Getting to know ArcGIS Network Analyst Extension

Let's say you are a GIS analyst for a fire department in your county and they want you to figure out how much time does it take for fire brigades from firestations to reach each census tracts in that county. In other words, what is the drive time for fire brigades to service a census tract in case an incident happens?

Next scenario, your department is cutting funds and wants to get rid of 4 of the fire stations in your county in a way that the remaining fire stations serve the census tracts within 17 min radius weighted by census population. How would you do that?

Network Analyst comes to your rescue! You do not have to program anything; this extension will make your life easier!

In this exercise, we will be learning about ArcGIS Network Analyst extension and how it can be useful for your research analysis. We will also be going through some of the functions that this extension offer us.

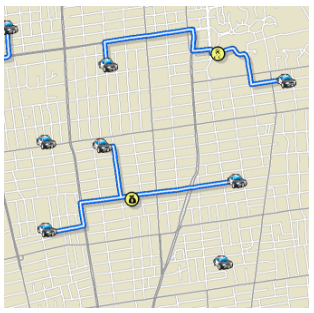
Now, you may be wondering what this extension is and how is it so powerful? Let's learn about it!

What is ArcGIS Network Analyst Extension?

ArcGIS Network Analyst provides network-based spatial analysis tools for solving complex routing problems. It uses a configurable transportation network data model, allowing you to accurately represent their unique network requirements. You can plan routes for an entire fleet, calculate drive-times, locate facilities and solve other network related problems.

With this extension, you can answer the following questions:

- What is the quickest way to get from point A to point B?
- Which houses are within five minutes of a fire station?
- A person wants to visit a store. Which branch should the potential customer visit to minimize travel time?
- Which firestations can respond quickest to an incident?



To answer all these questions and to solve the problems that we are focusing on today we will be doing the following exercises:

Exercise 1: Creating a network dataset

Exercise 2: Calculating travel time from each fire station to census tracts using OD Cost Matrix analysis

Exercise 3: Locating all the fire stations which are within 17 min radius of the census tracts using Location Allocation analysis

OK! Now, we understand a little bit, of what the extension does but we do not know what it entails to perform our analysis. In other words, what are the important things that we need to keep in mind before even starting!

To start with, we need to build a network dataset and how do we do that what are the key components of it? Let's learn about those.

What is a network?

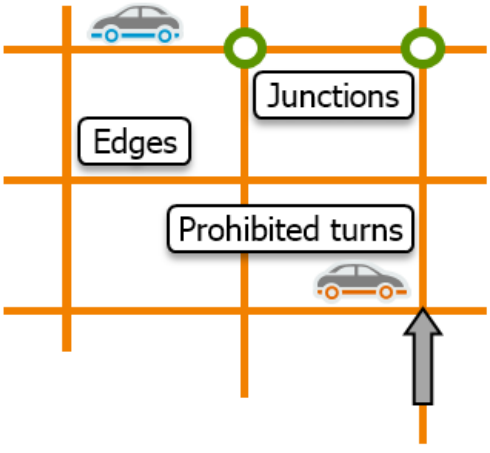
A network is a system composed of interconnected parts or elements. These elements are combined to represent possible routes from one location to another. Like roads, networks are used for the transportation of people, resources, and goods.

You can perform analysis related to this network travel by modeling potential travel paths using a network. The most common network analysis is routing, which is finding the shortest path between two points.

A network dataset is used to model real-world networks and facilitate analysis. Network datasets not only contain the locations and attributes of streets and highways, but they also include information about how they are related to each other. Roads can be connected, have turns that are allowed or prohibited, and provide other details that affect what travel paths are possible and how long travel might take.

Network Elements

There are three main types of network elements:



Edges

Connect to other elements using junctions and are the links over which agents travel.

Junctions

Connect edges and facilitate navigation from one edge to another. Junctions come from vertices or point features to represent street intersections in a road network.

Turns

Store information that can affect movement between two or more edges.

Network Attributes

Attributes describe elements!

Attributes hold details and properties about your network dataset. . Examples of attributes include the time to travel a given length of road, which streets are restricted for which vehicles, the speeds along a given road, and which streets are one-way.

There are four kinds of attributes:

Cost

Cost attributes work as impedances, which penalize traversal over an element in the network. Network datasets must have at least one cost attribute. If you have a numeric field in the feature class representing length or time, you can use that field to create a cost attribute. For example: Drive time, Road length etc.

Descriptor

Descriptors contain general information to calculate the values for other three attributes. For example: Number of lanes, speed limit

Restriction

Restrictions prohibit traversing certain edges (roads) in certain directions. For example, One-way Street, closures etc.

Hierarchy

Hierarchy differentiates among road types to help network analysis, and it allows a network dataset to assign priority. For example: Highway, Primary road etc.

Network Evaluators

Evaluators determine attribute values!

An evaluator is used to calculate a value for each attribute to determine total costs. There is an evaluator for attributes of each of the network elements (edges, junctions, and turns) and each of their source feature classes.

Some evaluator types are based on the source data or another source.

Field: Field evaluators use values from fields in the source feature class.

Constant: Constant evaluators assign a single value to all elements in a group.

Edge traffic: Average or live traffic feeds represent traffic on the network for more accurate analysis.

Other evaluator types are calculated in several different ways.

Exercise 1: Creating a network dataset

Now we know that to run any analysis on this extension and to answer our questions, we first need to build a network dataset. The only key component needed for that is the streets data. In this exercise, we are using Streets data from ESRI.

Steps to create a Network Dataset:

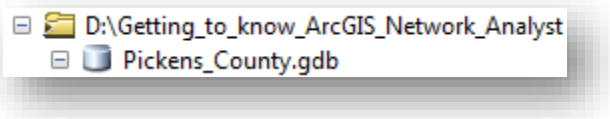
You now know the design, components, and features of a network dataset, and the next step is to create a network dataset.

- Start **ArcMap**.

Before you begin, you must turn on the Network Analyst extension.

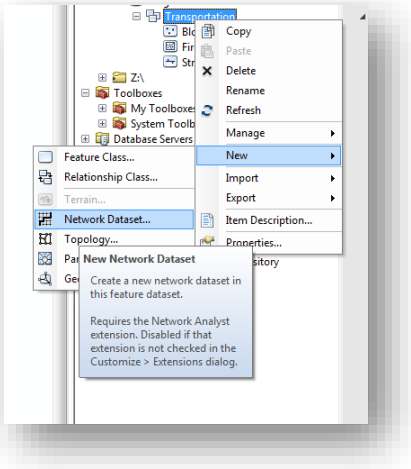
If necessary, from the Customize menu, choose Extensions.

In the Extensions window, select the box next to Network Analyst and then click Close.

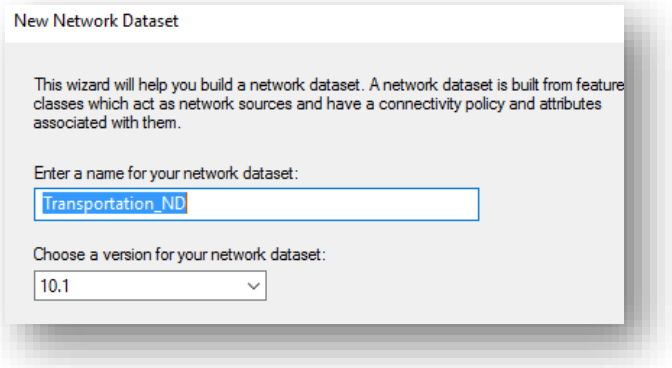


If necessary, open the Catalog window.

- In the Catalog window, right-click Folder Connections and choose Connect to Folder. Browse to **D:\Getting_to_know_ArcGIS_Analyst**, and click OK.
- In the Catalog window, expand the folder that you connected to locate the **Pickens_County** geodatabase.
- Expand the **Pickens_County** geodatabase.
- Right-click the **Transportation** feature dataset, which contains the Streets source feature class. Point to New, and then choose **Network Dataset**.
  All source feature classes must be in one feature dataset.



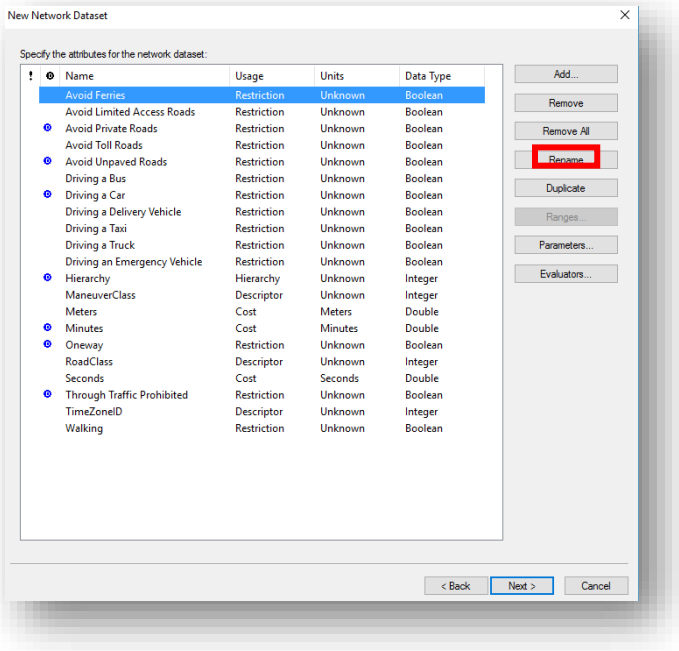
- Accept the default network dataset name of **Transportation_ND**.
- For the version, **leave the default setting**.
- Click **Next**.
- For the feature class that will participate in the network dataset, the Streets source feature class is already selected for you. If not, then select the **Streets_Centerlines**.
- Click **Next**.
- For the option to model turns, keep the **default setting of Yes**.
- This option to model turns will help with analysis, and a source table called Global Turns will be created if a source does not already exist in your feature dataset.



- Click **Next**.
- If you had more sophisticated data and needs, connectivity has settings that would allow you to change how the network dataset interprets how streets are connected. You can edit connectivity after creating the network dataset, if needed. For this exercise, you do not need to change the connectivity settings.
- Click **Next**.

This dataset has elevation values in the fields F_ZLEV and T_ZLEV, so the network dataset will know whether streets intersect or not.

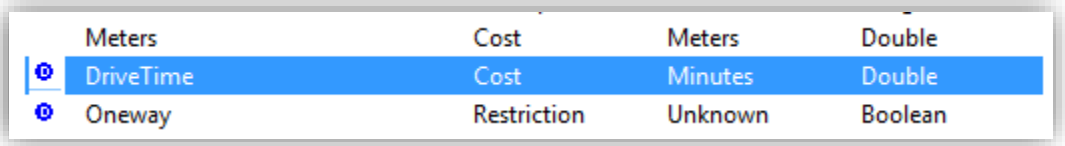
- Verify that Using Elevation Fields is selected, and then click **Next**.



Remember, ArcGIS Network Analyst finds common fields in the source feature classes that you assign to create corresponding network attributes, and those attribute values are then assigned using evaluators.

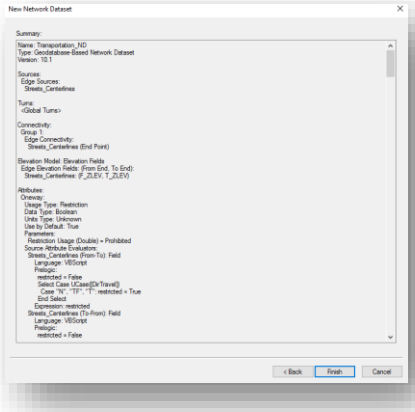
One goal for this network dataset is to model drive times. When performing analyses on the network, this allows you to selects: What is the quickest route for someone who is driving a car?

- To accomplish this, you must set up a cost attribute **DriveTime**
- The Minutes attribute that Network Analyst automatically detected in the source data represents drive times, so you can change the name to something more appropriate. Select the Minutes row, click Rename, type **DriveTime,** and press **ENTER**.



- Click **Next**.

On this page, you can set up an additional travel mode if you need to perform analysis for modes such as travel by truck, walking (pedestrian), and so on. You would copy the default travel mode, which is created for automobile travel, and add additional impedances, such as no U-turns and slower top speeds for trucks.



- Click **Next**.
- For driving directions, leave the **default setting of Yes** and click **Next**.

A service area index can expedite the creation of service areas, which is one area of network analysis. This action can be done after the network dataset is created and built, if needed.

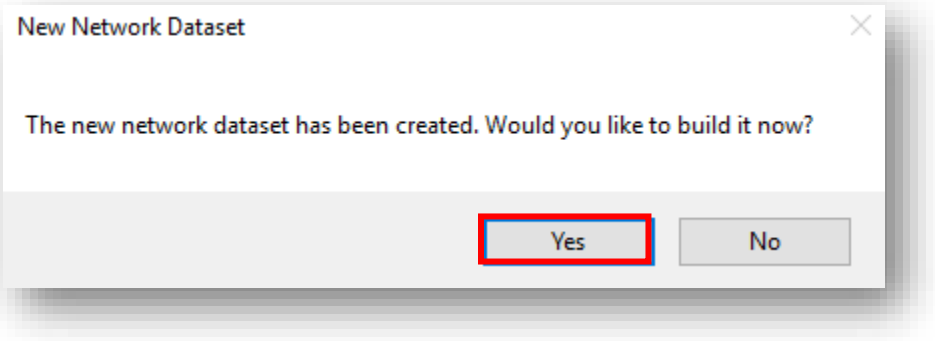
- Click **Next**.

View the summary page, which lists all the information and inputs for the network dataset that you are about to create for your review.

- Click **Finish**.

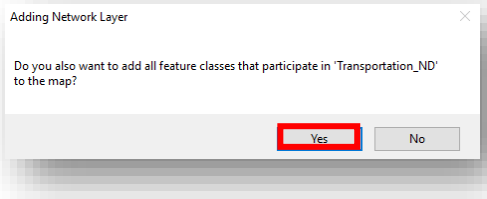
You will now build a network dataset.

- In the New Network Dataset pop-up window, click **Yes** to build the network dataset.



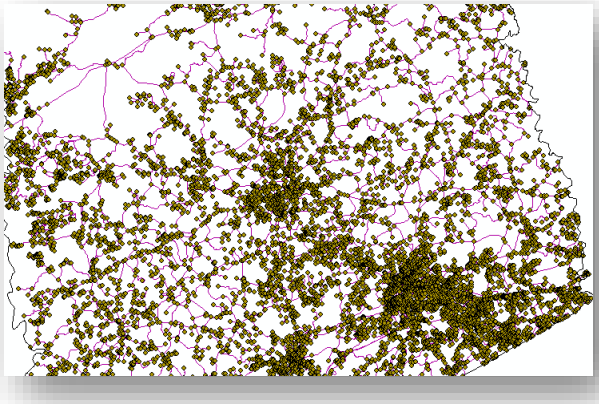
The build process determines which network elements are connected and populates the attributes of the network dataset.

You must build the network before you can perform any network analysis on it. You also have to build if you edit an existing network dataset, or copy and paste (move) it from one workspace to another.



- In the Adding Network Layer pop-up window, a message displays that asks if you want to add the feature classes to the map so that you can use them to create network analysis layers. You do not need to do this step to perform analysis. Click **Yes**.
- In the Catalog window, confirm that the Transportation_ND and Transportation_ND_Junctions network datasets appear within the Transportation feature dataset.

After performing these initial steps, you would be ready to continue on to your analysis.



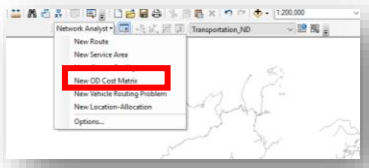
Exercise 2: Calculating travel time from firestations to census tracts by creating an OD cost matrix

An origin-destination (OD) cost matrix analysis can be used to create a matrix showing travel times or distances along a transportation network using a network dataset. You can use the OD cost matrix solver to assign fire stations to the nearest tracts, which firestations will serve what tracts.

You can create an origin–destination cost matrix for firestations to tracts centroids. The results of this matrix can be used to identify tracts that will be serviced by each firestation within a 10-minute drive time. Also, you can find the total drive time from each firestation to census tracts.

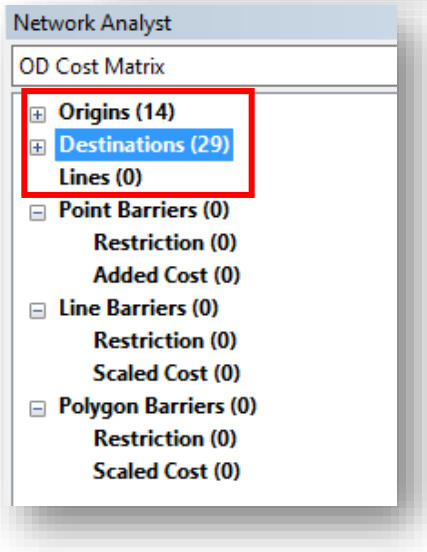
Steps:

- Click Network Analyst on the Network Analyst toolbar and click **New OD Cost Matrix**.
- The OD cost matrix analysis layer is added to the Network Analyst window. The network analysis classes (Origins, Destinations, Lines, Point Barriers, Line Barriers, and Polygon Barriers) are empty.
- The analysis layer is also added to the Table Of Contents window.



Adding origins

- In the Network Analyst window, **right-click Origins** (0) and **choose Load Locations**.
  The Load Locations dialog box opens.
- Under **Location Position**, click **Use Geometry**.
- Click **OK**. The **14 origins** are displayed on the map and listed in the Network Analyst window under Origins.



Adding destinations

- In the Network Analyst window, right-click **Destinations** (0) and **choose Load Locations**.
- Choose Census_tracts in the Load From drop-down list.
- Under **Location Position**, click **Use Geometry**.
- Click **OK**. The **29 destinations** are displayed on the map and listed in the Network Analyst window under Destinations.

Setting up the parameters for the analysis

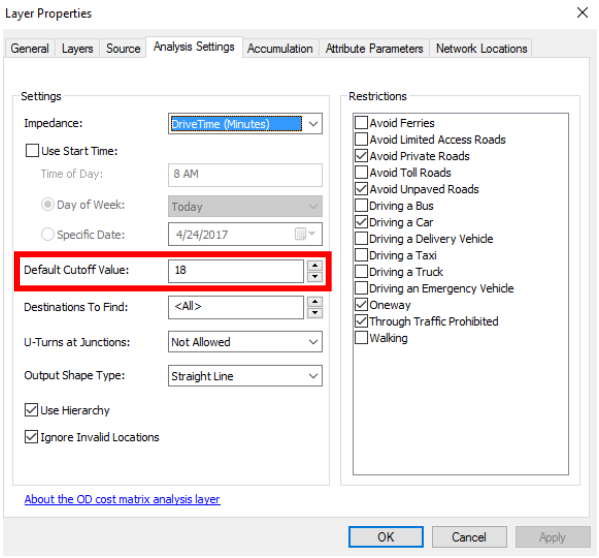
Next, you will specify that your OD cost matrix will be calculated based on drive time. You will set a default cutoff value of 18 minutes and ensure that all destinations are found within the specified cutoff.

Additionally, you will specify that U-turns are not allowed everywhere and the output **Shape type should be a straight line**. Since all these trips are on roads, one-way restrictions must be followed. All invalid locations (locations not found) will be ignored.

Steps:

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

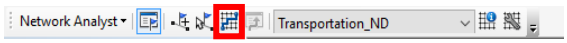
- Click the **Analysis Settings tab**.
- Make sure that the Impedance drop-down list is set to **DriveTime (Minutes).**
- Type **18** in the **Default Cutoff Value** text box.
- This will create origin–destination paths from each firestation to all census tracts that can be reached within 10 minutes.
- Make sure that **Destinations To Find is set to <All>.**
- Click the **U-Turns at Junctions set to Not Allowed**
- Make sure that Output Shape Type **is set to Straight Lines**.
- Make sure that **Ignore Invalid Locations is checked**.
- Check **Oneway** in the Restrictions list.
- Click **OK**. The parameter settings are saved.



Run the process to create the OD cost matrix

Steps:

1. Click the **Solve** button on the Network Analyst toolbar.
2. The OD lines appear on the map. There are 151 lines are created.

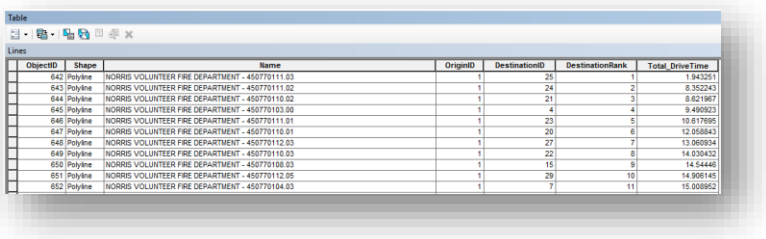


Allocating fire stations to census tracts

Based on the OD cost matrix, you can now identify the tracts that would be served by each fire station.

Steps:

1. In the Network Analyst window, right-click **Lines (151)** and choose **Open Attribute Table**. The Lines table opens. The Lines table represents the origin–destination cost matrix from each firestation to the tracts within an 18-minute drive time.

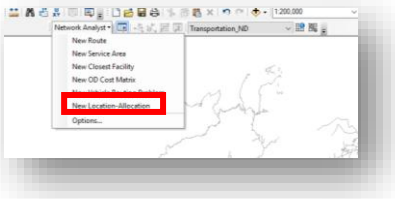


2. The OriginID column contains IDs of firestations. The DestinationID column contains IDs of tracts. The DestinationRank is a rank assigned to each destination that is served by a firestation based on the total drive time.
3. To save the Lines layer, right click on it and choose **Export Data** and save it your **gdb**

Exercise 3: Which out of 14 fire stations are the ones that offers Maximum Coverage if we want to get rid of 4 of them within 17 mins?

The main objective of this exercise is to locate fire stations close to population centers. You will perform the location-allocation analysis using your own data:

Steps:



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

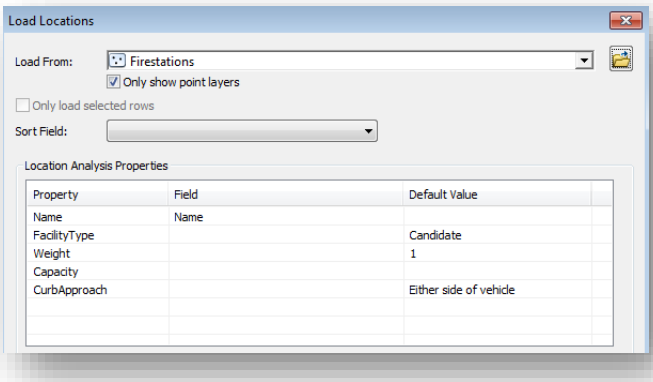
2. The location-allocation analysis layer is added to the Network Analyst window. The network analysis classes (Facilities, Demand Points, Lines, Point Barriers, Line Barriers, and Polygon Barriers) are empty. The analysis layer is also added to the Table of Contents window.

Adding candidate facilities

You will add the candidate fire stations to the network analysis class Facilities. These are the places where you already have a fire station. The solution from the location-allocation process will include a subset of these fire stations. You will load the point features from Census_tracts into the Facilities class of the location-allocation layer.

Steps:

1. In the Network Analyst window, right-click Facilities (0) and choose Load Locations.
3. The Load Locations dialog box opens.
2. Select **Firestations** from the Load Locations drop-down list. The Location Analysis Properties section of the Load Locations dialog box lets you specify which attributes of the Census_tracts feature class contain the values that Network Analyst will use to solve this location-allocation problem.
4. In the Location Analysis Properties section, make sure the Name property is automatically mapped to the Name field.
5. For the FacilityType property, under the Default Value is Candidate..
6. Click **OK**.

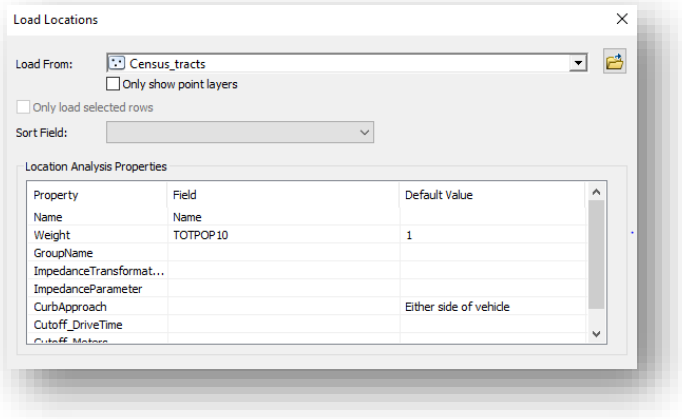


Adding Demand Points

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

Steps:

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



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

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

4. Click the Field column for the Weight property and choose **TOTPOP10**.

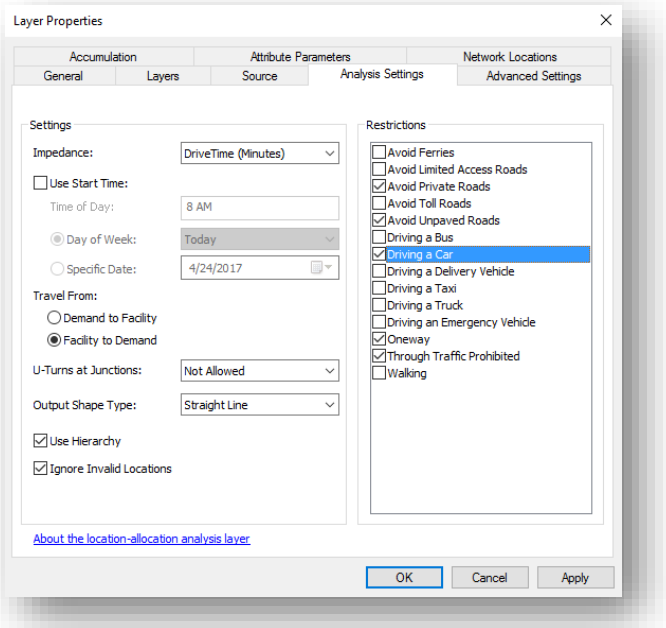
Each demand point will be weighted by the population from the 2010 census.

5. Click **OK**.

Setting up the properties of the location-allocation analysis

Steps:

1. Click the **Analysis Layer Properties** button on the Network Analyst window.
2. The **Layer Properties** dialog box opens.
3. Click the **Analysis Settings** tab.
4. Make sure that Impedance is set to **TravelTime (Minutes)**.
5. Set Travel From to default option, **Facility to Demand**, is a good choice for the classic minimize impedance and maximize coverage problem types. However, for maximize attendance, maximize market share, and target market share, the demand tends to travel to the facilities, thus Demand to Facility is often a good choice for them.
6. Click the U-Turns at Junctions drop-down arrow and choose **Not Allowed**.
7. Set **Output Shape Type to Straight Line**. Although the output will be displayed with straight lines, the travel costs are still measured along the network.
8. Make sure that the **Use Hierarchy** and **Ignore Invalid Locations** boxes are checked.
9. In the Restrictions frame, make sure that **RestrictedTurns** and **Oneway** are checked. Your Analysis Settings tab should look like the following graphic:
10. Click the **Advanced Settings** tab.
11. Click the Problem Type drop-down list and choose **Maximize Coverage**. These problem types are often referred to as models.
12. Increase **Facilities to Choose** to **10**.

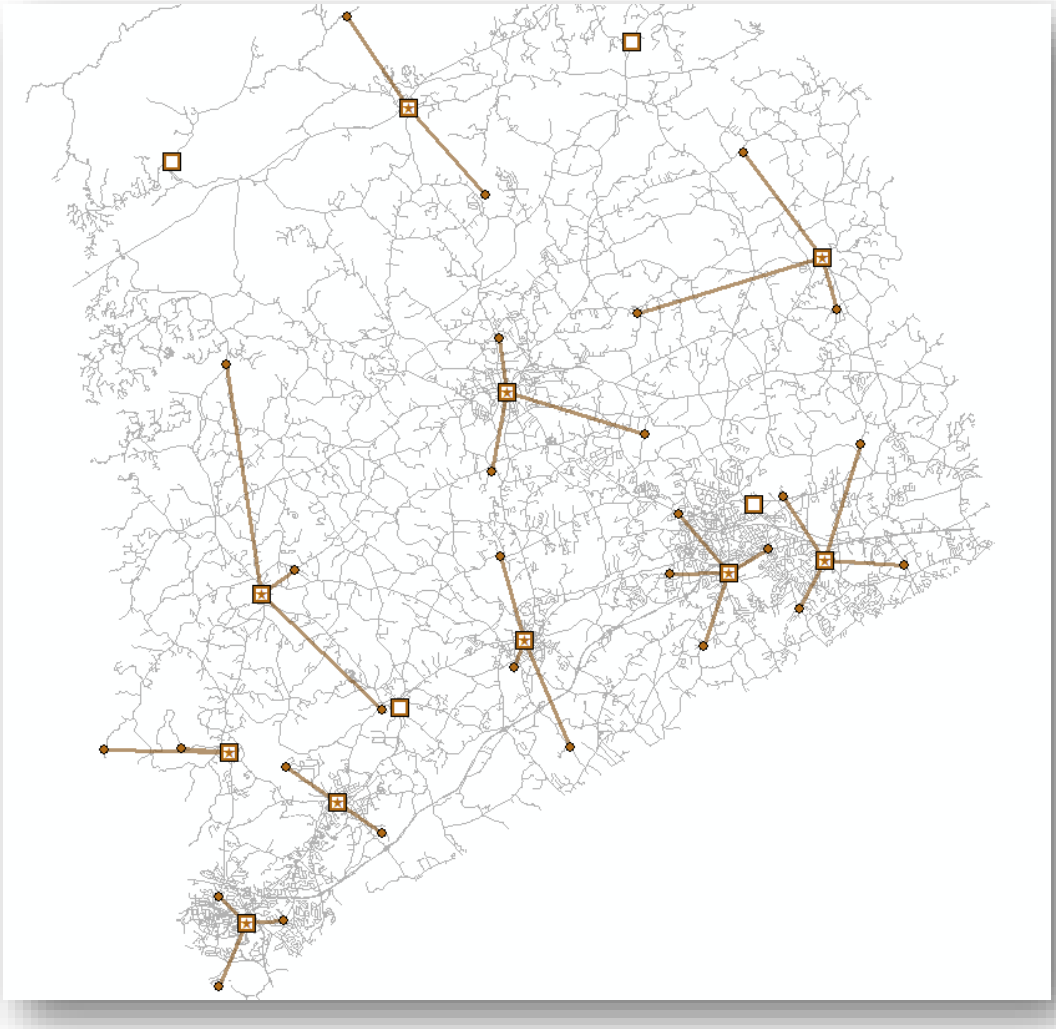


13. ArcGIS will try to find 1 more location where we can put up a firestation optimally serve the 29 demand points.
14. Increase Impedance Cutoff to **17**.
15. Make sure that Impedance Transformation is set to **Linear**.
16. Click OK.

Run the process to determine the best store locations

Steps:

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



3. Now you will inspect the results in more detail.
4. In the **Table of Contents**, right-click the Facilities sublayer and choose Open Attribute Table.

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

Facilities

ObjectID	Shape	Name	FacilityType	Weight	Capacity	DemandCount	DemandWeight
57	Point	NORRIS VOLUNTEER FIRE DEPARTMENT	Candidate	1	<Null>	0	0
58	Point	CLEMSON UNIVERSITY FIRE AND EMERGENCY MEDICAL SERVICES	Chosen	1	<Null>	3	15385
59	Point	CENTRAL FIRE DEPARTMENT STATION 2	Chosen	1	<Null>	2	8815
60	Point	LIBERTY FIRE DEPARTMENT	Chosen	1	<Null>	3	12152
61	Point	PUMPKINTOWN FIRE DEPARTMENT	Candidate	1	<Null>	0	0
62	Point	CITY OF PICKENS FIRE DEPARTMENT	Chosen	1	<Null>	3	11844
63	Point	HOLLY SPRINGS VOLUNTEER FIRE DEPARTMENT	Chosen	1	<Null>	2	5137
64	Point	CITY OF EASLEY FIRE DEPARTMENT STATION 1	Chosen	1	<Null>	4	17483
65	Point	CITY OF EASLEY FIRE DEPARTMENT STATION 3	Chosen	1	<Null>	4	22252
66	Point	CENTRAL FIRE DEPARTMENT STATION 1	Chosen	1	<Null>	2	9731
67	Point	DACUSVILLE FIRE DEPARTMENT	Chosen	1	<Null>	3	9584
68	Point	CITY OF EASLEY FIRE DEPARTMENT STATION 2	Candidate	1	<Null>	0	0
69	Point	VINEYARDS FIRE DEPARTMENT	Candidate	1	<Null>	0	0
70	Point	SIX MILE VOLUNTEER FIRE DEPARTMENT	Chosen	1	<Null>	3	11288

6. The DemandCount column lists the number of demand points assigned to each of the chosen facilities. The DemandWeight column lists the demand that is allocated to each facility. In this case, the value represents the number of census tracts that will fall in these facilities radius.
7. Close the Facilities table.
8. In the Table Of Contents, right-click the Demand Points sublayer and choose Open Attribute Table.
9. Examine the attributes of the Demand Points table. The Facility ID column has a value of the chosen facility the demand point was allocated to.
10. The Weight column contains the population count that was loaded from the census tract feature class. The AllocatedWeight column contains the amount of demand that was apportioned to the associated facility. The amount of weight allocated is based on the linear distance decay and the 17-minute cutoff parameters you set in the Layer Properties dialog box.

ObjectID	Shape	Name	Weight	FacilityID	AllocatedWeight
59	Point	450730306.02	4447	59	4447
60	Point	450770101.00	3003	63	3003
61	Point	450770102.00	4410	70	4410
62	Point	450770103.00	5669	70	5669
63	Point	450770104.01	2134	63	2134
64	Point	450770104.02	5526	62	5526
65	Point	450770104.03	2010	62	2010
66	Point	450770105.01	2776	67	2776
67	Point	450770105.02	3267	67	3267
68	Point	450770106.01	3541	67	3541
69	Point	450770106.02	6971	65	6971

11. In the Table Of Contents, right-click the Lines sublayer and choose Open Attribute Table. This table contains one record for each demand point allocated to a facility. To save the Lines layer, right click on it and choose Export Data and save it your gdb.

ObjectID	Shape	Name	FacilityID	DemandID	Weight	TotalWeighted_DriveTime	Total_DriveTime
320	Polyline	CLEMSON UNIVERSITY FIRE AND EMERGENCY MEDICAL SERVICES - 450770112.02	58	84	5694	32586.423421	5.722941
321	Polyline	CLEMSON UNIVERSITY FIRE AND EMERGENCY MEDICAL SERVICES - 450770112.03	58	85	6122	19361.180745	3.162558
322	Polyline	CLEMSON UNIVERSITY FIRE AND EMERGENCY MEDICAL SERVICES - 450770112.05	58	87	3569	17944.160101	5.027784
323	Polyline	CENTRAL FIRE DEPARTMENT STATION 2 - 450730306.02	59	59	4447	72382.162226	16.276627
324	Polyline	CENTRAL FIRE DEPARTMENT STATION 2 - 450770112.04	59	86	4368	13907.035959	3.183845
325	Polyline	LIBERTY FIRE DEPARTMENT - 450770110.01	60	78	3215	20101.424799	6.252387
326	Polyline	LIBERTY FIRE DEPARTMENT - 450770110.02	60	79	6469	21046.776841	3.253482
327	Polyline	LIBERTY FIRE DEPARTMENT - 450770110.03	60	80	2468	21377.686527	8.661948
328	Polyline	CITY OF PICKENS FIRE DEPARTMENT - 450770104.02	62	64	5526	24129.939499	4.36662
329	Polyline	CITY OF PICKENS FIRE DEPARTMENT - 450770104.03	62	65	2010	10377.663963	5.163017
330	Polyline	CITY OF PICKENS FIRE DEPARTMENT - 450770107.00	62	70	4308	43665.580164	10.135929
331	Polyline	HOLLY SPRINGS VOLUNTEER FIRE DEPARTMENT - 450770101.00	63	60	3003	34198.780095	11.388205
332	Polyline	HOLLY SPRINGS VOLUNTEER FIRE DEPARTMENT - 450770104.01	63	63	2134	15765.468041	7.387754
333	Polyline	CITY OF EASLEY FIRE DEPARTMENT STATION 1 - 450770108.01	64	71	4765	24452.898997	5.131773
334	Polyline	CITY OF EASLEY FIRE DEPARTMENT STATION 1 - 450770108.03	64	73	4513	18902.613352	4.188481
335	Polyline	CITY OF EASLEY FIRE DEPARTMENT STATION 1 - 450770108.04	64	74	3278	8962.504323	2.734138

Now, you are an expert on Network Analyst! Make sure to test other features this extension offers!!