specify icon, set the point style to be a 6 pixel wide medium blue filled circle, and click [OK] 
- ☑ click on the Allocate tab and explore the choices available



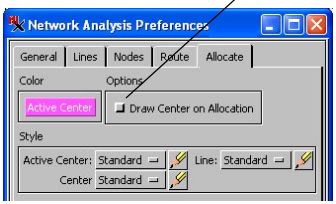
Route

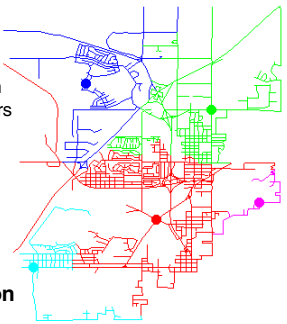


Adds label with ordinal stop number.

Adds points to indicate turn locations.

These buttons let you retain drawing of the stops / centers for the last calculated route / allocation after their deletion from the Stops / Centers list.





Allocation

Default Routing Solutions

STEPS

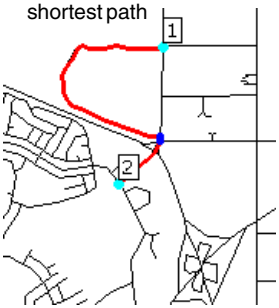
☑ position the cursor over the cloverleaf in the upper center of the View window (with focus) and press the <+> key (plus) to zoom in

☑ click on the Add Near Stop icon 

☑ click on the two intersections shown (nodes 118 and 124)

☑ click on the Calculate Route icon 

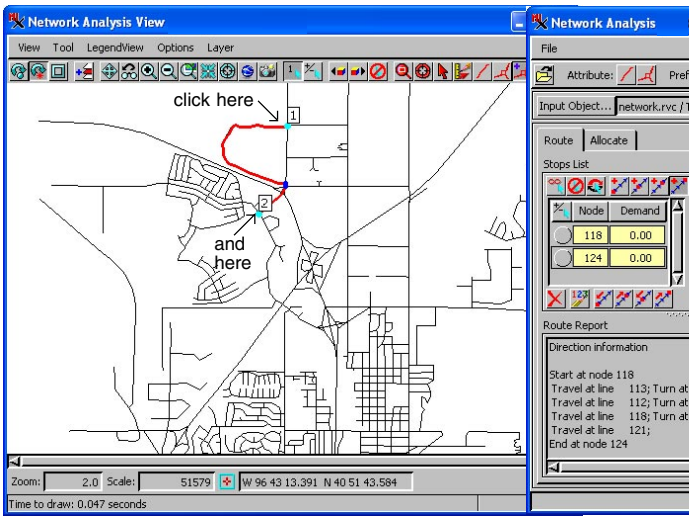
☑ note that the route selected is not the shortest path



The purpose of this exercise is to demonstrate the importance of assigning attributes to elements and using those attributes for network analysis. Lines have an impedance value of one (1.00) by default. Thus, unless you specify some other attribute(s) to provide or contribute to impedance, the suggested path will incorporate the fewest number of lines without regard for distance or other factors.

In this exercise, the route calculated incorporates a line that is more than 2.5 times the length of two other lines that provide a more direct path. However, the result obtained is correct using the default settings because the total impedance of the path selected is less than for the shorter path. The total impedance in this case is equal to the number of lines, which is four for the path selected and five for the shorter path.

A variety of node and line attributes may result in identification of a path that seems intuitively wrong, such as this one. However, that's why network analysis is so valuable; it uses the attributes you specify and identifies the path with the least impedance. This path is often not the path you would pick by eye.

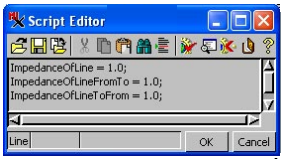


All added stops are listed here by node number.

Information about the route is displayed here after the route is calculated.

Using Length to Assess Cost

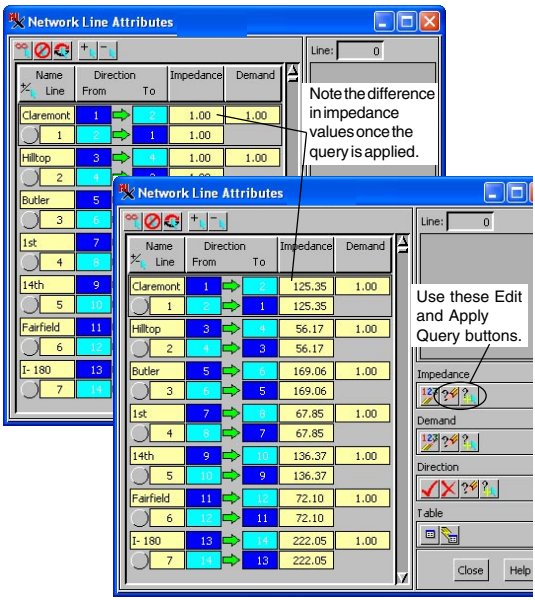
The Network Line Attributes window opens when you click on the Network Line icon in the Network Analysis window. This window can be open at the same time as the Network Node Attributes window so you can work on the attributes for both element types at the same time.



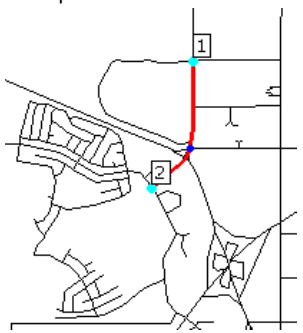
The Query Editor for lines provides the three possible means for assigning values to lines by query, which assign a default value of 1 to every line, so you can see the syntax for each of the possibilities: assignment applies to the line as a whole (ImpedanceOfLine); applies in the start to end direction (ImpedanceOfLineFromTo); or applies in the end to start direction (ImpedanceOfLine ToFrom). You need to remove or comment out the second two statements if you are going to assign the same attribute to both directions of the line, otherwise the separate directions will later be set to 1.0 and cancel any attribute assignment made to both directions.

STEPS

- ☑ click on the Clear Route icon and the Network Line icon, both in the Network Analysis window
- ☑ click on the Edit Query icon in the Impedance panel of the Network Line Attributes window
- ☑ choose Insert / Field (or type) to change the value for ImpedanceOfLine to LINESTATS.Length
- ☑ remove any other statements from the query (or comment them out by inserting a # at the beginning of the line)
- ☑ click on [OK] in the Query Editor window
- ☑ click on the Apply Query icon in the Impedance panel
- ☑ click on the Calculate Route icon
- ☑ note the difference in the route from that in the previous exercise



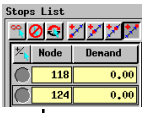
The length of the route decreases from 2.6 to 1.3 km after assigning length as the impedance value.



Steps for a New Route

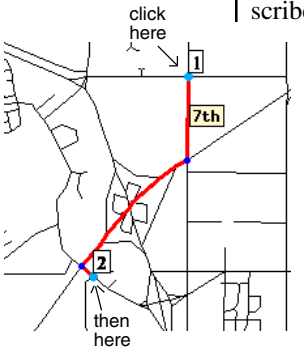
STEPS

- ☑ click on the Clear Route icon in the Network Analysis window
- ☑ click on the Selection indicator for both of the nodes in the Stops List or click on the Include All icon
- ☑ click on the Delete Selected Stops icon below the Stops List
- ☑ click on the Add Near Stop icon
- ☑ click on the two intersections shown (nodes 183 and 157)
- ☑ click on the Calculate Route icon



Choosing to clear a route removes the calculated path, but leaves all stops along the way. You can then add more stops or adjust the order of the stops and recalculate the route. To compute a route that does not use some or all of the stops in the current route, the stops must also be deleted from the Stops List.

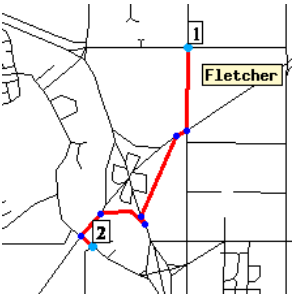
This exercise is intended to show you how to begin a new route and to point out another type of problem you will encounter unless you are using a vector object with network topology. Network topology by itself is not sufficient to avoid these problems unless nodes that represent intersections where roads do not actually meet (for example, the over-pass / underpass situation) have been removed and the appropriate lines joined. You will likely encounter intersections where turns need to be disabled even with correct network representation of the roads. The most common instance is an intersection where left turns are not allowed, but all variants may be found including intersections where right and left turns are permissible, but you cannot proceed straight across. The next exercise describes how to accommodate all of these situations.



Impedance = path length

Although the path calculated when impedance is determined by line length appears to be a better choice, neither of the routes shown is legitimate. Both involve getting on the Interstate where there is no on ramp. Your result should be the same as shown at the left.

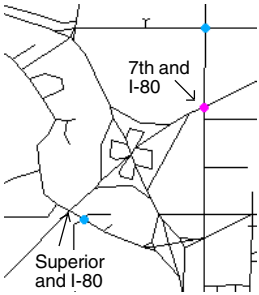
The path shown at the right also involves travel in the wrong direction on access roads. The means to prevent wrong-way travel is discussed in a later exercise.



Impedance = number of lines

Disabling Turns

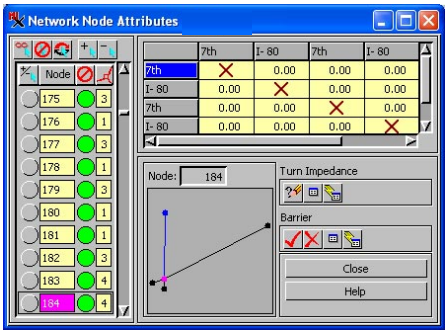
The turn matrix in the Network Node Attributes window appears as soon as you select a node using the Select Near Node tool or by clicking in the Node box in the Network Node Attributes window. A graphic depiction of the intersection and all associated lines is also shown. You can determine exactly which line is referenced in each row and column of the turn matrix by clicking on the row and column headings in the turn matrix. The line referenced then appears in the corresponding color in the graphic. The rows represent the lines incoming to the selected node while the columns represent the lines outgoing from the node. The incoming / outgoing identification is repeated in the DataTip associated with each heading.



The turn matrix initially shows X's for all U-turns (except at dead-ends). An X indicates that the turn is disabled. You disable other turns by right clicking in the corresponding box. The initial impedance value is then replaced by an X. U-turns can be enabled by entering a positive impedance value for these turns.

STEPS

- ☑ click on the Select Near Node icon in the Network Analysis View window
- ☑ click on the Network Node icon in the main Network Analysis window
- ☑ click on the node shown at 7th and I-80 (node 184)
- ☑ click on the first "7th" entry at the left of the turn matrix in the Network Node Attributes window
- ☑ right-click on each entry in the matrix that represents a turn from I-80 onto 7th or vice versa
- ☑ click on the node indicated at Superior and I-80 (node 156), and right-click on all entries that represent turns between I-80 and Superior



If you left-click in the turn matrix, a Prompt window opens so you can alter any value. Negative one (-1) is the numeric equivalent of disabled.

If you can proceed in only one direction from each incoming line, there should be only one numeric entry in each column of the turn matrix.

	7th	I- 80	7th	I- 80
7th	X	X	0.00	X
I- 80	X	X	X	0.00
7th	0.00	X	X	X
I- 80	X	0.00	X	X

The turn matrix for node 184 should appear as above when complete.

	Superior	Superior	I- 80	I- 80
Superior	X	0.00	X	X
Superior	0.00	X	X	0.00
I- 80	X	X	X	X
I- 80	X	X	0.00	X

The turn matrix for node 156 should appear as above when complete.

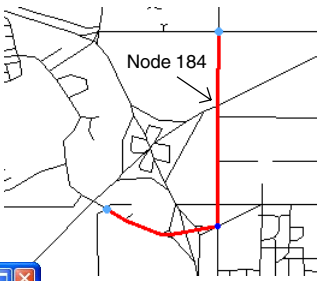
Saving Assigned Attributes

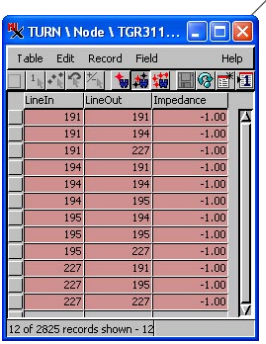
STEPS

- ☑ click on the Clear Route icon 
- ☑ click on the Calculate Route icon 
- ☑ note the significant alteration between this route and that determined in the exercise on page 10
- ☑ click on the Write Table icon in the Turn Impedance panel of the Network Node Attributes window 
- ☑ click [OK] in the Turn Table window to accept the default table name and description
- ☑ click on the Show Layer Manager icon on the toolbar in the Network Analysis View window if the Layer Manager is not open
- ☑ select nodes for drawing by turning on the Show Nodes toggle in the Vector Layer Controls
- ☑ expand the vector layer and the nodes in the Layer Manager
- ☑ turn on the Select icon for nodes, and open the Turn table 
- ☑ click on the Select icon on the Network Analysis View window toolbar, and select individual nodes to view the associated turn information (in particular nodes 184 and 156, for which you disabled turns in the previous exercise, but others as well) 

You have assigned attributes for both lines and nodes in the course of the exercises on the last few pages. You will assign more attributes to lines in the exercise on the next page, so we will wait to save those attributes. Assigned attributes are saved as database tables. These tables can be reloaded for subsequent network analysis sessions. You can also alter or add to the node and line attribute information and save it again, replacing the original table, or save it as an additional attributes table. You might want multiple attributes tables for the same vector object depending on the focus of the network analysis. For example, the ability to use certain streets or cross certain intersections may be quite different depending on whether the calculated path is intended for vehicles or pedestrians.

In order to view database records associated with selected elements, those elements must be selected for drawing and the Select tool must be active. Attached records are not located when you use the Select Near Node tool that identifies associated node information in the Node Attributes window.





The Turn table includes entries only for fields in the turn matrix with non-zero impedance values. This tabular view shows all the turn impedance information associated with node 184.

Marking One-Way Streets

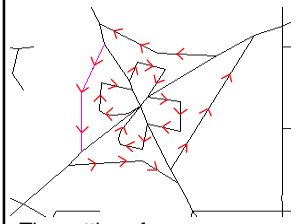
Identifying disabled turns in the exercise on page 11 changed the calculated route sufficiently that wrong way travel was no longer an issue when the new route was calculated in the exercise on page 12. However, to prevent wrong-way travel for all routes, you need to mark one way streets. It is not necessary to set the turn impedances to prevent turning the wrong way when unidirectionality has been assigned to a line.

There are a total of eight lines in the cloverleaf that require one-way assignment. The allowed directions of travel are indicated by the arrows in the cloverleaf enlargement at the right. Some of these roads have no name shown in the Network Line Attributes window because the original TIGER file does not have this attribute for these unnamed access and interchange roads.

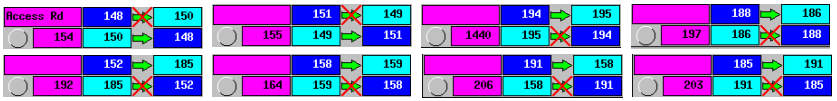
When you click on a line in the View window, the line list automatically scrolls so that line is visible, and highlights it in the active line color both in the View window and in the list. The line and the two associated nodes are also shown in the upper right of the Line Attributes window. The nodes are color coded so the direction of travel is easy to determine.

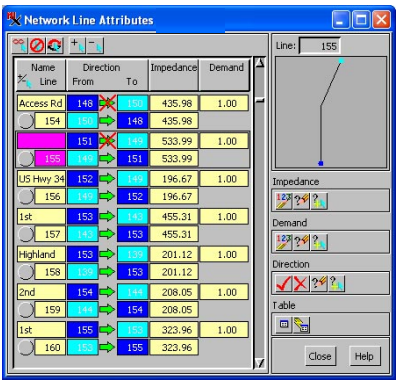
STEPS

- ☑ zoom up on the cloverleaf
- ☑ with the Network Lines icon on (Network Analysis window) click on the Select Near Line icon in the View
- ☑ click on each of the eight lines and turn off the wrong-way direction by clicking on the green arrow; look at the line diagrams (below and in the Network Line Attributes window) and node colors to determine the direction to disable

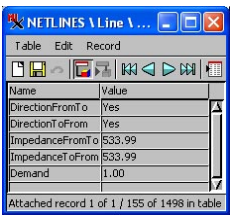


The settings for access roads (top row) and interchanges (bottom) are shown below starting at the North and moving anti-clockwise.





- ☑ click on the Write Table icon in the Table panel of the Network Line Attributes window and accept the default table name



Single record view of line attributes for line 155 after saving table.

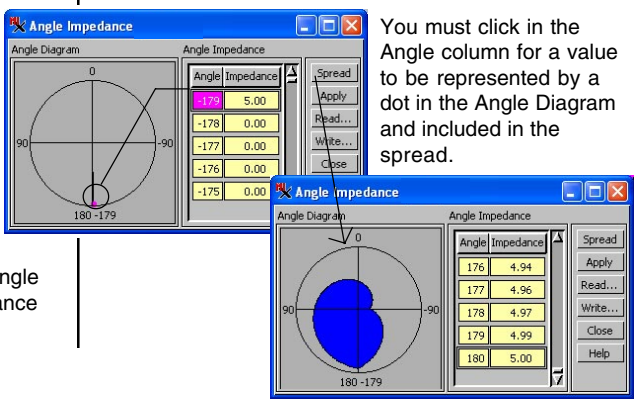
Angle Impedance Assistant

STEPS

- ☑ have the Network Node icon on in the Network Analysis window
- ☑ if you have exited the Network Analysis process since completing the exercise on page 12, click on the Read Table icon and select the table saved in that exercise
- ☑ click on the Edit icon in the Turn Impedance panel of the Network Node Attributes window
- ☑ click on the first field in the Angle column (-179) and note the dot (also in the Selected Angle color) in that position on the Angle Diagram
- ☑ click in the Impedance field and change the value for this angle to 5
- ☑ scroll down to -90 or click inside the circle near -90 in the diagram and scroll as necessary, then click on -90 in the angle column
- ☑ change the Impedance value for this angle to 1
- ☑ repeat steps 6 and 7 but substitute 0 for the Angle and 0.1 for the Impedance
- ☑ repeat steps 6 and 7 except substitute 90 for the Angle and 3 for the Impedance
- ☑ repeat steps 6 and 7 except substitute 180 for the Angle and 5 for the Impedance
- ☑ click on [Spread]

Just as some line characteristics, such as length and speed limit, can be used to determine impedance for all lines, turn angle can be used to assign impedance at all intersections. Angle impedance is not simply a property of nodes; it depends on which line(s) you use to approach and leave the node. Assigning a higher impedance to left than right turns implies a longer time delay for left than right turns, which is generally true (at least in countries that drive on the right). These impedance values are only assigned to enabled turns; recall that all U-turns, except those on dead-end roads, are disabled by default.

The angles you select and values you enter in the Angle Impedance window define the spread intervals and ranges. A spread applies an even gradation between the impedance values set for one selected angle and the next. In this exercise, angles from -179 to -90 have values evenly spread between 5 and 1, respectively. Angles from -90 to 0 have impedance values from 1 to 0.1; angles from 0 to 90 have values spread from 0.1 to 3, and so on. As successive angles are selected for inclusion in the spread, their dots in the Angle Diagram are connected by an arc (in the Spread Range color). If you do not see a colored arc on the Angle Diagram, you have not yet selected two angles. Angles are deselected once a spread is applied.



You must click in the Angle column for a value to be represented by a dot in the Angle Diagram and included in the spread.

Spread, Apply, and Save

You can enter specific angle impedance values that you do not want to include in a spread by clicking in the impedance column to change the value without also clicking in the Angle column (1, below right). Such entered values will, however, be replaced if you apply a spread over a range that includes the angle. You can also select a narrowed range for spreading and alter the initial result in a portion of the Angle Diagram (2 and 3).

The Angle Impedance window keeps its last settings throughout the current Network Analysis session regardless of whether you apply any changes before you close the window. If you want to "clear" the Angle Diagram, select 180 and -179, set them both to zero, and click on the Spread button.

The Angle table you save is basically a "lookup table" for the Turn table. If the value you see in the turn matrix is found in the Angle table, it is not also saved in the Turn table. If the value in the turn matrix has been changed from the value assigned by the Angle Impedance Diagram, it is stored in the Turn table. The Turn table you would get if you save following this exercise is exactly the same as you saved on page 12; you have not changed any numeric impedance values from those determined by the Angle Diagram.

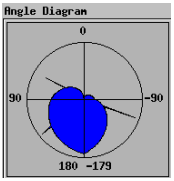
The independence of the Turn and Angle tables makes it possible to mix and match these tables when determining routes and allocation. Just be sure to read and apply the desired Angle table before you read the Turn table. The Angle table acts as a lookup table for the Turn table, which keeps the Turn table from becoming any larger than necessary. The Turn table contains only the exceptions to the information supplied by the Angle Diagram.

STEPS

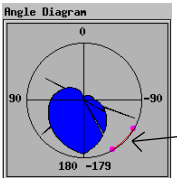
- ☑ click on [Apply]
- ☑ click on [Write] and accept the defaults
- ☑ click on [Close]
- ☑ click on the Select Near Node icon, select node 184, and compare the turn matrix to that before applying impedance from the Angle Diagram (see page 11)

	7th	I- 80	7th	I- 80
7th	X	X	0.13	X
I- 80	X	X	X	0.33
7th	0.11	X	X	X
I- 80	X	0.17	X	X

1) Impedance values for individual angles have been increased from that assigned by the spread.

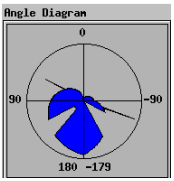


2) New, limited spread range defined (-120 to -150).



spread range graphic indicator

3) Spread range from -150 to -120 then from 120 to 140 altered after initial spread and other changes.



Panning to Selected Elements

If you have not already taken a break, before this exercise is a good time for one. Select the same object and read the saved tables before beginning again.

STEPS

☑ zoom up on the cloverleaf

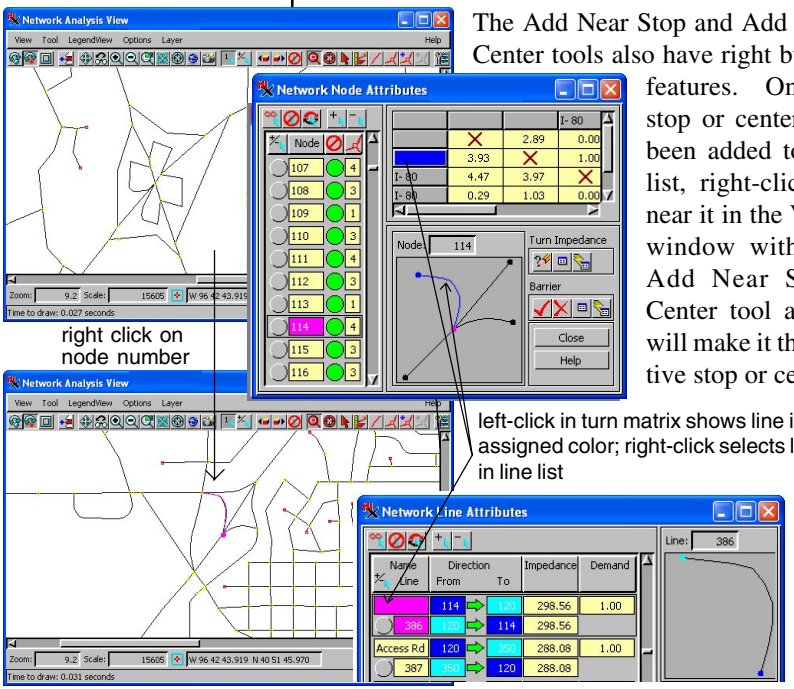
☑ click on the Network Nodes icon if the Network Node Attributes window is not open

☑ scroll the Node list in this window and use the left mouse button to click on a variety of node entries in the list; note the View does not change

☑ right-click on an entry in the list and note the View scrolls to center the newly selected node

There are so many features available in the Network Analysis process that some will initially appear hidden from the novice user because the features are assigned to the right mouse button. You were introduced to a short cut for disabling turns available from the right mouse button (page 11). You are introduced to a number of other right mouse button features in this exercise.

The Network Node Attributes window is also tied to the Network Line Attributes window if you right-click an incoming or outgoing line name in the turn matrix. A left click on the line name in the turn matrix shows that line in the assigned color in the graphic panel of the Network Node Attributes window. A right-click scrolls the line list in the Network Line Attributes window as necessary to select the corresponding line and highlights the line in the View window.



The Add Near Stop and Add Near Center tools also have right button features. Once a stop or center has been added to the list, right-clicking near it in the View window with the Add Near Stop/ Center tool active will make it the active stop or center.

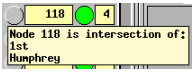
Network Node Attributes Window

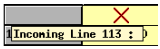
You have used the Network Node and Line Attributes windows in a number of exercises without a detailed description of the interface components. The time has come for such a description. The windows are presented separately because their features are so numerous and not all are further discussed in other exercises.

STEPS

- ☑ with the Network Node Attributes window open, move the cursor down the nodes list, pausing for DataTips on a number of different nodes
- ☑ click on a node field and observe the DataTips for some incoming and outgoing lines in the turn matrix
- ☑ click on incoming and outgoing line name fields in the turn matrix and observe the effects in the graphic panel

The DataTips for nodes tell whether the node is on a line, at an intersection or a deadend and provides names for the streets involved.





The DataTips for the lines in the turn matrix tell whether the line is incoming or outgoing relative to the active node, the line number, and the name of the line if named.

The Append / Subtract Selection icons add or subtract the nodes selected in the View window to the nodes selected in the Network Node Attributes window. Thus, you can use any of the generally available selection tools, including selection by query, to determine what is selected in the list.

Clicking on name fields (left button) shows field and corresponding line (in graphic panel) in incoming / outgoing color. Right-clicking highlights line in View window and, if open, in the Network Line Attributes window.

Turns off all Selection buttons.

Turn matrix (you can scroll to see all the values or, preferably, enlarge the window).

Turns on all Selection buttons.

Opens Angle Impedance window.

Toggles state of Selection buttons.

Updates turn matrix with previously saved Turn table values.

Selection buttons let you select nodes for application of group action (set/remove barrier).

Creates Turn table from values in matrix (see page 15).

Creates Barrier table from current settings.

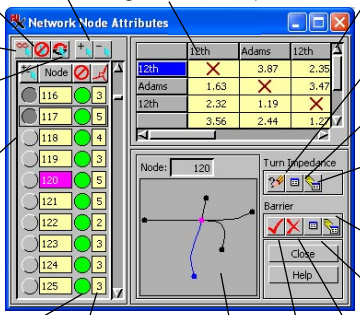
Read Barrier table.

Remove Barrier status.

Barrier indicator (red if barrier).

Number of lines attached to node.

Set Barrier status for selected nodes.



The graphic panel shows all lines attached to the active node. The elements shown are updated by selecting a new node in the node list, using the Select Near Node tool in the View window, or clicking on a peripheral node to "walk" along a line (see next exercise).

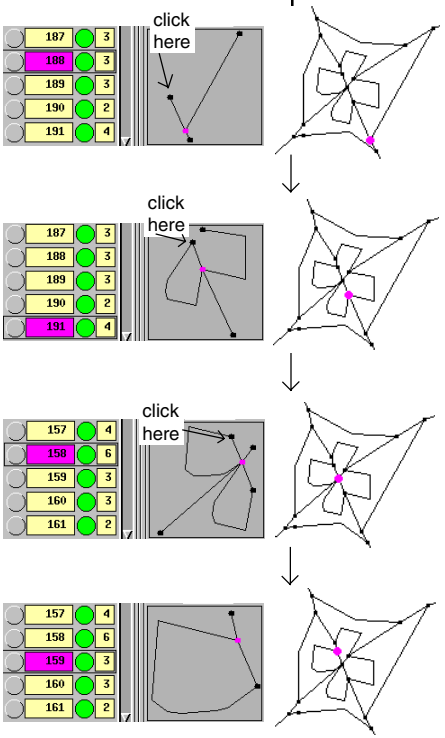
Stepping through the Network

STEPS

- ☑ with the Network Node Attributes window open and a node selected, click on one of the peripheral nodes in the graphic area
- ☑ note the effect in the Network Node Attributes window and the View window
- ☑ repeat steps 1 and 2 several times (you need not follow along a single road as shown in the illustration)

Each time you click a peripheral node (a node to one side or the other of the currently selected node) in the graphic panel of the Network Node Attributes window, you change the active node for network analysis. The information for the new active node is shown in the turn matrix and the corresponding node is drawn in active node style in the View window. Remember you can right-click on the active node field to scroll the contents of the View window if you step to a node currently out of the View. You can also right-click on a line of interest in the turn matrix to scroll the line list in the Network Line Attributes window to show its information.

There is some ambiguity in the application of the words *active* and *marked* to elements in the Network Analysis process. When you use the GeoToolbox or queries to mark (select) elements in the View window, you end up with an active element that is part (or all) of the marked set. There is no direct correspondence between this marked set and being selected for network analysis operations until you click on the Append / Subtract Selection icon. The active element from the marked set does not translate into the active element for network analysis in any case; this active status is only conferred by clicking on an element with the Select Near Node / Line tool active or by clicking on it in the node / line list in the corresponding Network Attributes window. Additionally, the active node can be changed by the methods described in this exercise.



Network Line Attributes Window

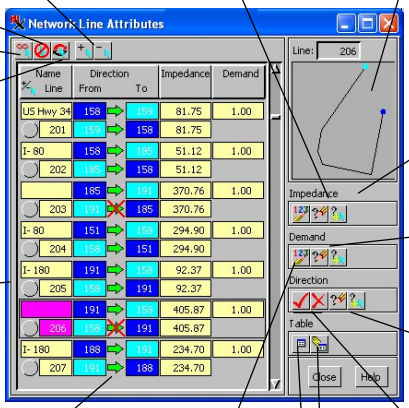
The attributes for network lines are stored in a single table that includes impedance, demand, and directional restrictions for each line in the object. The attributes for network nodes are stored in separate tables: Turn, Angle, Barrier, Stop, and Center. The Turn table is a special table that you cannot directly edit. It contains as many records for each node as are necessary to fully define turn impedance for that node, which can be up to the square of the number of connected lines. The Angle table has 360 or fewer records. The Barrier table has one record for each node with a single logical (yes / no) field.

STEPS

- ☑ with the Network Node and Network Line Attributes windows open, right-click on one of the line names in the turn matrix (Node Attributes)
- ☑ note the effect in the Network Line Attributes and View windows
- ☑ use the Select Near line tool to select a different line
- ☑ repeat steps 1, 2, and 3 several times
- ☑ examine the available DataTips

The Append / Subtract Selection icons add or subtract the lines selected in the View window to the lines selected in the Network Line Attributes window. Thus, you can use any of the generally available selection tools, including selection by query, to determine what is selected in the list. For example, you could disable all residential streets for large truck traffic.

The graphic panel shows the active line with end nodes color coded to define direction. The line shown is updated by selecting a new line in the line list or using the Select Near Line tool in the View window.



Turns off all Selection buttons.

Lets you enter an impedance value for all selected lines.

Turns on all Selection buttons.

Toggles state of Selection buttons.

Enter/apply a query to determine impedance values.

Selection buttons let you select lines for application of group action (set demand / impedance, enable/disable directions).

Enter/apply a query to determine demand values.

Enter/apply a query to set allowable directions.

Enable/disable direction toggles.

Lets you enter a demand value for all selected lines.

Open a network line attributes table to update the impedance, demand, and disabled directions for lines.

Save the current impedance, demand, and directionality of lines as a database table.

Enable/disable travel in both directions for all selected lines.

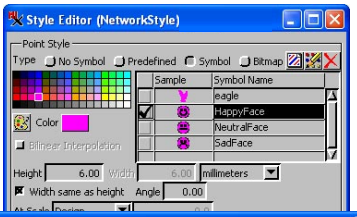
More About Styles

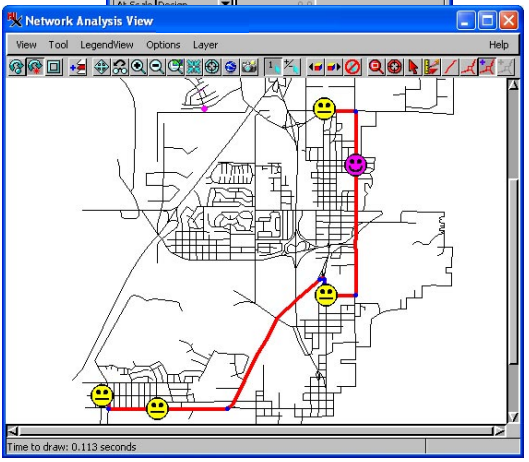
STEPS

- ☑ click on the Preferences icon in the Network Analysis window 
- ☑ click on the General tab (if it's not already selected), then on the [Styles] button, and select the NETWORK-STYLE object from the NETWORK Project File
- ☑ click on the Route tab and set the Active Stop color to magenta (100% red, 100% blue)
- ☑ with the Active Stop option button set to Standard, click on its Specify icon 
- ☑ set the Point Style Type to Symbol, check the box next to the Happy Face symbol, and set the Height to 6 mm
- ☑ with the Stop option button set to Standard, click on its Specify icon, set the Point Style Type to Symbol, and select NeutralFace from the symbol list 
- ☑ set the Path color as a solid, red line, 1 mm width
- ☑ place 4 or 5 stops, then calculate the route 
- ☑ click on the stops list in the Network Analysis window to change the active stop and notice the effect

For most vector applications, you are better off to use styles stored as a subobject of the vector rather than as a main level object. A style subobject keeps the drawing styles with the vector so they do not get separated inadvertently when transferring files. The styles used in Network Analysis, however, are not specific to the input vector object but rather to the temporary, network vector object generated in the process. You will want to have the same symbols and patterns available for use with a variety of input objects. You can select a subobject for use, as you did on page 6, but it is often difficult to remember just which vector has the desired subobject.

The style object used in this exercise has two symbols selected from the style objects provided with the TNT products and several derived from glyphs in TrueType fonts. How to acquire symbols from these sources and how to create your own are described in the *Creating and Using Styles* booklet.





If you choose a symbol or line pattern for the active node or line, respectively, they will appear in the View window as designated but not in the corresponding Network Attributes window. The Network Attributes windows incorporate the active color but not symbolic representation.

Allocation Networks

Allocation refers to the movement of materials into or out of a number of centers all of which serve the same purpose, such as elementary schools, fire stations, or warehouses. The line and node attributes you identify for routing are also relevant for allocation. For example, you probably want to include length as a factor in the impedance so that the distance traveled, rather than the number of lines, is used when making allocation assignments. Allowable turn directions may also make a difference in which center a street is assigned to.

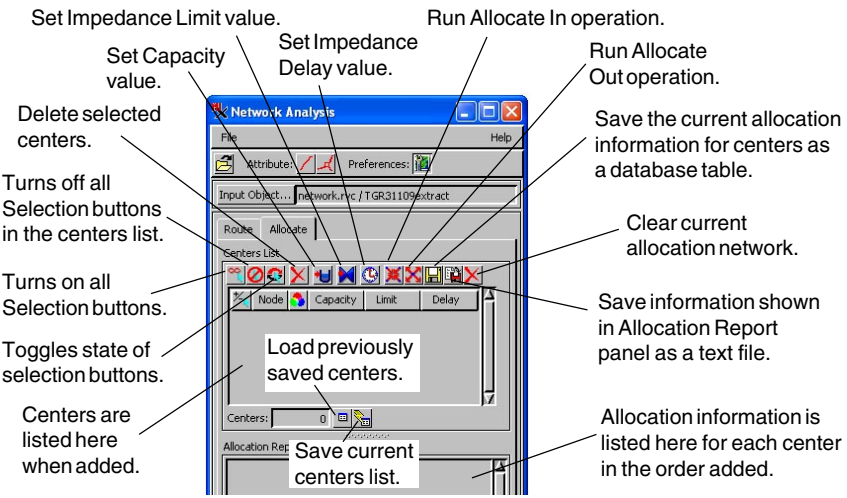
Additional constraints are important in identifying centers, such as the maximum capacity and the impedance limit. Demand values are necessary before capacity limits can be meaningful. Each line has a default demand value of 1.00 so that in the absence of actual demand information, the capacity of a center is reached when the number of lines in its network equals the limit set. Impedance limits, such as the maximum distance of travel to a center, can be reasonably set and applied with no more information than the standard vector attributes.

Vocabulary: The **Allocate In** function identifies the network lines that should be used to bring people or materials to each identified center. Getting children to school is an "Allocate In" operation. The **Allocate Out** function identifies the network lines that should be used to distribute from a center. Determining pizza delivery areas for a pizzeria with multiple locations is an "Allocate Out" operation.

STEPS

- ☑ click on the Allocate tab
- ☑ move and pause the cursor over the various icons to familiarize yourself with their functions
- ☑ turn off display of nodes

Note that the Network Node and Line Attributes and Preferences windows can be open at the same time. Close these windows by clicking on their icons again.



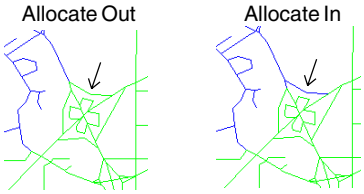
Allocation without Constraints

STEPS

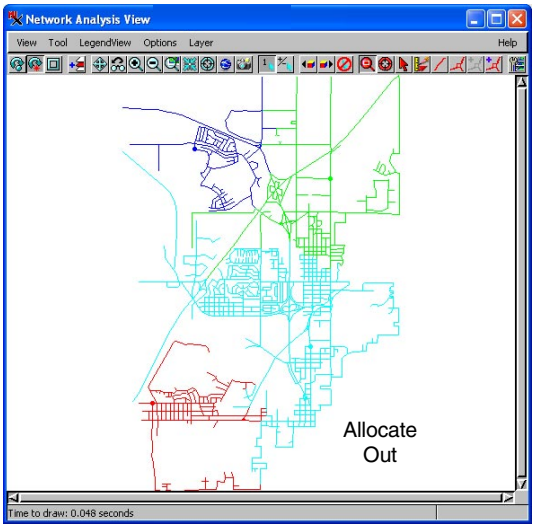
- ☑ click on the Add Near Center icon in the View window 
- ☑ add four widely spaced centers as illustrated
- ☑ click on the Allocate Out icon and note the results 
- ☑ examine the report
- ☑ click on the Clear Allocation icon 
- ☑ click on the Allocate In icon 
- ☑ compare the results

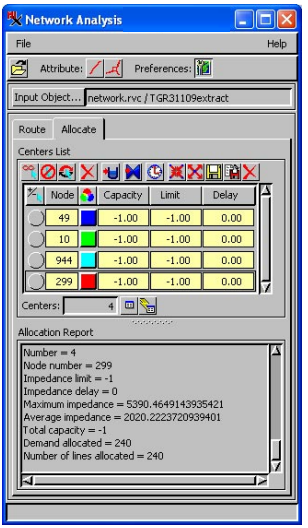
If at any time you exit the Network Analysis process and start again for one of the exercises, it is assumed that you open the same object used throughout this booklet and reload the NETLINES, ANGLE, and TURN tables for any exercise after page 15. (See page 15 if you do not recall how to reload both turn and angle values.)

Demand, capacity, and impedance limits have dramatic effects on an allocation network, as you will see in later exercises. Without such constraints, all lines in the selected object are assigned to one center or another (unless attributes prevent assignment). The lines assigned to centers will often change between Allocate In and Allocate Out operations where different center networks meet when line and node attributes are taken into account. Expert evaluation is still required to assess the feasibility of the network, as shown at the left where one line switches center assignment between Allocate In and Out operations; it makes no sense for a distal line in a network to be a highway offramp.



Node and line attributes affect a center's line assignments.





Impedance Limits

Allocation networks are subject to additional constraints that do not apply in the routing situation. One of these constraints is an impedance limit, which is the maximum impedance allowed for any path to a center. You may own a business that delivers products from a number of locations and discover that there is some great advantage (insurance, vehicle wear and tear, customer satisfaction, or other factors) to limiting the delivery area for each to 5 kilometers. You may, for example, want to plan the location of schools so that children have to walk no further than 2.5 kilometers. You then enter the maximum desired travel distance as the impedance limit. This limit can be the same for all centers or different for one or more centers.

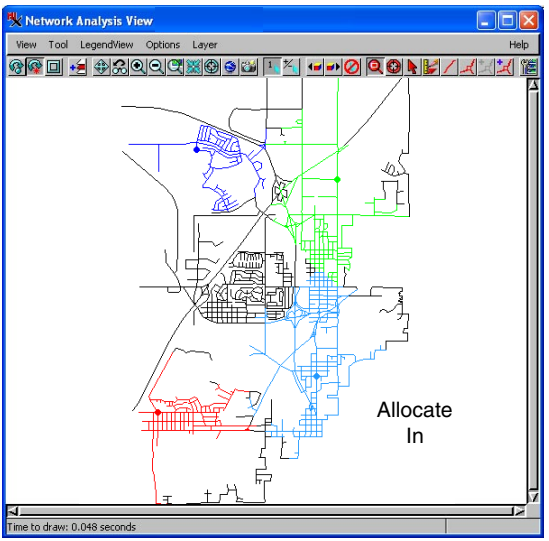
When impedance limits are set, all lines may not be assigned to one of the centers. You can simply accept these gaps in coverage, you can consider repositioning centers to achieve complete coverage, or you may rethink the limit you set. Unfortunately, we know of no algorithm that can determine the "optimal" placement of centers so that the entire area is covered with the fewest number of centers.

You enter a single value for all selected centers in this exercise. You can set the Impedance Limit Value for individual centers by clicking in the Limit column for that center in the Centers List. You can also use the Set Impedance Limit Value icon with fewer than all of the centers selected, and the entered value will be assigned only to those selected.

STEPS

- ☑ click on the Clear Allocation icon 
- ☑ click on the Include All icon at the left above the list of centers 
- ☑ click on the Set Impedance Limit Value icon 
- ☑ enter 2500 and click [OK]
- ☑ click on the Allocate In icon and note the results 

An impedance limit of 2.5 km does not provide full coverage of the area with the existing centers (black lines are not covered).



Locating Centers

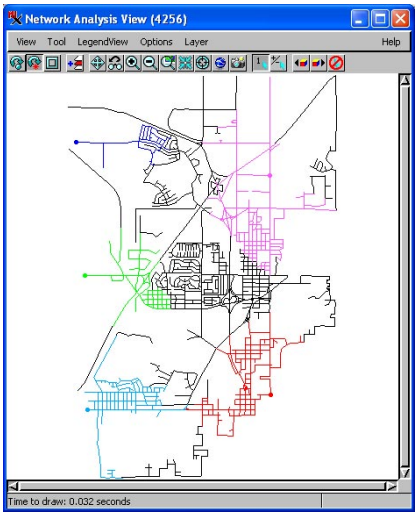
STEPS

- ☑ click on the Include All icon then on the Delete Selected Centers icon (the 4th icon from the left, not the rightmost)
- ☑ add five centers positioned approximately as shown
- ☑ click on the Include All icon then on the Set Impedance Limit Value icon, enter 2500, and click [OK]
- ☑ click on the Allocate In icon
- ☑ click on Delete Selected Centers
- ☑ add five new centers positioned near an inner edge of the first allocation areas (except as shown)
- ☑ repeat steps 3 and 4
- ☑ set the Impedance Limit for all centers back to -1.0

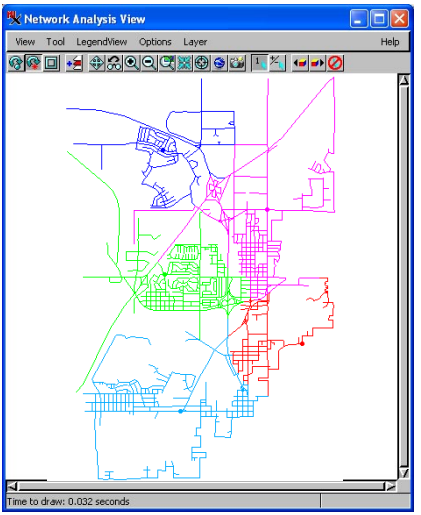
One strategy for locating centers that have an impedance limit is to first position a few centers at or near the periphery of the vector object and run the desired Allocation operation. Next, reposition the centers to be nearer to the interior edge of the allocation areas determined, and run the allocation again.

The example on this page again points out the importance of a knowledgeable user to determine how the centers should be positioned initially and then how they should be repositioned to improve the allocation results. It may not always be possible to find locations for the desired number of centers with an impdance limit imposed, which may be acceptable. For example, if the centers are schools and some areas fall outside the impedance limit, busing could be provided for those areas. Other possibilities are to change the impedance limit so that more lines are included for each center or to increase the number of centers.

centers positioned near edge

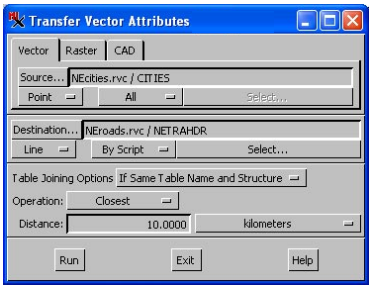


centers moved to inner edge of originally allocated area and reallocated



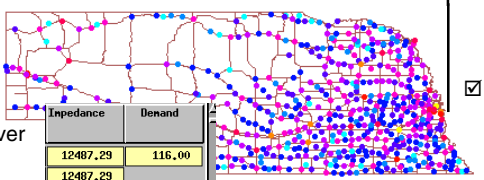
Establishing Demand

Establishing demand from the types of data generally available is often not a straight forward task. Population is one of the most common factors used to establish demand. However, population data is usually point data and demand is a line associated attribute. You can use the Transfer Attributes process to associate the point population data with the lines you plan to use for network analysis. Often vector objects include an outline, such as city, county, or state boundaries, that does not represent lines that can be used for travel. You can avoid attaching population attributes to such lines using selected key field attributes or a query to limit the lines eligible for attribute transfer.



The method described for attribute transfer to lines often results in the attachment of multiple records to many of the lines (for example, household population data transferred to city streets). A special query statement (shown below) is necessary for all attached records, rather than just the first attached record, to be considered when determining demand.

(Internal.LeftPoly > 0) and (Internal.RightPoly > 0)



Impedance	Demand
12487.29	116.00
12487.29	
7219.59	1196.00
7219.59	

Points for attribute transfer displayed over recipient network lines.

DemandOfLine = SetSum(CITY[*].POPULATION)

* Choose By Attribute only if the lines have a key field attribute that distinguishes lines appropriate for inclusion in the network from those that are not. The script suggested is intended only for the situation where all but the outer bounding lines are appropriate for use as network lines.

This exercise is intended for appropriate data of your own. If you do not have such data now, remember this reference for when you acquire such data.

STEPS

- ☑ choose Geometric / Attributes / Transfer Attributes
- ☑ click on [Source] and select the vector object that contains points with attributes you want to use to establish demand
- ☑ click on Destination and select the object you will use in Network Analysis
- ☑ set the destination element to Lines and the select option menu to By Attribute or By Script*
- ☑ click on [Select] and choose the attributes or enter the query at the left, then click [OK]
- ☑ set the distance high enough that all records will be transferred, and click on [Run]
- ☑ launch the Network Analysis process, select the vector to which attributes were transferred and follow the procedure on page 9 to assign impedance by length
- ☑ click on the Edit Query icon for Demand, entering the query at the left but substituting the name of your table and field for CITY and POPULATION, respectively
- ☑ click on the Apply Query icon in the Demand panel

Introducing Capacity

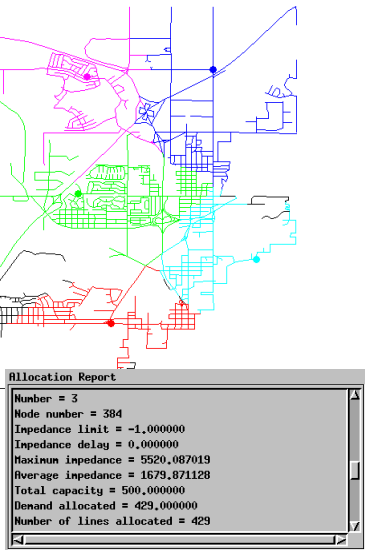
If you did the last exercise, continue with that object for this exercise. You will need to add centers and adjust capacity values to be in line with the demand you assigned.

STEPS

- ☑ if you don't have your own vector with demand values assigned, pick up where you left off on page 24
- ☑ click on the Include All icon in the Centers List panel 
- ☑ click on the Set Capacity Value icon 
- ☑ enter 250 and click [OK]
- ☑ click on the Allocate In icon (or Allocate Out if more appropriate for your demand data) 
- ☑ choose a center with unassigned lines on all sides, click on its capacity field, enter 500, and click [OK]
- ☑ again click on Allocate In (or Out) 
- ☑ scroll through the report and note how closely each center comes to being at full capacity

Capacity is the number that can be accommodated by a center. It may be the number of students a school can accommodate, the quantity of perishable goods that can be delivered in a day, the number of seats in a theater, or the number of parking spaces at a mall. The capacity of the centers in a network can be the same or different. In order for capacity to be meaningfully used, you need a reasonable estimate of demand. The default demand is 1.0 for each line. Thus, without altered demand values, the capacity is reached when the number of lines feeding the center equals the value set.

An exclusive area is established as network lines are allocated to centers such that once all paths to / from a center are assigned, that center's area cannot be increased even if the center is under capacity. There are a variety of options available to you as the decision maker when you run into such circumstances: change the position of centers, alter the capacity of centers, or override the assignment of certain lines by manually reallocating territories.



Checking the report lets you judge whether the capacity of planned centers is sufficient or, perhaps, too great.

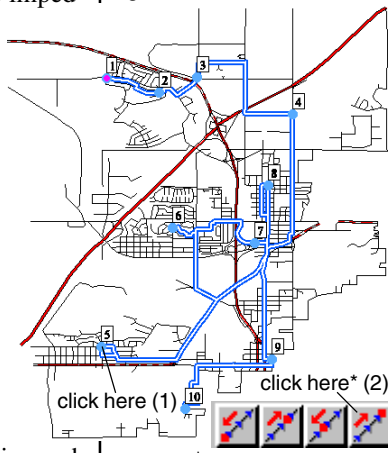
More Complex Analysis

The complexities of network analysis are many. Some have been specifically mentioned, others alluded to, and still others await your discovery.

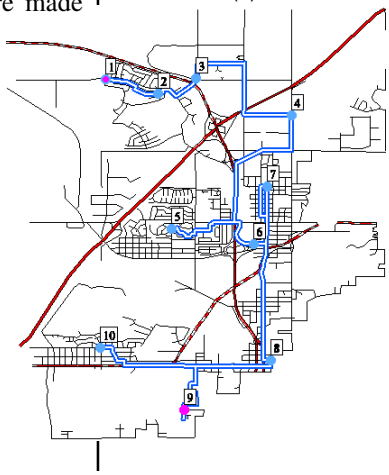
One concept not yet introduced that probably needs some explanation in this booklet is impedance delay. **Impedance delay** lets network lines be preferentially assigned to a center until the impedance delay value for another center is reached. The center to which you want lines assigned first should have an impedance delay value of zero. Other centers may have the same or different higher values assigned to them.

Network analysis problems may often require a combination of many or all of the control components available. You may have a number of closely spaced centers from which to deliver products but one has easy access to a major highway, one is in a shopping district with little parking, and so on. You may want to organize your deliveries such that all addresses within a mile of the shopping district center are delivered by bicycle from that center, intermediate distance deliveries are made by car from a different center, and the highway-convenient center makes deliveries by truck to more distant locations. The impedance delay feature helps you specify such requirements. To ensure that long distance deliveries are allocated to the desired center, you might also have to assign impedance limits to the other centers to keep their delivery areas within city limits.

Changing the order of stops is a simple matter. The initial convoluted path shown here was simplified by selecting stop 5 (click on node number in Stops list) and clicking on the Move Stop to End icon, then running the process again.




click on Calculate Route (3)



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NETWORK ANALYSIS

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