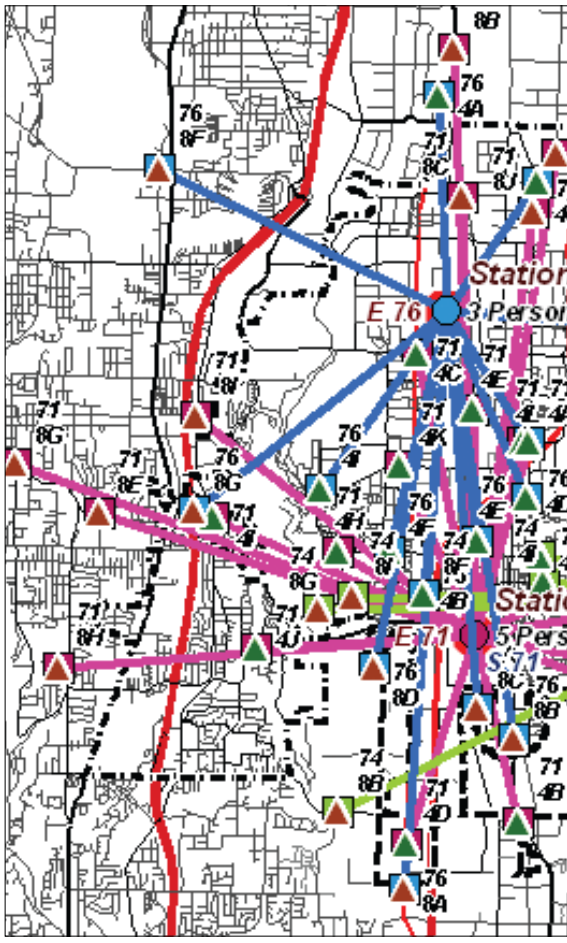
Convincing the Chief

Proving that time-based networks really work

By Mike Price, Entrada/San Juan, Inc.



Many recent *ArcUser* articles have shown how to design, build, and run time- and distance-based travel networks for emergency response modeling. These model posted or customized speeds, global turn rules, and slope corrections. Previous articles assumed that the modeling parameters and analytical findings were correct.

This tutorial uses data from Fire District (FD) 37 in South King County, Washington, and re-creates two analyses that were recently performed by agency staff to validate the district's time-based network travel model. The ArcGIS Network Analyst extension's OD (Origin-Destination) Cost Matrix will be used to test and validate actual timed trial runs for several stations.

Previous tutorials that appeared in the July–September 2007, October–December 2007, and Summer 2008 issues of *ArcUser* can be used to review the ArcGIS Network Analyst modeling method and the concepts of distribution and concentration. These articles provide more information on how emergency responders use time as a response measure.

Getting Started

To begin the exercise, visit the *ArcUser Online* Web site at www.esri.com/arcuser and download the sample dataset for this tutorial. This is the fourth in a series using Fire District 37 data, so the parent folder is named FD37_4.

1. Unzip the archived sample dataset at or near the root directory of a local drive. The archive creates a folder called FD37_4.
2. Open ArcCatalog and explore the data in FD37_4. Notice that there are three subfolders named DBFFiles, SHPFiles, and Utility. All exercise data is registered in Washington State Plane NAD83 North Zone U.S. Feet (WASP83NF).
3. Inside SHPFiles, notice the WASP83NF folder. This shapefile subfolder contains several shapefiles and layer files that will be used in this exercise.
4. Inspect the DBFFiles folder and see that Time_Runs_1 contains run data for four FD 37 fire stations, recorded at four- and eight-minute travel points.
5. Open RunSummary1.xls and see that it contains one worksheet, Statistical Summaries, that is ready to tabulate statistics for the four- and eight-minute runs for each station.
6. Leave ArcCatalog open.

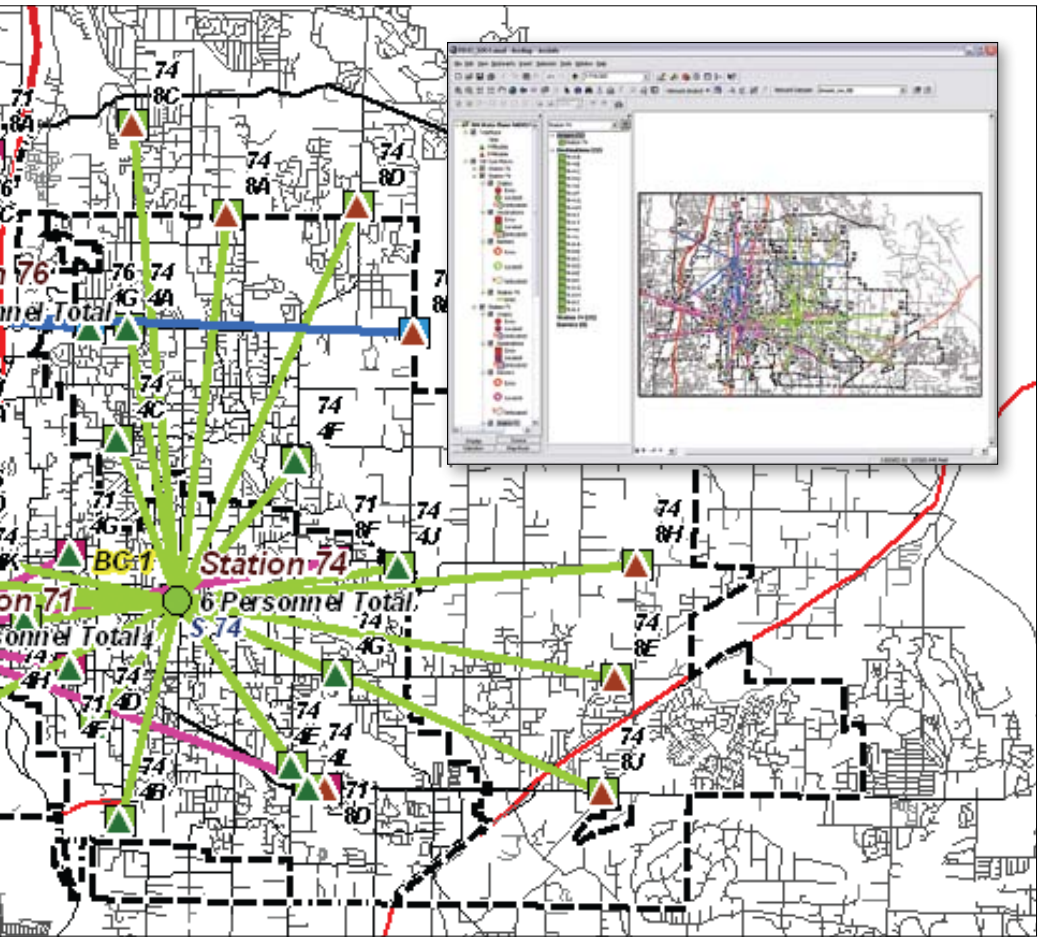
To gather data for this project, station duty crews at each station were instructed to drive 10 different routes from their station to locations on the street network. They drove the routes at speeds at or near accepted response speeds, in light to moderate daytime traffic, and in good weather. The apparatus officer noted the exact location of the four-minute and eight-minute time point on each route. These time points were then mapped and are available for this exercise as a dBASE table including WASP83NF coordinates.

Building a Network Dataset with Network Analyst 9.3

In ArcCatalog, verify that the Network Analyst extension is available and active.

1. Navigate to FD37_4/SHPFiles/WASP83NF and locate streets_nw.shp. Preview the attribute table for this layer. Notice that it contains network-ready data including fields for a time cost in minutes, length in miles, and one-way flags. These fields will be used to build a network dataset.
2. In the Catalog tree, right-click streets_nw.shp and select New Network Dataset. Accept the default name and click Next.
3. Inspect Connectivity and accept End Point as the only connector; click Next. The streets use geometry rather than elevation to define crossing relationships, so do not modify connectivity.
4. Click Next and accept Global Turns; click Next again.
5. In the network attributes window, click the Add button to add an attribute. In the new Add New Attribute dialog box, type Length_Mi for Attribute, choose Cost for Usage Type, choose Miles for Units, and leave Data Type as Double. Notice that Minutes and Oneway are both default parameters because the primary test will be fastest travel time, not the shortest distance.
6. Highlight Minutes and click the Evaluators button. In the Evaluators dialog box, select the Default Values tab. For the Turn element, click on the word Constant to see four options. These options now include a new one in ArcGIS 9.3 called Global Turn Delay. Select this option and press F12.
7. A new Global Turn Delay Evaluator appears. Notice that this evaluator supplies defaults but allows modification of the intersection approach angles and the delay times. Also notice, that feature classes can be used to create complex relationships between different street classes.
8. Save the map document.

The streets in this sample dataset are rather simple and will only require the use of one Local class. The Seconds field in this dialog box accepts values for delays for straight travel (with and without crossing roads), right and left turns, and U-turns. After tuning the streets in the sample dataset, it was determined that the delays shown in Table 1 work best throughout the district.



What You Will Need
- ArcGIS Desktop (ArcView, ArcEditor, or ArcInfo license)
- Microsoft Excel
- ArcGIS Network Analyst extension
- Sample dataset from *ArcUser Online*

This exercise models data from Fire District 37 in South King County, Washington, and re-creates two analyses to validate the district's time-based network travel model using the ArcGIS Network Analyst extension's Cost OD (Origin-Destination) Matrix.

Direction	Description	Sec
Straight	From Local to Local Road across No Roads	0
Straight	From Local to Local Road across Local Road	1
Reverse	From Local to Local Road	30
Right Turn	From Local to Local Road	2
Left Turn	From Local to Local Road	4

Table 1: Delay values

To add these values to this project, type the values for these delay values into the Seconds field, or load a prebuilt XML time set from the \Utility folder created by the sample dataset archive. To load the XML file, click the Load From File button on the dialog box, navigate to \Utility, and select GlobalTurns_00_01_02_04.xml. The optimal values will post automatically.

Turn window width can be changed interactively. After using the mouse to resize portions of the colorful azimuth graphic, reset or retype Width values (in degrees) to restore the defaults or reload the XML file. Click OK to close the Global Turn Delay Evaluator, click OK to accept the updated Evaluators, and click Next. Accept Driving Direction defaults and click Next again.

A summary of the network dataset parameters that have been set appears in a scrolling window. Select and copy this text into a WordPad file. Name the file with the creation or last modification date and save the text file in the \SHPFiles\WASP83NF folder. Inspect this file carefully and observe the new global turn rules.

Click Finish, then Yes to build the new network dataset. Once this is completed, close ArcCatalog and open ArcMap.

Loading and Mapping Network Streets and Time Runs

In ArcMap, open the FD37_SOC4 ArcMap document file located in the FD37_4 root folder. Inspect this map document. The data is very similar to data used in previous District 37 tutorials. However, in this case, only three stations appear. These stations were selected to show variety within the district. The project opens in Layout View and shows location, apparatus, and staffing for Stations 71, 74, and 76. The Time Runs layer, at the top of the TOC, does not have a valid data connection. At the end of this next process, that problem will be fixed.

Station 71 is an engine/squad station with five on-duty personnel. It is located just south of the Kent downtown area. Station 74 includes a ladder, a squad, and a battalion chief (six personnel), located on high ground in eastern Kent. It is situated on an arterial street and much of the surrounding land use is residential. Station 76 is a three-firefighter engine station located in the northern Warehouse district.

1. Before adding data to the project, confirm that the Network Analyst extension is available and its toolbar is visible.
2. Open an empty Network Analyst Window. Click the Add Data button on the Standard toolbar and navigate to \SHPFiles\WASP83NF.
3. Load the network dataset streets_nw_ND. When prompted, do not load other participating feature classes.
4. In the TOC, drag streets_nw_ND below the Network Streets and turn it off.
5. Navigate to the \DBFFiles folder and load Trial_Runs_1.dbf.

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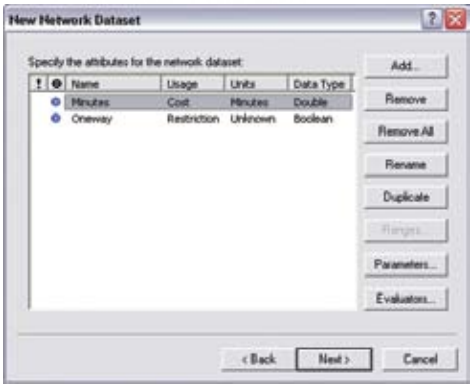
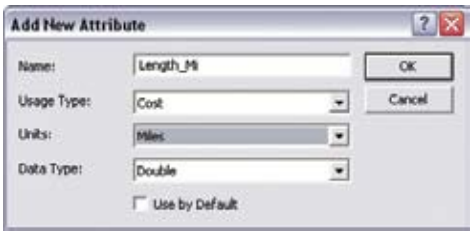


In ArcCatalog, create a new network dataset.



Create a new attribute, Length_Mi, for this network dataset with Cost as the Usage Type and Miles as the Units.

Set the default values for the Minutes evaluator and use the new Global Turn Delay for the type of turn.

Set the Seconds delays field values in the Global Turn Delay evaluator as shown here and listed in Table 1.

6. Open the table for this file and locate the East and North fields. Using these and applying the correct Washington State Plane coordinates, the data can be registered.
7. In the TOC, right-click Trial_Runs_1.dbf and choose Display XY Data. Set the X Field to East and the Y Field to North. Click Edit.
8. In the Spatial Reference Properties dialog box, click Select and specify NAD_1983_StatePlane_Washington_North_FIPS_4601_Feet from the choices under Projected as the coordinate system. Click OK and OK to exit both dialog boxes.
9. After Trial_Runs__1Events loads, right-click on it and choose Data > Export Data. Apply the data frame's coordinate system, name it Trial_Runs_1.shp, and store the file in \SHPFiles\WASP83NF. Do not add the shapefile to the data frame.
10. Next, double-click on Time Runs, the layer that has a broken data connection, and set Trail_Runs_1.shp as its data source. Remove Trial_Runs__1Events.
11. Make the Trial Runs layer visible and inspect its points. Each point is labeled to show the station, time interval, and run code. Switch from Layout View to Data View.
12. Save the project.

Building and Solving an OD Cost Matrix for Station 71

The next task will be building three origin-destination matrices—one for each station and its time run data. There are many ways to build and analyze this run data, but creating a separate matrix for each station will allow quick viewing of statistical data for each time subset. There are more sophisticated ways to model and present this data, but this exercise uses a simplified approach. After creating the matrix for Station 71, the process will be repeated for Stations 74 and 76.

1. Be sure that the Network Analyst toolbar and window are available. Click on the Network Analyst drop-down in the toolbar window and choose New OD Cost Matrix.
2. In the TOC, right-click on OD Cost Matrix (just created) and select Properties. In the General tab, rename the layer Station 71. Click the Accumulation tab and check the Length_Mi and Minutes boxes. In the Analysis Settings tab, verify that Impedance is set to Minutes.
3. Open attribute tables for Time Runs and Selected Fire Stations layers. In the Selected Stations table, select the only record for Station 71. In the Trial Runs table, use an attribute query to highlight all 22 records for Station 71.
4. In the Network Analyst window, right-click on Origins and select Load Locations. In the Load Locations dialog box, set Sort Field to INDEX. For the Name Property, click on Field and choose LABEL. Under Location Position, choose Use geometry and specify 500 and Feet for the search tolerance. Click OK. Verify that the single Station 71 record in Selected Fire Stations is selected.
5. Right-click on Destinations, choose Load Locations, and select the 22 records for Station 71 selected in the Trial Runs attribute table. In the Load Locations dialog box, set Sort Field to INDEX and the Name property field to LABEL. Be sure that the correct (i.e., selected) 22 records load. If non-Station 71 records load, delete them and reload the correct ones. (Note: Do not delete records when modeling Concentration because the tabular join to INDEX, necessary for this operation, will fail.)
6. Create new OD Matrices for Stations 74 and 76 using this procedure. Be sure to select and load the correct origin and destination records. Rename each OD matrix and group all matrices in one group layer named OD Cost Matrix Group.
7. Save the project.

Create an events layer from Time_Runs_1.dbf and export the georeferenced data to a shapefile.

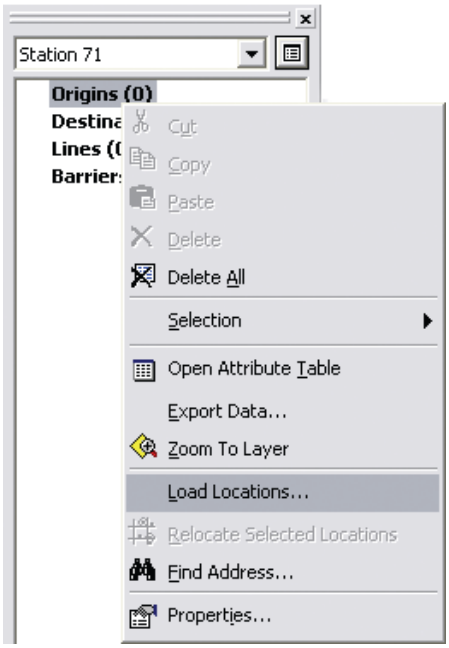
Solving and Analyzing OD Cost Matrix Results

The three matrices are now ready to solve.

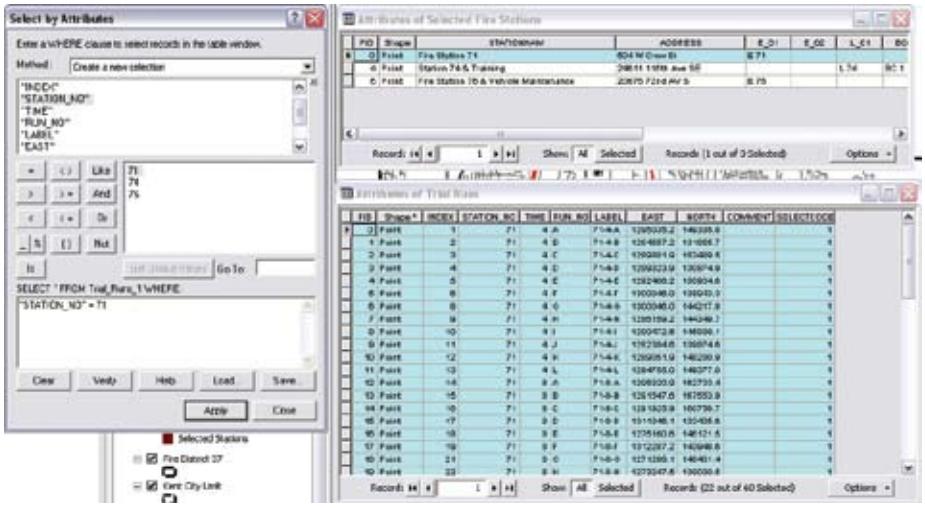
1. In the OD Matrix group, right-click on the matrix for Station 71 and select Solve. Under Destinations, Lines will be populated.
2. Right-click on Lines, choose Properties, and use the General tab to rename it Station 71. Using Properties, also change the line width to a three-point width and apply bright distinct colors.
3. Repeat this process for the Station 74 and 76 matrices.
4. Save the map document again.

This exercise builds two-node vector lines that show the connection between a fire station and its trial run points. Network Analyst actually posts the shortest travel time and route distance in the Lines table. Although the route is represented by a straight line, it actually follows the fastest network.

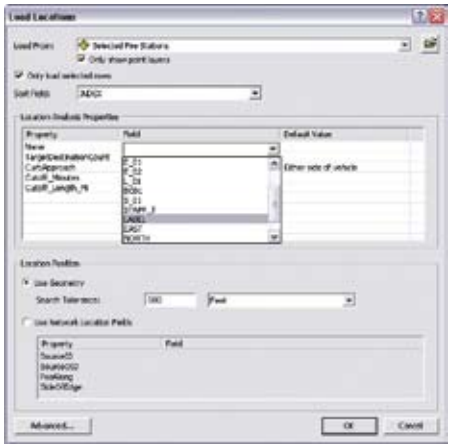
1. Under the OD Cost Matrix group, right-click on the Lines solution for each station and open its attribute table. Stack the tables. Select the four-minute records for each station by querying out records with Total_Minutes less than 5.0.
2. To quickly tabulate and display statistics for each station's four-minute runs, locate and right-click on each table's Total_Minutes field and choose Statistics.



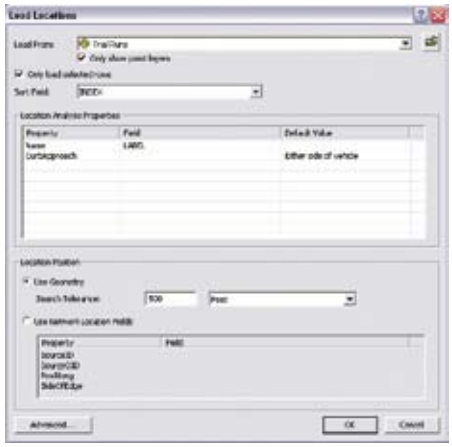
In the Network Analyst window, load the locations in the OD Cost Matrix for Station 71 by right-clicking on Origins and choosing Load Locations.



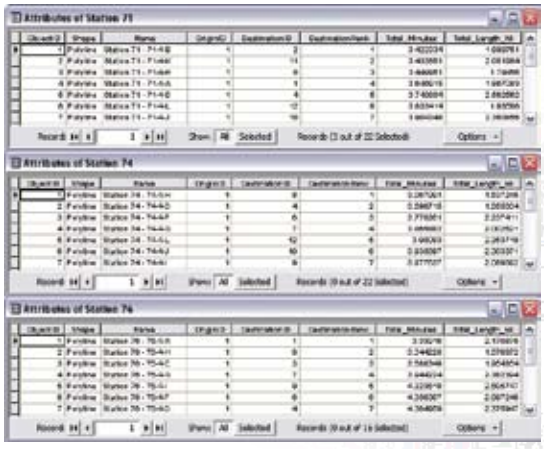
In the Selected Fire Stations table, select the only record for Station 71. In the Trial Runs table, use an attribute query to highlight all 22 records for Station 71.



In the Load Locations dialog box for Selected Fire Stations, set Sort Field to INDEX, set the field for Name property as LABEL, and under Location Position, choose Use Geometry and specify 500 and Feet for the search tolerance.



Right-click on Destinations, choose Load Locations, and select the 22 records for Station 71 selected in the Trial Runs attribute table. In the Load Locations dialog box, set Sort Field to INDEX and the Name property field to LABEL.



Under the OD Cost Matrix group, right-click on the Lines solution for each station and open its attribute table. Stack the tables.

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3. Inspect the statistics for the sub-four-minute runs for each table, particularly the Mean and Standard Deviation values.

It certainly would be nice to place this data in a table so it could be studied. To quickly post this summary data, open the Excel spreadsheet template, RunSummary1.xls, provided in the sample dataset, and copy values from the four-minute statistics generated for each station to the appropriate cells in the spreadsheet.

In ArcMap, under the four-minute statistics for Station 71, copy and paste the Mean value from the summary spreadsheet to the Mean, Minutes field in the attribute table for Station 71 in ArcMap. Repeat for the Run Count; Maximum, Minutes; Minimum, Minutes; and Standard Deviation fields. Gather the same statistical data for Stations 74 and 76.

To generate statistics the eight-minute run data for each station, simply click the Options tab on the table for each station and chose Switch Selection. Copy and paste the eight-minute run statistics into the spreadsheet.

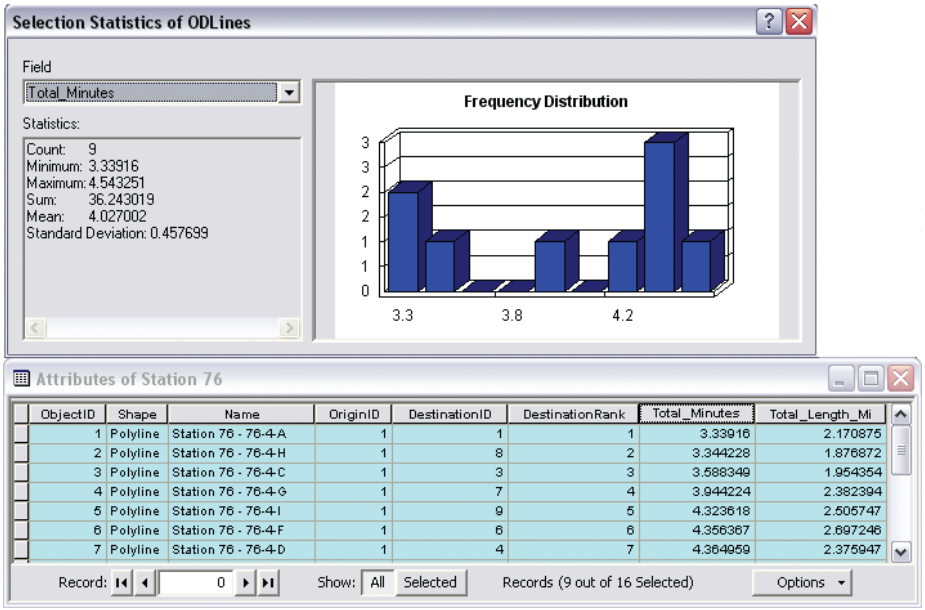
Now that the time Runs for three District 37 fire stations have been summarized, inspect RunSummary1.xls. Notice that the mean values for all four- and eight-minute runs are very close to the target times. In each station's travel area, the average actual time is very close to the targets. Each station's dataset includes records that represent times greater than and less than the targets. Smaller standard deviation values suggest tighter clustering around the mean. In general, District 37 managers are very satisfied with the performance of this travel network. These trial runs have shown that slightly liberal turn rules and posted speed are valid measures of emergency response capability.

Summary

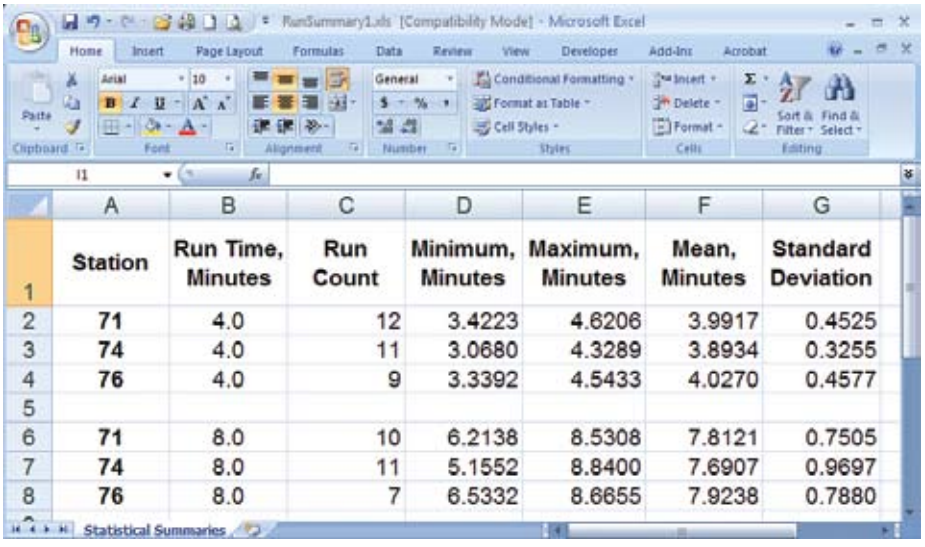
This exercise used the Network Analyst OD Cost Matrix to compare actual measured travel times to modeled values. Overall, this analysis demonstrated a very good correlation between modeled and actual times. District 37 personnel continue assessing travel times and testing additional details that might improve the response model. As a corollary to this exercise, District 37 has also recognized the potential to use an OD cost matrix to test and validate actual travel times to specific incidents.

Acknowledgments

Special thanks go to the administration and staff of Fire District 37, South King County, Washington, and the many FD 37 and Kent City staff who provided data for this exercise. This allowed the mapping and evaluation of actual run time data captured by district firefighters and modeled real travel time data on city streets.



To quickly tabulate and display statistics for each station's four-minute runs, locate and right-click on each table's Total_Minutes field and choose Statistics.



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