Spatial Optimization Workflow

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Data and Input Layers

Data should be restricted to a given location using a shapefile for the jurisdiction of interest. The following input data and layers are needed to identify candidate locations.

CDC Social Vulnerability Index (SVI): The CDC Social Vulnerability Index (SVI) was downloaded from the CDC's Agency for Toxic Substances and Disease Registry from SVI Data and Documentation Download. We recommend using the SVI for census tracts relative to the state, rather than to the national average.

Current list of cooling centers: This data should ideally be point location and geo-referenced. You may wish to restrict your list of cooling centers to those with air conditioning, or include both those with air conditioning and those that just offer water and shade (hydration stations).

Parcel data from jurisdiction: Often available from tax assessor or city/county government, the data includes parcel use codes and zoning including how parcels are currently used.

Street Network: Often available from city/county governments, this data can be used to develop a street network, the process of which is detailed via an ESRI tutorial Create a Network Dataset but an amateur explanation can also be found on YouTube How to make a Network Dataset in ArcGIS Pro by The Geomathematician.

(Optional) Survey for vulnerable populations: Point in Time survey of those experiencing homelessness was incorporated as additional demand locations in one of our counties. That survey is only representative of where those were experiencing homelessness lived for the day the survey was taken, in early 2022. This data should be geocoded and

Layer Development

Spatial optimization was accomplished using ArcGIS Pro 2.9.1, using the *Network Analyst* extension and the *Location-Allocation* option. Briefly, the Network Analyst extension allows for users to optimize the connections between entities. Here, we are geographically optimizing the location (*location* -allocation) of the candidate locations to reach maximum coverage of the demand locations (residential parcels). This tool requires three sets of input: (a) existing locations, (b) demand locations, and (c) candidate locations, which are then placed on a street network to select potential locations that meet the user set criteria optimally.

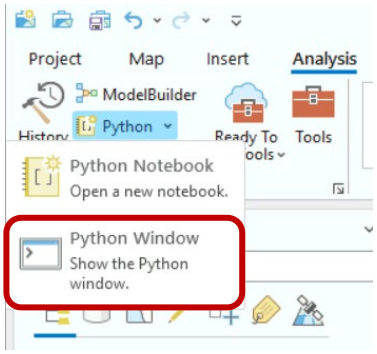
A. Existing Locations: are current cooling center locations
B. Demand Locations (Parcel data): Parcel data was processed by developing a categorization scheme for parcels by use type. Residences including fixed foundation residences and mobile homes were designated as demand locations. Finally, empty lots, recreation centers, common areas, and private drives were removed from the residential parcels as they do not house residents, marked as residential adjacent parcels. Some parcel data may not include mobile homes, so mobile home park data could supplement the parcel data.
C. Candidate Locations (Parcel data): This included three candidate location markers – public schools, assisted living centers including commercial nursing homes, hospitals, and places of

worship. Religious institutions were included as "miscellaneous commercial" in the UseDesc attribute. Filtering to "miscellaneous commercial", locations were further identified with a keyword search using the "Mail 1" attribute (the first line written when mailing an item to that location). Keywords used included: Church, Iglesia, Buddha, Islam, Jewish, Temple, Chapel, Evangelical, Methodist, Parish, and Catholic.

a. In our tax assessor regional databases, this information was included in the description of parcel data fields including: PptDesc, SptDesc, and UseDesc attributes. These parcel use codes have three hierarchical layers of increasing/decreasing specificity – The broad "Ppt" description, the more specific "Spt" Description, and the close to exact "Use" Description.

Pre-Processing

1. Add SVI and street network layers to ArcGIS. We used ArcGIS Pro 2.9.1.
2. Limit the analysis to the most highly vulnerable tracts via the CDC SVI. We used the top 25% as a cutoff for "highly vulnerable"
    i. In very large counties, you may need to do a smaller subset. For example, you could select 5 parcels from each tract that were highly vulnerable. See related Python code in order to determine this.



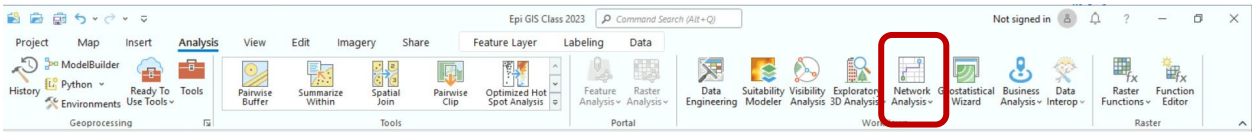
Loading Layers for Replication

1. For transparency, a GDB file has been provided to you to replicate these results.
2. If you choose to use this dataset, download from GitHub, and upload into your GIS project.
3. Once uploaded, load the following layers into your Map Contents
    a. Existing Locations:
        i. Cooling_Centers_Geocoded
    b. Candidate Locations:
        i. AssisstedLivingFacilities_Points
        ii. PublicSchool_Points
        iii. PlaceofWorship_Points
    c. Demand Locations:
        i. MobileHome_Points
        ii. FixedFoundation_Points
    d. Street_Network_Feature_Class
    e. Twentyfive_percent_Most_Vulnerable_Census_Tracts (optional)
    f. CDC_SVI_2018_Clip (optional)
    g. Tucson_Street_Network_Dataset (optional)

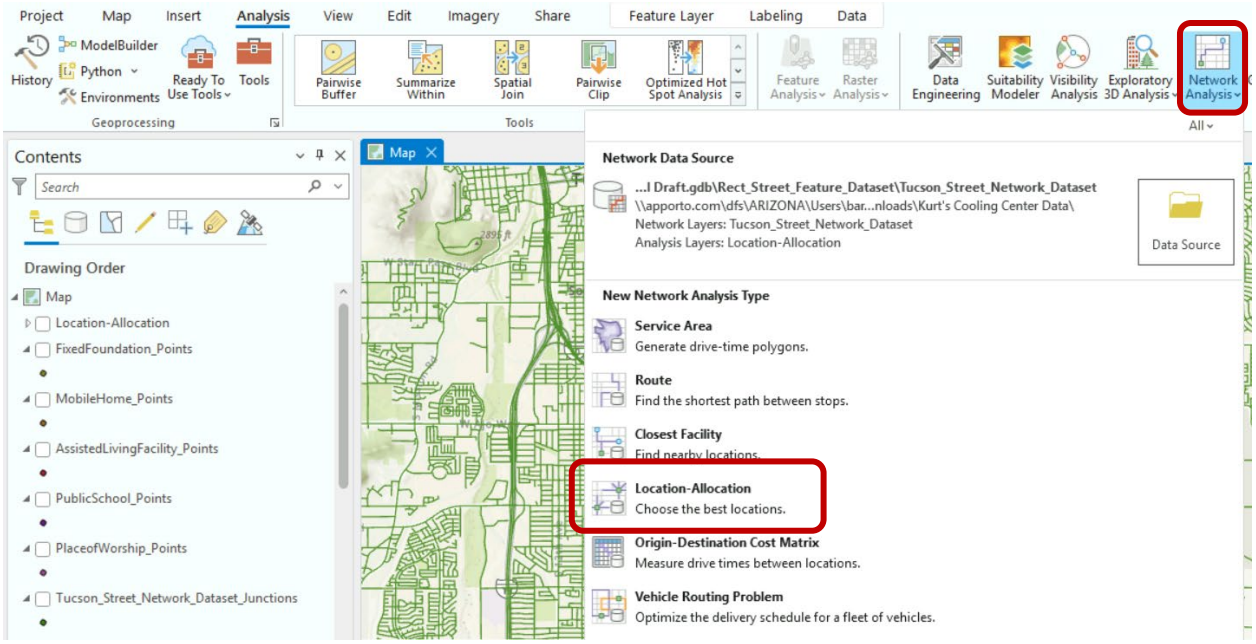
Note: The following layers represent cooling center locations, candidate locations in the 25% most vulnerable census tracts by SVI, and demand locations from the 25% most vulnerable census tracts by SVI. Optional layers are provided for visualizing the output. The .gdb file also contains images which can be used to replicate the Sample Output image at the end of this protocol.

Running the Optimization

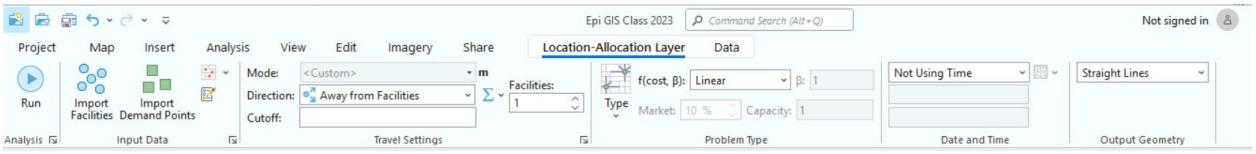
1. Using the *Network Analyst* extension and the *Location-Allocation* option. In the **Analysis Tab**, select **Network Analysis**.



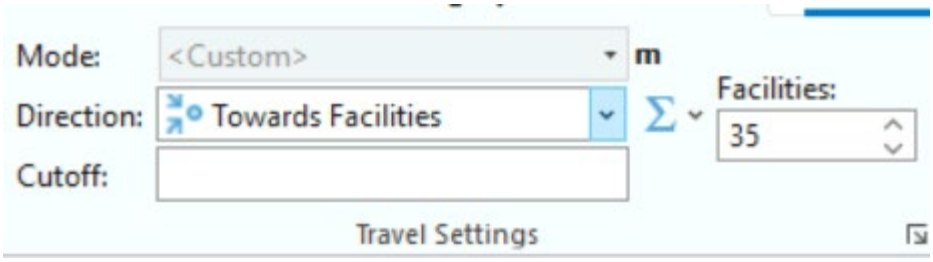
2. The function we will run is **Location Allocation**. Which creates a new layer to which ArcGIS Pro will allocate the locations.



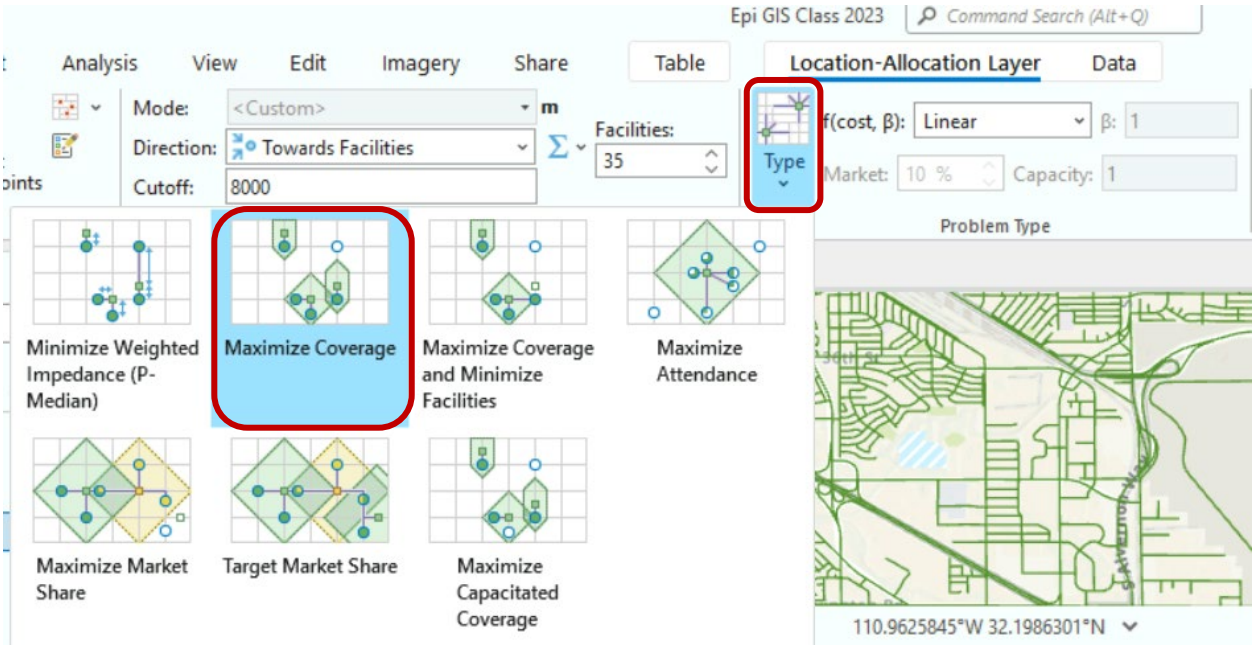
3. Once the layer is created, new tools will popup:



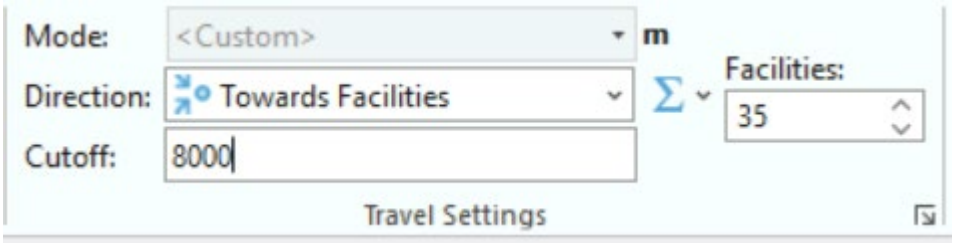
- **Mode**: can be adjusted for pedestrian, car, etc. For now, leave as is. Make note of the **Units** next to the Mode. This is dependent on the road network dataset. For example, our road network is in meters (m).
- **Direction**: change to "**Towards facilities**"
- **Facilities**: This is how many facilities you want to have in the end: existing plus new. So if you want 20 new, and you have 15 existing , 15 old + 20 new = 35.



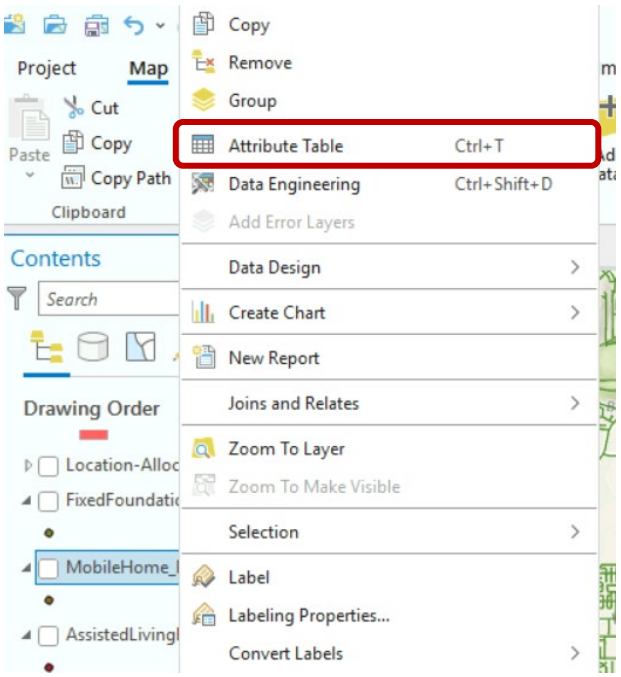
- **Type**: Type of problem. Select **Maximum Coverage**.



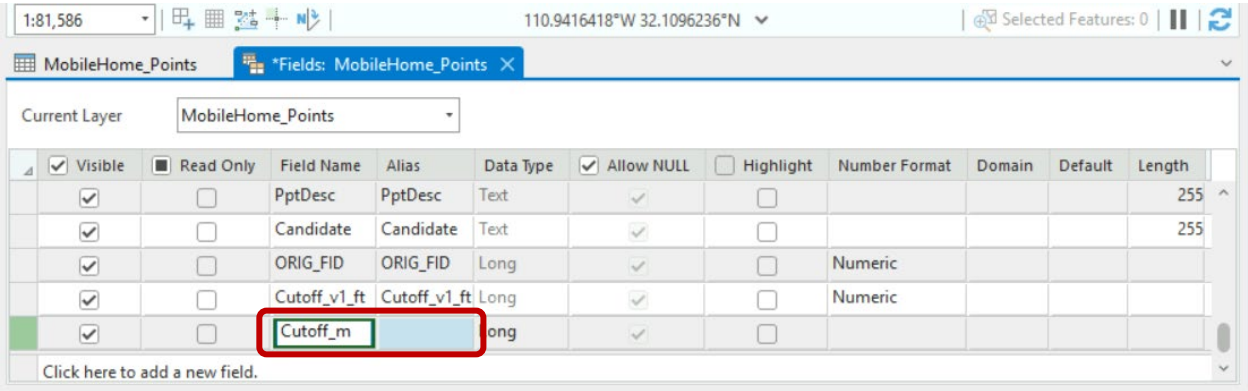
- **Cut-Off**: this is an impendence and constrains the optimization to reasonable distances. In the end we want separate values for residential, point in time data, and mobile home data. For now, set the maximum distance across all 3 in the cutoff field, taking into account the unit measure.
    - Residential: 8 km (unit is m, so 8000)
    - Point in time: N/A for one county, could be applicable for others
    - Mobile: 5 km



4. Open the Attribute Table for your residential, point-in-time and mobile home data to **add cutoff values** for each. In this example, we open our MobileHome_Points layer, and add a cutoff value for 5000 (5 km).



To add a new attribute for cutoff length, click “add value.” This will open up a new tab (see below). Enter the name of the new attribute. Close the tab by clicking the “X” and saving changes. Create a new variable for your cutoff length.



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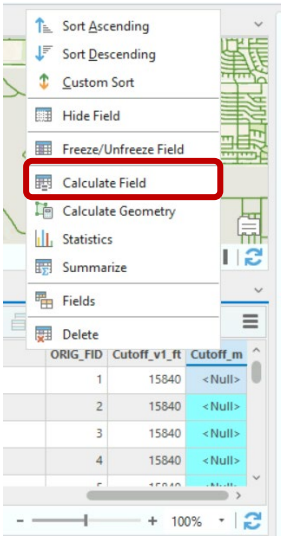
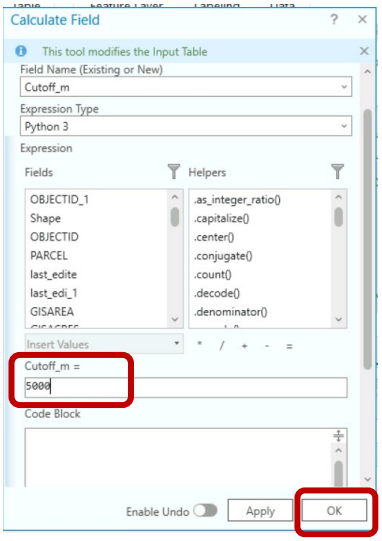
Scroll to the end of the attribute table to add the value to your new attribute.

Right click on the attribute and select "Calculate Field." Add the value to the variable to apply the same cutoff for each.

Then, Click OK.





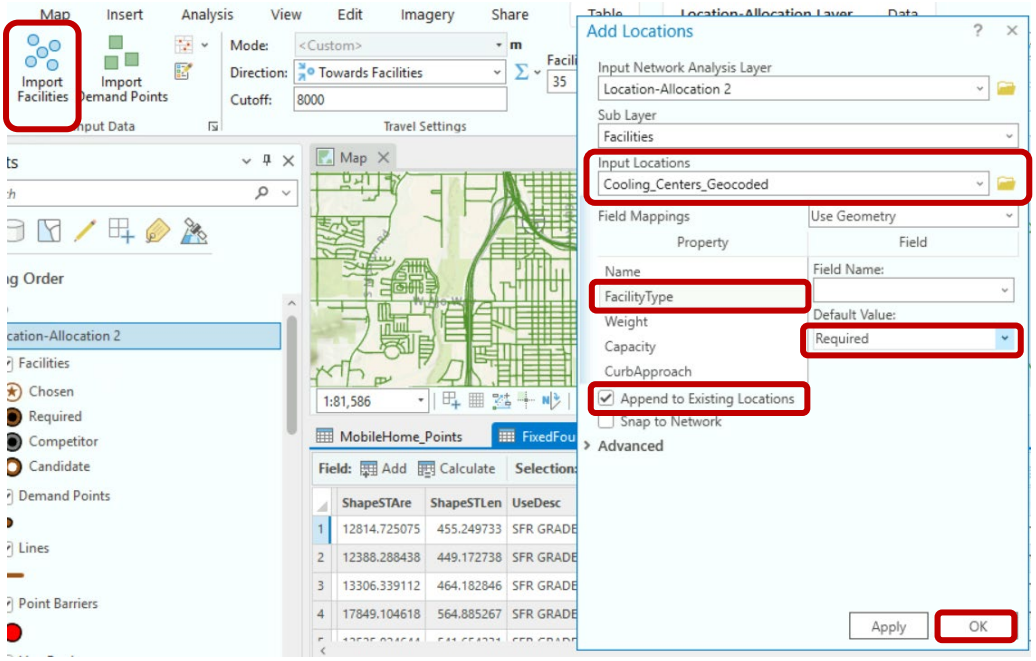
Note: Be sure to repeat this process for ***all*** of your demand layers. In this example, we would repeat this process for residential and for mobile home layers.

Below is the list of spatial optimization parameters that we used.

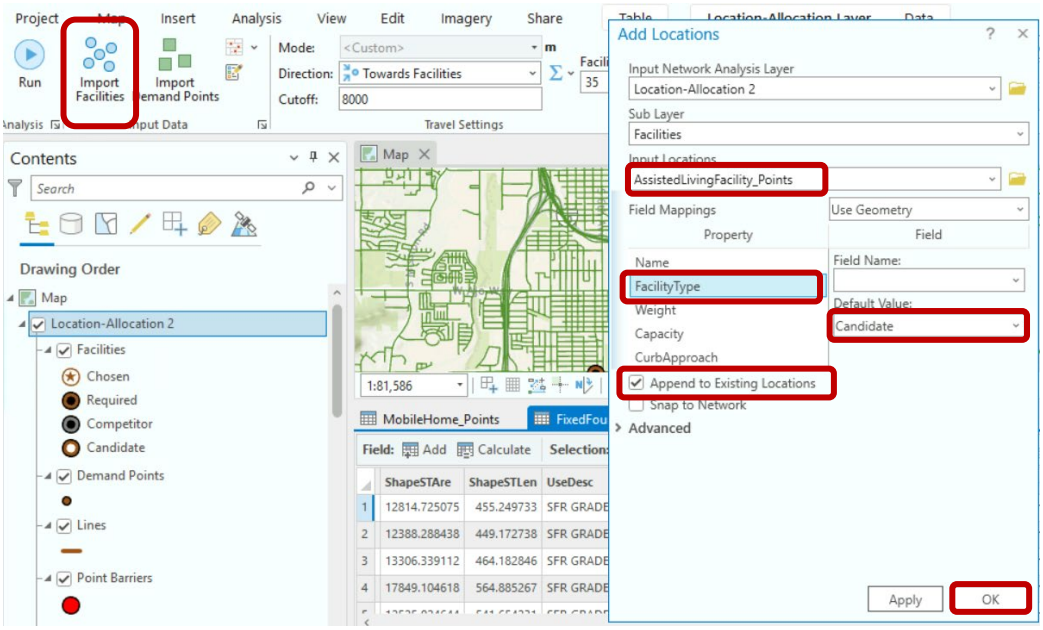
Table. Spatial Optimization User selected parameters.

Parameter	Options/Definition	County 1	County 2
Mode	Can be adjusted for pedestrian, car, etc.	Not used	Not used
Units	Are dependent, defined by the imported network dataset	meters	Feet
Direction	The direction by which the locations will be identified, e.g., from the candidate out or from the residence to the candidate	"to facilities"	"to facilities"
Cut-Off	This is an impendence factor which constrains the optimization to reasonable distances.	Fixed foundation Residential – 8 km Residential mobile homes – 5 km	- Residential: walking 5 miles (i.e., 26400 ft) - Point in time: 1 mile - Mobile Home: 3 miles
Facilities	The number of new facilities to end with: existing plus the desired number of new locations	35 = 15 existing 20 new	123 = 113 existing 10 new
Type	Type of problem being solved (e.g., minimize impedance, maximize coverage)	Maximize coverage	Maximize coverage

5. **Import Existing Locations:** In your Location-Allocation tab, select “Import Facilities” to import the existing locations of cooling centers. Set the “Facility Type” to **Required** and make sure **Append to Existing** is always selected.

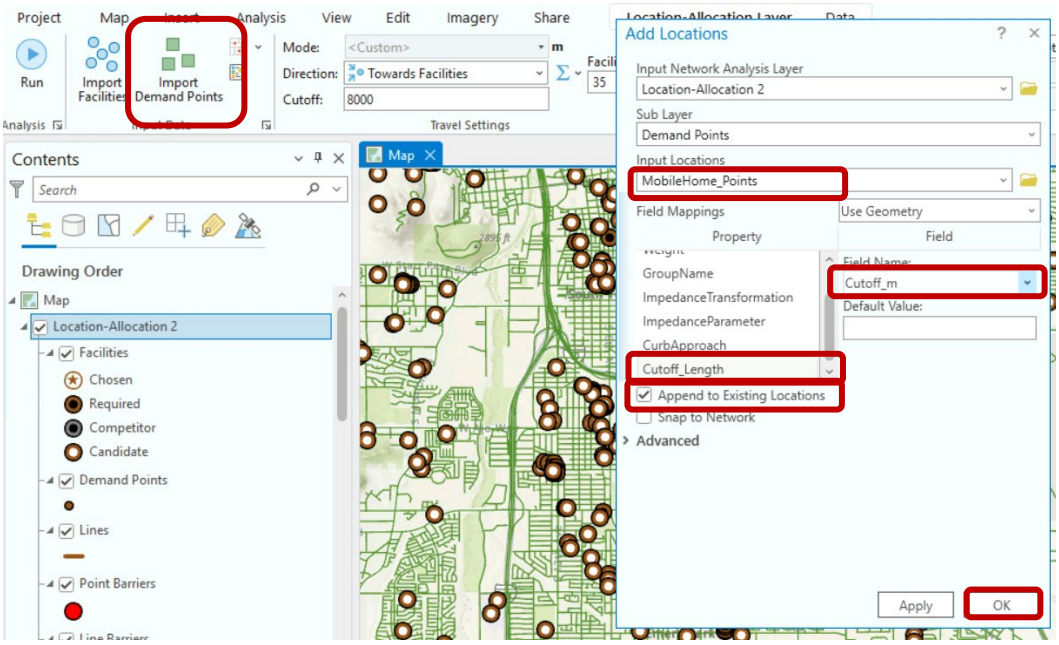


6. **Import Candidate Locations:** For each candidate location layer, select **Import Facilities** to add potential Candidate Sites. Set the Facility Type to **Candidate** and make sure **Append to Existing** is always selected. Repeat this process for each candidate location type (in this example we repeated this process three times for assisted living, public schools, and places of worship).

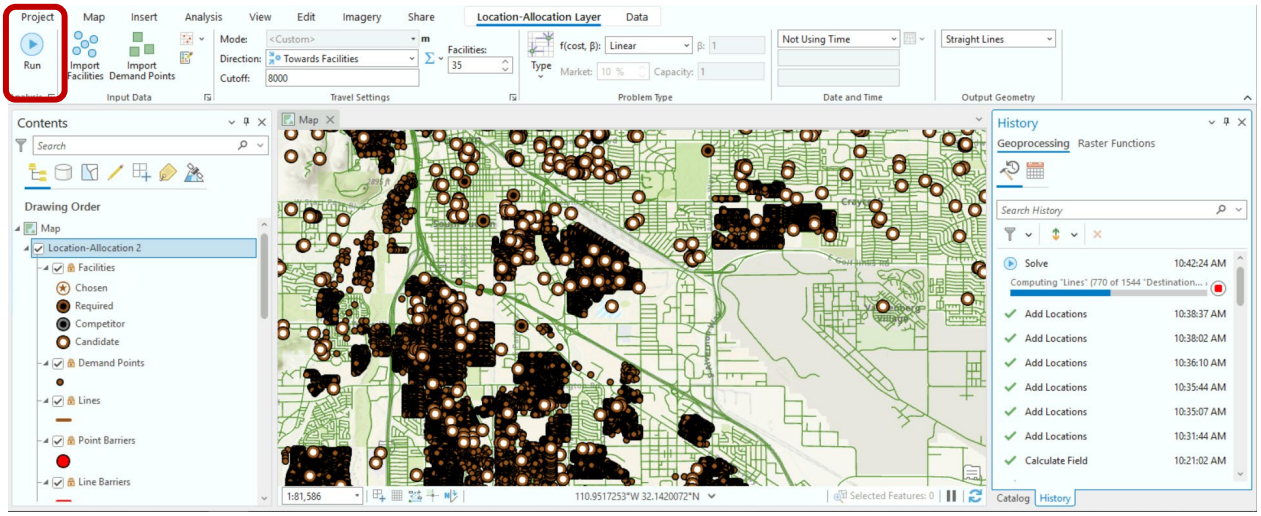


7. **Import Demand Locations:** For each demand location layer, select **Import Demand Points**. Select the layer of interest for **Input Locations.** Select **Cutoff_Length** from the list of attributes in the Property table. Set the **Field Name** to the name of your cutoff variable, in this example it's "**Cutoff_m**". Remember to repeat this process for each layer, for example, we repeated this process twice for residential and mobile home data. If you want to change the cutoff value, redo step 4.

   Note: The output of the workflow does not include location attributes. If you want to export any of the output layers, you may need to do a spatial join to the input data in order to have this information.



8. Once you have verified all steps are complete, Click **Run**



Deliverable

To complete this project, develop a map from the Location-Allocation output which can be used by stakeholders to identify candidate locations, mapped with current locations, for Pima County, AZ. Describe your map, what it is showing, and how you got the output. Explain what you did in this exercise and your symbology choices for the map.