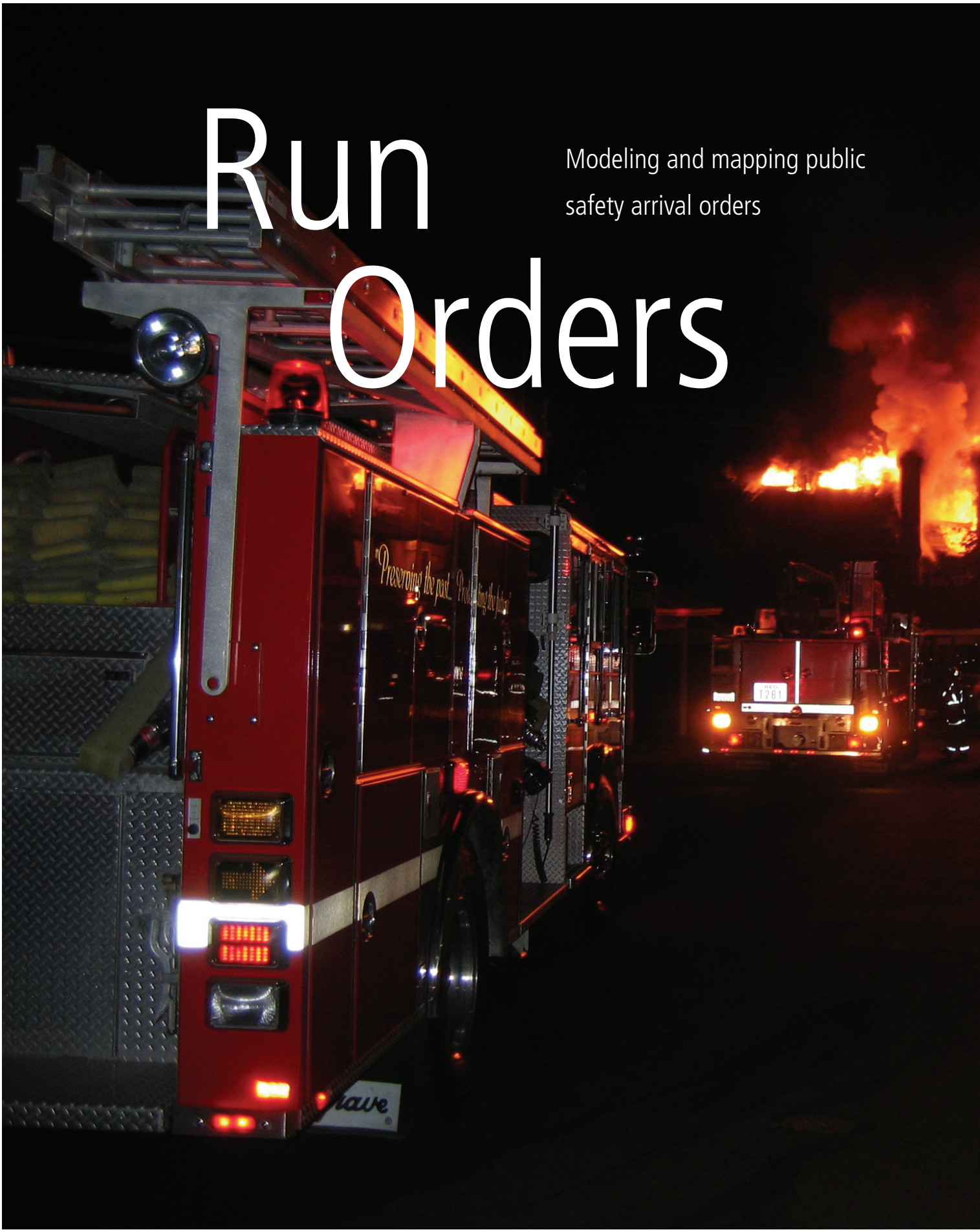
Run Orders

Modeling and mapping public safety arrival orders



What You Will Need
- ArcGIS Desktop (ArcView, ArcEditor, or ArcInfo license)
- ArcGIS Network Analyst extension
- Sample data downloaded from *ArcUser Online*
- 500 MB of free disk space

By Mike Price, Entrada/San Juan, Inc.

Timely integrated response to emergencies limits suffering and damage. GIS helps responding agencies provide better service. This is the last in a series of articles, which began in the October–December 2006 issue of *ArcUser* magazine, that have demonstrated how fire departments can model service areas and response using the ArcGIS Network Analyst extension.

Run orders allow a public safety agency to predict and map the arrival sequence and times for responders traveling to an incident from multiple locations. Previous exercises in *ArcUser* used optimized travel areas generated using the ArcGIS Network Analyst extension to identify the station from which the first responders (i.e., First Due) will arrive for a given location. By sequentially remodeling each First Due provider, Second Due coverage areas can also be mapped.

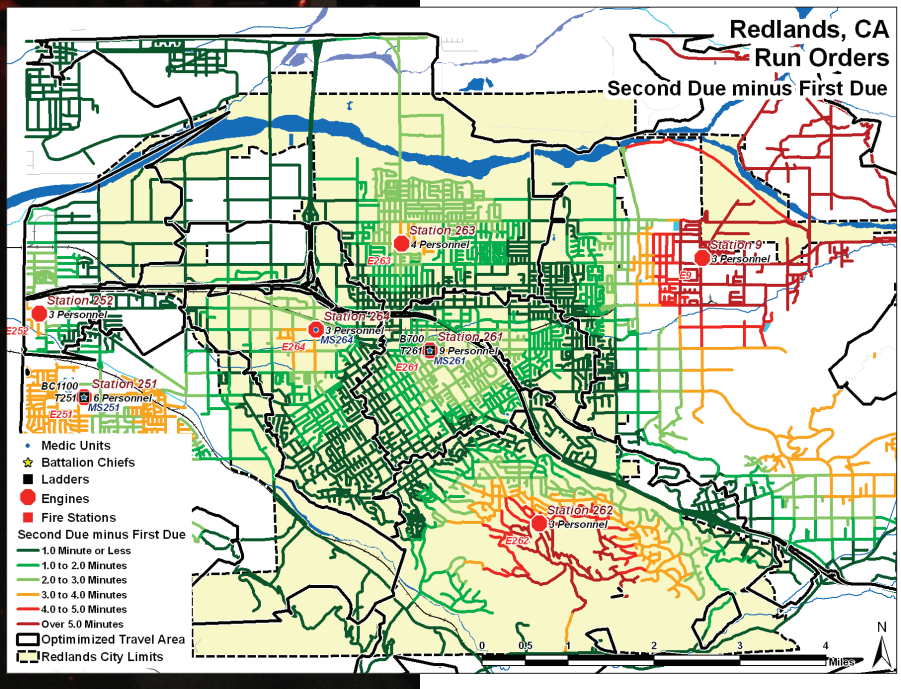
Response modeling beyond Second Due coverage areas has always been difficult. In "Do It Yourself—Building a network dataset from local agency data," which appeared in the Summer 2009 issue of *ArcUser,* a sample dataset for the city of Redlands, California, was modified so it would support time-based travel modeling with ArcGIS Network Analyst 9.3.

Working this exercise requires a basic understanding of ArcGIS Desktop and the ArcGIS Network Analyst extension. To review modeling travel networks with ArcGIS Network Analyst, including information on distribution and concentration, and to work other exercises in this series, visit the Learn How to Model Networks page (www.esri.com/news/arcuser/avmodel.html).

This exercise extends the street data that was enhanced in the previous exercise to include information about arrival orders and times for up to five emergency responders. In addition, areas where First Due coverage is within national standards will be identified and backfilled response analyzed when the nearest provider is already on a call. To ensure safe, quick entry into a structure by responders, the time lapse between arrival of the first and second units will be determined.

This tutorial shows how to model and map arrival orders for four fire stations near ESRI's headquarters in Redlands, two western stations in the nearby city of Loma Linda, and one station to the east of Redlands in Mentone. It involves a complex workflow that includes definition queries, tabular joins, field and geometry calculations, and data exports. It requires great attention to detail.

Instead of using the dataset produced when working the 2009 Summer issue exercise, use the sample dataset for this tutorial available from *ArcUser Online*. It has been converted from shapefiles to a file geodatabase and contains several additional fields that support run orders, and the network dataset used will be built inside a geodatabase feature dataset. Even though the sample dataset is small, you will need at least 500 MB of hard drive space to complete this exercise. Also note that the Closest Facility solution is complex and will take some time to solve.



Run orders model response scenarios. This map shows the approximate time interval that the first crew on scene will wait for the second crew to arrive.

Getting Starting

Download the sample dataset, Redlands.zip, from *ArcUser Online,* which contains all the data necessary to perform this tutorial. Unzip Redlands.zip near the root of your project folder and open its contents in ArcCatalog. Navigate to the Redlands folder, expand the Redlands_Fire geodatabase, and preview the Run_Order_Model feature dataset in Geography and Tablemodes. As in the previous exercise, the projected coordinate system is North American Datum (NAD) 1983 California State Plane Zone V, and the unit of measure is the U.S. Survey Foot.

Preview the feature class named Network_Streets, as shown. Notice this street data is very similar to the street data used in the exercise in the last issue. With Network_Streets selected, switch to table view and explore the table structure. Scroll to the fields on the right side

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and note the new fields: INDEX, CENT_X, CENT_Y, STAT_01, and TIME_01. All fields contain zero values but they will soon be populated with the arrival order and times for the five closest stations.

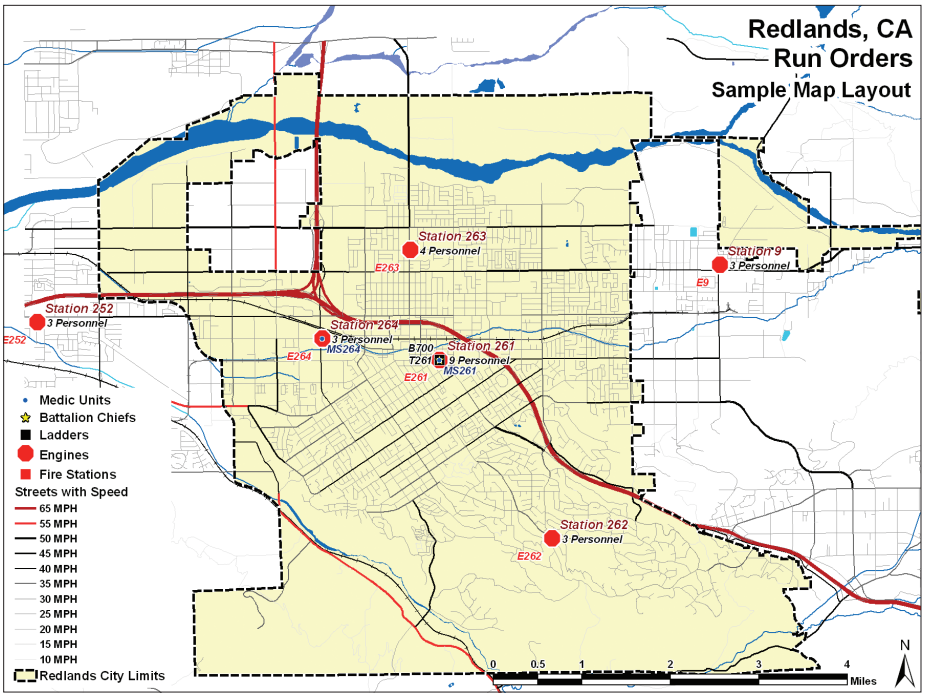
Building the Network Dataset

The next step is building the Redlands Network_Dataset in ArcCatalog.

1. Right-click on Run_Order_Model and select New > Network Dataset. Accept the default name, Run_Order_Model_ND, for this feature class.
2. Continue through the Network Dataset wizard, accepting defaults until you get to the wizard pane for specifying attributes for the Network Dataset. With Minutes selected, click the Add button. In the New Attribute dialog box, add a new attribute named Length_Mi and set its units to Miles and the Data Type to Double. Click OK.
3. Reselect Minutes. Click the Evaluators button and select the Default Values tab. Right-click the Turn and choose Type > Global Turn Delay. Click Apply.
4. Press F12 to open the Global Turn Delay Evaluator and type in the delay parameters shown in Table 1. Click OK and OK again to return to the dialog box for specifying attributes.
5. Click Next to continue and accept the directions defaults.
6. Click Next, select the summary text, copy and paste it to a WordPad document, and save that document with the project.
7. Click Finish and build the network. Inspect it when ArcCatalog has finished processing.

Creating Indexes, Generating Centroids, and Exporting Data

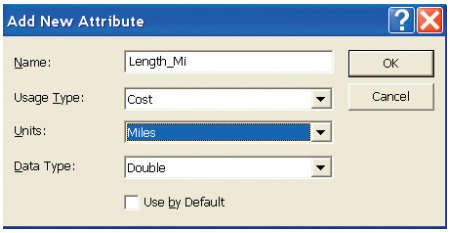
1. Close ArcCatalog and open ArcMap. Navigate to the \Redlands folder and open Redlands01.mxd. Switch from Layout View to Data View.
2. Open the attribute table for the Streets with Speed layer. Scroll to the right, study the fields, and locate the INDEX, CENT_X, and CENT_Y fields.
3. Right-click on INDEX and open the Field Calculator. Double-click on OBJECT_ID1 to add it to the formula box. Click OK to populate this field with a sequential index.
4. Right-click on the header for CENT_X and select Calculate Geometry. Choose X Coordinate of Centroid to perform this calculation. Use the data frame coordinate system (NAD 1983 StatePlane California V FIPS 0405) and Feet US as the units for this project. Click OK.



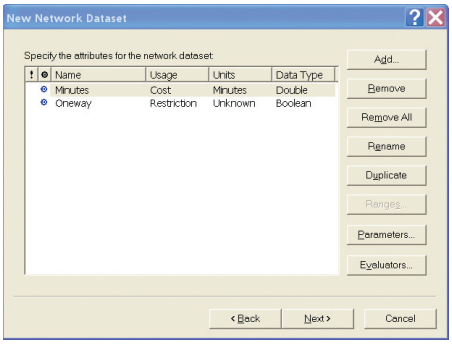
This tutorial models response from fire stations in and near ESRI's headquarters in Redlands, California.

Direction	Description	Seconds
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 parameters



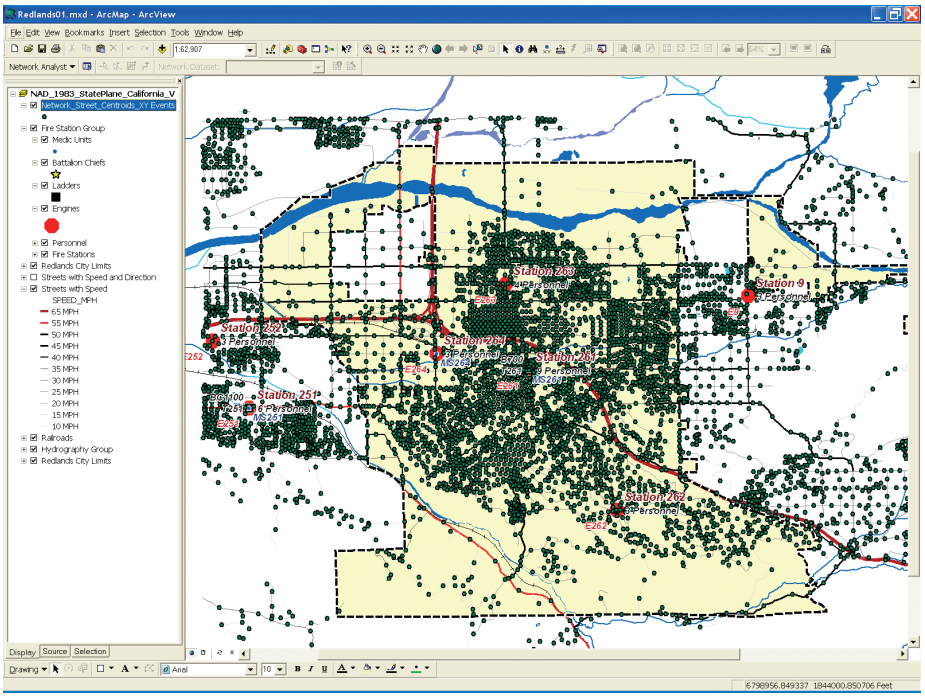
Specify another attribute for the network dataset called Length_Mi. With Minutes selected, click the Add button and set its units to Miles and the Data Type to Double.



5. Repeat this procedure for CENT_Y to calculate values for the Y Coordinate of Centroid field. Inspect the calculations and save the project.
6. Now, export this table to a dBASE file so these points can be used to map street centroid points. In the Attributes of Streets with Speed table, click the Options button and select Export. Specify All Records and save the table in the \Redlands\DBFFiles folder as Network_Street_Centroids_XY.dbf. Click on the Source tab of the table of contents (TOC) and add the table to the map.

Mapping Incidents

The ArcGIS Network Analyst extension Closest Facility solver requires two input datasets: Locations and Facilities. To build run orders, load Fire Stations as Facilities and the street segment centroids as Incidents. Determining the five closest facilities to each centroid Incident will involve considering seven possible Facilities and almost 6,500 Incidents, so this model might take some time to run. On the Source tab of the TOC, right-click on Network_Street_Centroids_XY.dbf and select Display XY Data. In the Display X,Y dialog box, set the X Field to CENT_X and the Y Field to CENT_Y. Click OK. After processing is complete, open the



Use the Network_Street_Centroids_XY.dbf to create an XY Event layer that will be the input for Incident Data needed when calculating Closest Facility.

Network_Street_Centroids_XY.dbf and inspect the location of these centroid points. Save the project.

Loading Facilities and Incidents

With the XY event theme created, it is time to add the network dataset, load Facilities and Incidents, and define the Closest Facility rules.

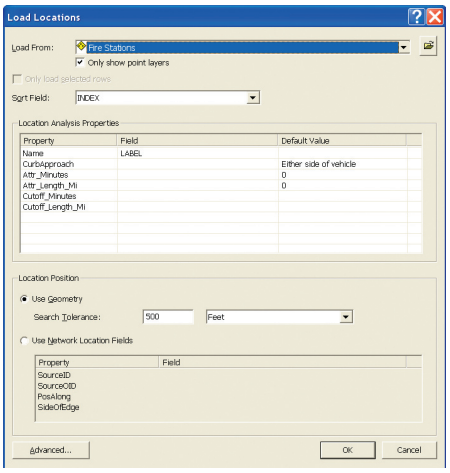
1. If necessary, make the Network Analyst extension active, load its toolbar, and open a Network Analyst window.
2. Click the Add Data button and navigate to the Run_Order_Model_ND, located in the Run_Order_Model feature dataset, and add it. Don't add all the feature classes that participate.
3. In the TOC, place Run_Order_Model_ND just below Streets with Speed layer and make it not visible.
4. Click the Network Analyst drop-down and select New Closest Facility. The Closest Facility group is added at the top of the TOC and the Network Analyst window. In the TOC, move the Closest Facility to a location just above the Redlands City Limits layer at the bottom of the TOC.
5. In the Network Analyst window, right-click on Facilities and select Load Locations. Specify Fire Stations and Load From source. Carefully apply the loading parameters listed in Table 2 and click OK. Save the project.
6. Right-click on Incidents and choose Load Locations. Carefully apply the loading parameters listed in Table 3 and click OK. This may take considerable time, so be patient. If the process hangs, close ArcMap, reopen the last saved project, and load it again. Inspect the loaded incident data. If it is correct, save the project again.

Parameter	Value
Load From:	FireStations
Sort Field:	INDEX
Location Position:	Use Geometry
Name (under Location Analysis Properties):	LABEL
Search Tolerance:	500 Feet

Table 2: Facilities loading parameters

Defining the Closest Facility Solver Parameters

1. In the TOC, right-click on Closest Facility layer and choose Properties.
2. In the General tab, rename it to Run Order Closest Facility. In the Analysis tab, set Impedance to Minutes, Default Cutoff Value to 20, and Facilities to Find to 5. Change Travel from to Facility to Incident. Accept defaults for all other parameters.
3. In the Accumulation tab, check the Length_Mi and Minutes attributes. Click Apply to save these parameters. Click OK. Save the project. In the TOC, right-click on Closest Facility and choose Solve. Now it's time to take a break. There are literally thousands of routes in this solution so this process may take more than 20 minutes. Close Warning Message that lists the centroid points not reached in 20 minutes. Once the process has finished, save the project.
4. Open the Routes table. If it contains approximately 32,000 routes and everything else looks OK, save the project again. The ArcMap document has just increased in size from about 2 MB to more than 100 MB.



Carefully fill out the dialog box when loading Fire Stations for Closest Facility analysis.

Joining Station Information to Each Route

Carefully study each field of the Routes attributes. This data will be used to build run orders for each street segment. Notice that the FacilityID field corresponds to the Index field in the Fire Stations table. The IncidentID field connects to the Streets Index. The FacilityRank

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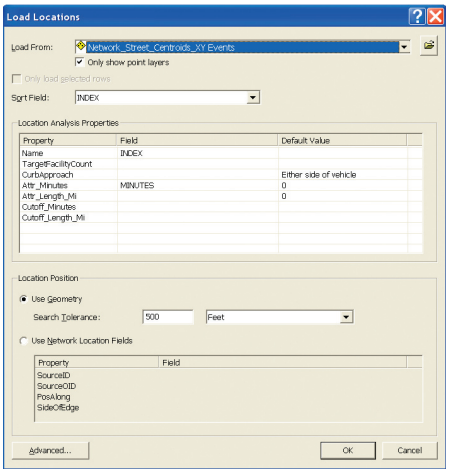
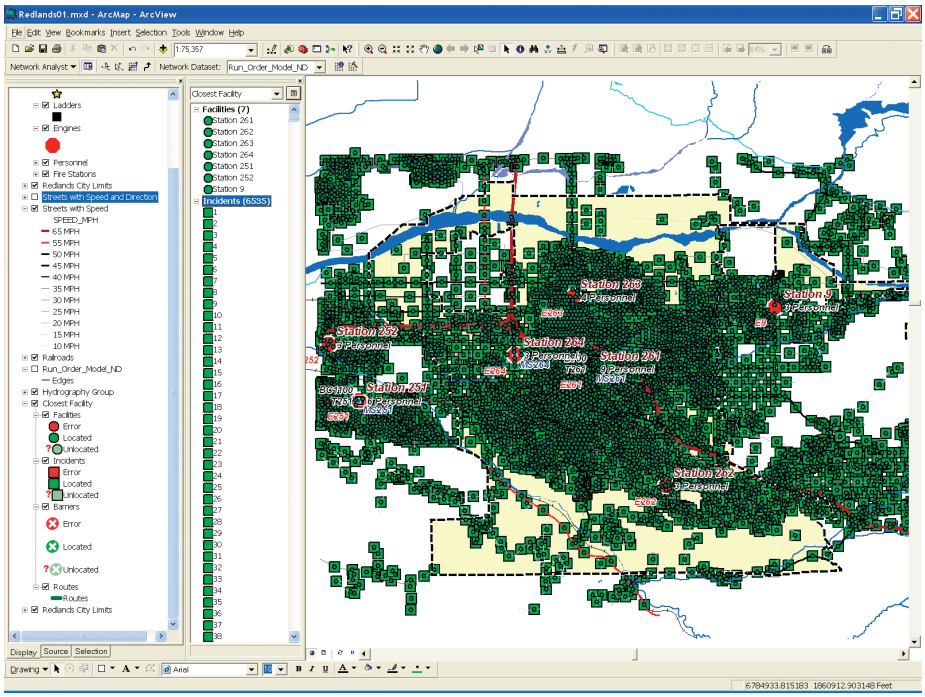


Carefully fill out the dialog box when loading the Network_Street_Centroids_XY.dbf for Closest Facility analysis.



Be patient while several thousand centroids load.

lists arrival order, and Total_Minutes contains the travel time for each station to each centroid. Open the Fire Stations table and place it above the Routes attributes.

1. Before exporting arrival data for First through Fifth Due, join station names, apparatus, and personnel to each route.
2. To join Fire Station data to the Routes, right-click on Routes in the TOC and select Join.
3. In the Join Data dialog box, choose Facility ID as the field in this layer that the join will be based on, choose Fire Stations as the table to join to the layer or load the table from, and choose INDEX as the field in the table to base the join on and choose Keep all records.
4. Click OK, allow indexing, and inspect the Routes table.

With the Station Number (STATION_N) for up to five responders for each modeled street segment, the next step is the crux of this entire procedure.

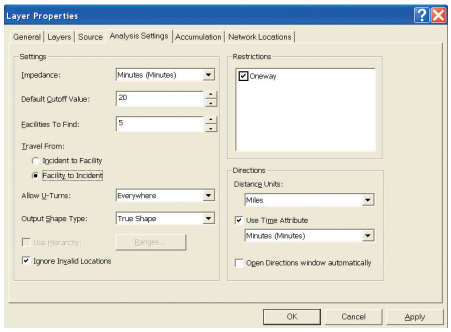
Exports and Joins

Now to export the five tables, one for each arrival order, individually join each table to the streets, and calculate station and travel time for each arrival. After successfully joining Routes to Fire Stations, the next step is to apply a definition query to filter the Routes attributes by arrival and export each subset to a separate dBASE table.

1. In the TOC, right-click on Routes and choose Properties. Click the Definition Query tab. In the formula box, request all records where CFRoutes.FacilityRank = 1. This subset represents travel records for first-on-scene stations. Times should be short, especially near fire stations.

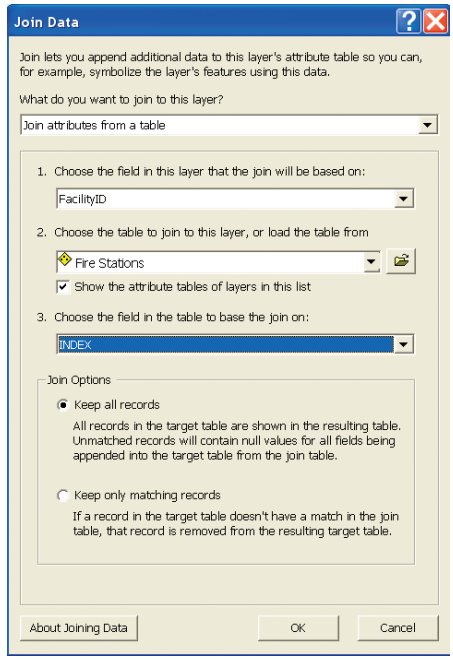
Parameter	Value
Load From:	Network_Street_Centroid_XYEvents
Sort Field:	INDEX
Location Position:	Use Geometry
Name (under Location Analysis Properties):	INDEX
Search Tolerance:	500 Feet

Table 3: Incident loading parameters

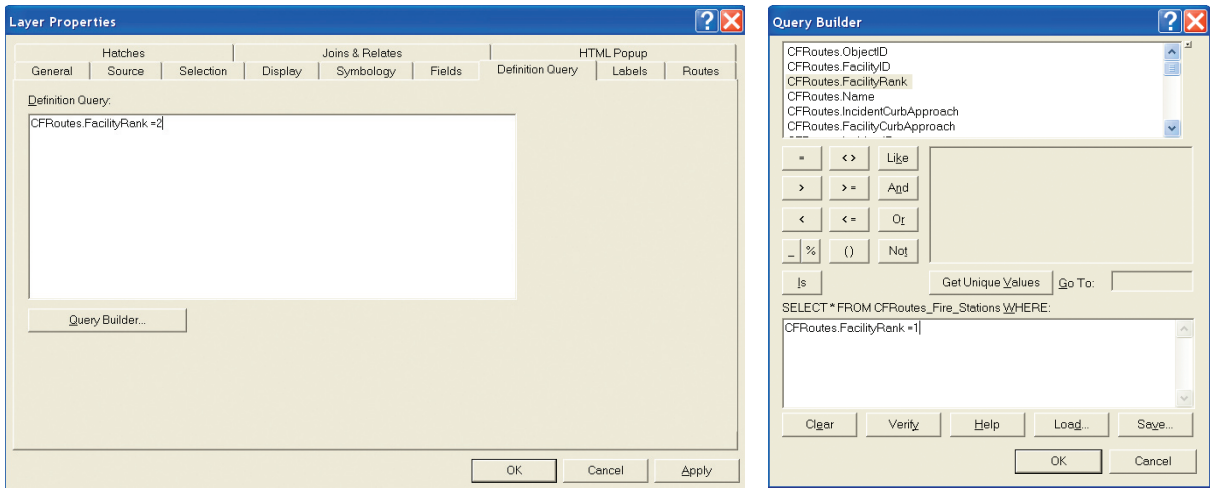


Carefully set the Closest Facility Solver parameters.

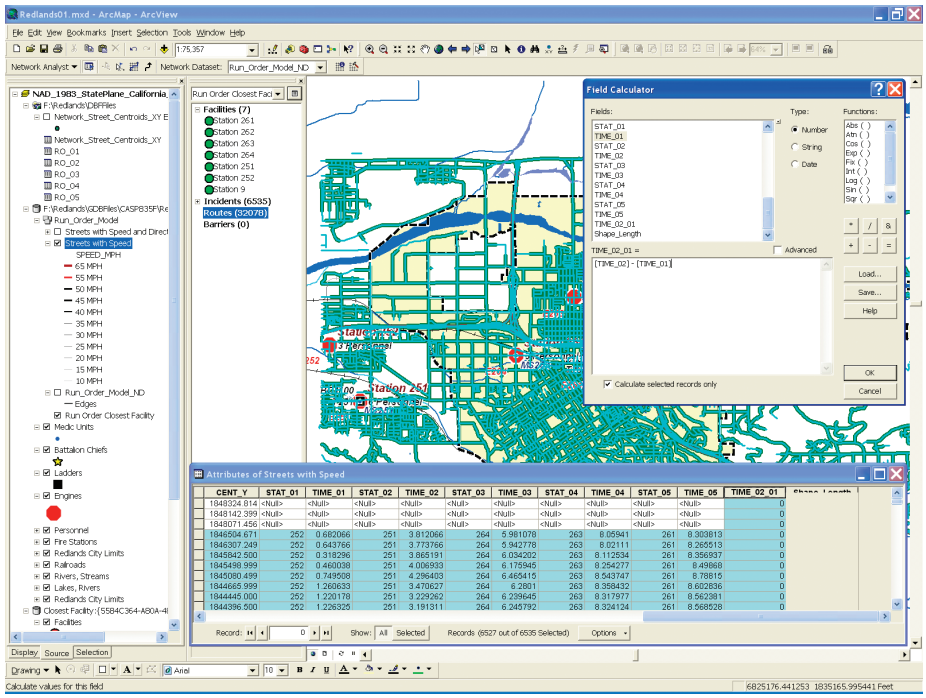
2. The next step is to export the First Due records. In the filtered Routes attribute table, click Options and select Export. Save the exported table to Redlands\DBFFiles and name it RO_01.dbf. Do not add the table to the map yet.
3. Reset the definition query to CFRoutes. FacilityRank = 2 and export again, saving as RO_02.dbf. Again, don't add the table to the map.
4. Repeat this procedure for RO_03, RO_04, and RO_05. Now, add all five RO files to your map. Save the project again.



Join the filtered dBASE files to the Street with Speed layer to calculate values, then remove the join.



In the TOC, right-click on Routes and select Definition Query. In the formula box, request all records where CFRoutes.FacilityRank = 1.



Use the Field Calculator to calculate the delay time between First Due and Second Due.

Populating Station and Time Fields with Joined Table Data

The final analytical steps include five separate joins, each followed by two quick calculations. Perform each operation carefully and check the data!

1. Open and inspect the attribute table for Streets with Speeds. Locate the STAT_01 and TIME_01 fields. Open and position RO_01.dbf below the streets attributes.
2. Right-click on Streets with Speed layer in the TOC and select Joins and Relates. Verify that there are no active joins for this table. (If there are any joins, remove them.) Next create a Join with RO_01, using INDEX as the Streets with Speed join field, RO_01 as the table to join, and IncidentID as its join field. Click OK to continue. Do not index this table. Open the table and verify the join.
3. In the joined table, navigate to STAT_01 and right-click its header. Select Field Calculator and populate the RO_01.STATION_NO field with values from Network_Streets.STAT_01.
4. Next, use the Field Calculator to populate the TIME_01 field with the values from the RO_01.Total_Minu field. Check the work. Null records represent streets that were not traversed within 20 minutes.
5. ***Now for a really important step. In the TOC, right-click Streets with Speed, select Joins and Relates, and remove the RO_01 join. Do not skip this step.***
6. Create new joins on Streets with Speed to the other RO tables using INDEX as the field the join is based on, the RO table (e.g., RO_02, RO_03), and IncidentID as the field in the table to base the join on. Populate the station (STAT_0x) using the formula Header = STAT_0x, the field to populate = Network_Streets.STAT_0x, and the value to use is RO_0x.STATION_NO. Populate the arrival time fields using the formula: Header = TIME_0x, the field to populate = Network_Streets.TIME_0x, and the value to use is RO_0x.Total_Minu. Be sure to remove the join each time.

Calculating Delay Time

Now, calculate the delay time between arrival of the first and second responders. A fire engine typically includes three or four firefighters. To safely conduct rescue and initial interior operations, more firefighters are often needed. Subtracting the First Due arrival time from the Second Due time will produce the approximate time interval between when the first on-scene crew arrives and a second crew arrives. Right-click on TIME_02_01 and choose Field Calculator. Enter the formula [TIME_02] – [TIME_01] in the formula window and click OK. Inspect this calculation and save again.

Mapping Run Orders—The Bonus Round

Now it is time to make some maps. The Redlands folder in the sample dataset contains a Bonus folder with several Layer files for symbolizing the various responders (First Due, Second Due, etc.). Load all these Layer files and create a Group Layer for them named Run Order Group. Place the group just below Fire Stations in the TOC. Collapse the legends for Second, Third, Fourth, and Fifth Due.

Notice that data links to all Run Order layers are missing. To fix this, right-click on First Due in the TOC and choose Data > Repair Data Source. Navigate to \GDBFiles\CASP835F\Redlands_Fire.gdb and select Network_Streets inside the Run_Order_Streets feature dataset. Fix all layers in the Run Order Group in a similar manner. Turn off all Run Order layers except First Due. Switch to Layout View and study the

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colors. These First Due polylines seem to cluster around their home stations.

Verifying Relationships

To verify First Due relationships, click Add Data and navigate to \Bonus_Files\SHPFiles\CASP835F and load Optimized Travel Area.lyr. Place it at the top of the Run Order Group. This response area optimization was built from the same Redlands Streets using the functionality in Network Analyst to optimize service areas. Notice the alignment of First Due Streets and optimized response area boundaries, providing visual confirmation of the First Due run orders.

Turn off First Due and turn on Second Due. Look closely at the home area for Redlands Station 261 and observe how Station 264 arrives second from the west, 263 comes in from the north, 262 fills in from the south, and Mentone 9 just reaches the eastern response area for Station 261 as Second Due. Check the Third, Fourth, and Fifth Due layers.

Finally, let's map the arrival time difference between First and Second Due. Turn off all Due layers and make the Second Due minus First Due layer visible. Study the color relationships. Green lines represent short time intervals and red lines represent long intervals. Notice the large time differences for each station are in closest proximity to that station.

Study the attributes to understand that the green lines in fringe areas are not entirely good. Even though the arrival difference is small, the First Due times often exceed five minutes. Look inside the City of Redlands. The time difference throughout much of the populated city is small, except in the most southern areas near Station 262 where all supporting responders must come from the north.

As a bonus exercise, create thematic legends for all layers in the Run Order Group and design a separate map for each. Load these maps into Microsoft PowerPoint to create an informative slide show.

Run Order Benefits and Limitations

Run orders provide emergency responders with an accurate, reliable way to model complex responses with travel from multiple locations. This workflow counts on response from fixed facilities with all responders who are dispatched simultaneously. This method works well for a static, districtwide model that includes automatic and mutual aid. As mobile dispatching and automated vehicle locators (AVL) become widely deployed, this workflow will need to be simplified to speed up individual event dispatching.

In more complex scenarios, appropriate lag times are applied to manually requested resources and volunteer responders to reflect additional time necessary for their departures. Also, unavailable units may be removed from the response stack. Apparatus types and personnel counts may also be included. As a word of caution in rural areas: when modeling long stretches of country roads, be sure to break street segments into appropriately short intervals.

Acknowledgments

Thanks to Chief Jeff Frazier and his staff at the Redlands Fire Department for providing fire station apparatus and personnel information and the staff of the City of Redlands GIS for the use of their excellent data. Special thanks to Tom Patterson and Russ Johnson at ESRI for helping make this exercise a reality.

For more information, take the ESRI instructor-led course *Working with ArcGIS Network Analyst.*