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<u>Locating Fire Stations in Gainsville</u>

Section 1: Define the problem:

For our problem definition we want to focus on 9 fire stations found in Gainsville, Florida. We will be placing 12 potential facility locations. This type of facility is a public service facility that should be located very strategically. We will be using *google maps distance calculator* as well as *calc maps*. Our main source of gathering distances will be google maps distance calculator. However, the purpose of using calc maps is to double check the distances and get the accurate data. We will be placing candidate facilities and locating them according to their latitude and longitude coordinates. To calculate these coordinates, we will be using google maps. They have a very straight forward and accurate way on finding the exact coordinate we want to use. The decisions that we must made are how to divide our map in order to have enough demand nodes. We also must make the decision of where to place a potential facility based on the map below.

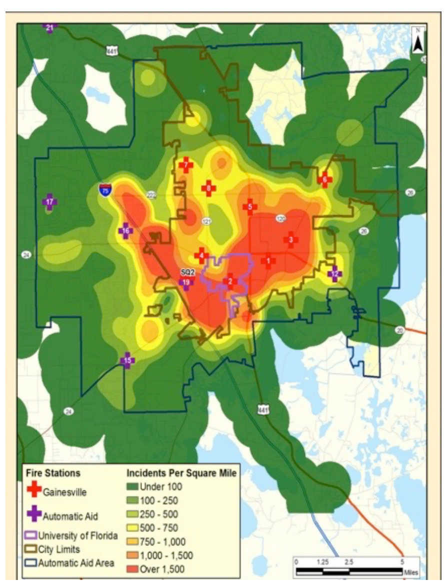

Figure 1

This map shows the areas in Gainesville which are the most exposed to any threats or hazards. Complementary, we did research on how the population is distributed and which areas should be a priority with relation to fire stations. United States census shows that the population is distributed very similar as shown in the map. The areas in red are also the most populated areas in Gainsville. We also have University of Florida located in purple, which in both the map and the census presents a very high population and a high incident per square mile.

.In addition, we decided to first start with an empty map of the city and place our own potential facilities (red points). After deciding the locations, we need to find a radius from the center of the facility to the demand nodes which that facility must cover. In this step, it is important to minimize the maximum distance from node 1 to its assigned facility, this means we need try to set our radius as small as possible, but all nodes must be covered. In the image below we can see an illustration on how we made the decisions to define the measure of the radius

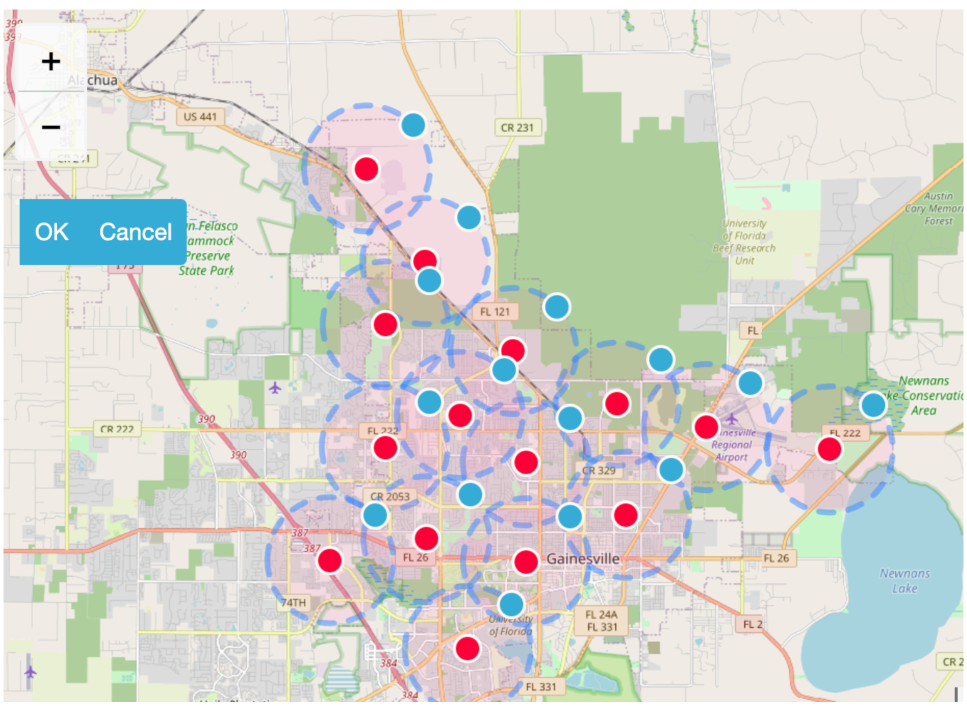

Figure 2

This is an example of our first attempt on deciding the length of the radius, as well as our first attempt on the potential facility locations. We first used 1.65 miles as our radius. What we observed is that even though all of the demand nodes are covered, we could decrease the length of the radius by moving the potential facilities to new ones. We arranged new locations multiple times and we came up with a new radius of 1.5 miles (2000 meters) and we reduced the number of possible locations to 11. We did this just to find a number that is feasible to put in the map.

For the measure of the radius calc maps is a great tool because it gives exact measurements and we are able to place the exact coordinates we assigned our facilities. Based on that information we were able to come with multiple alternatives on how should the length on the radius be. This tool allows us to try multiple distances without having to draw them manually on a map.

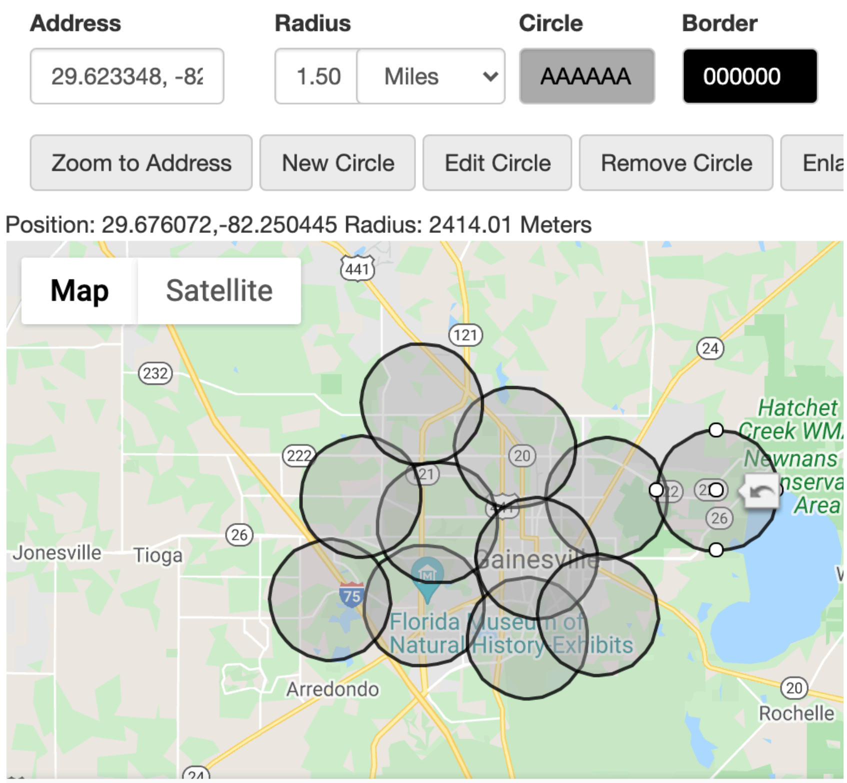

Figure 3

Another important decision was to decide how many nodes we would have. We came up with 36 nodes being a reasonable division on the graph. We decided to reduce the number of possible locations to 11 because on our scale 15 fire stations were too near to each other.

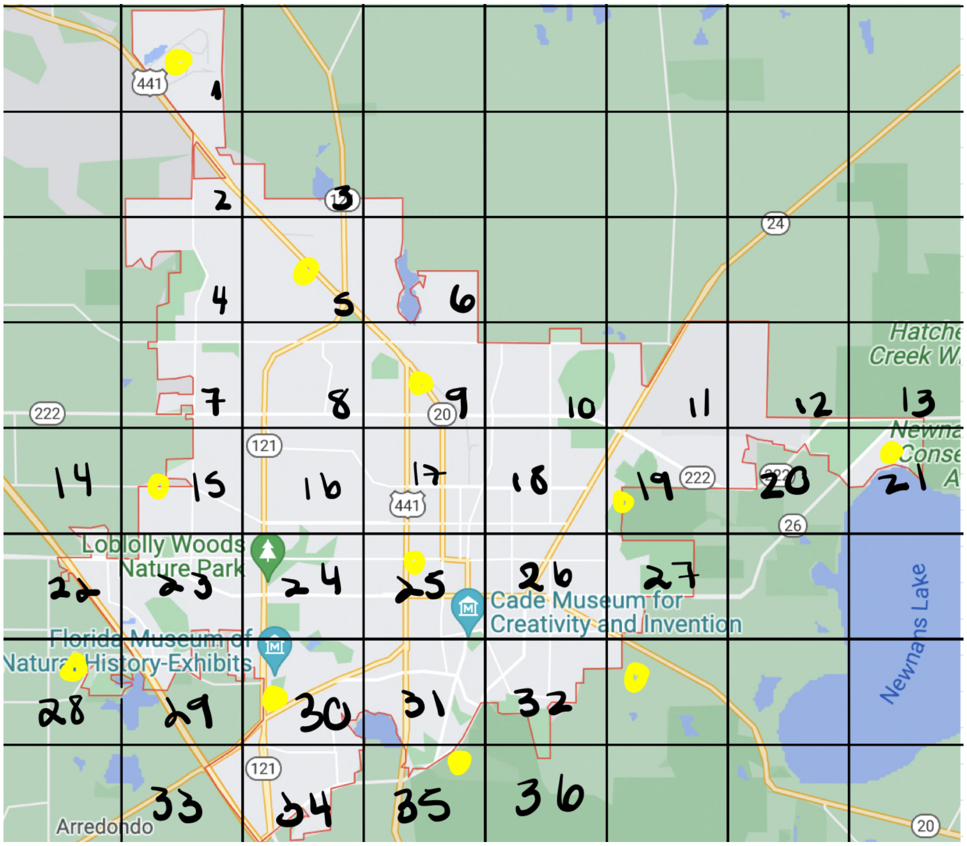

Figure 4

The tool used to make the divisions was good notes. They provide templates of pages with exact measurements, so we copied the same template on top of our map.

The criteria we are using for locating the fire stations facilities are based on real life situations. Fire stations involve minimizing time of arrival, since some minutes of difference could save lives or avoid big fires. After doing some research, we produced the following valuable information: The number and location of fire stations in a community is normally based on the distance between stations, the population served, and the threats at particular locations (Gay, W., & Siegel, A., 1987, pp. 3). Since we are working with a public service, we need to take all of those factors into account. The constraints that limit the decisions we could eventually come up with are economic, location wise (ex. certain location could be a protected natural area). Also, we can be limited in the limit of personnel that we can hire to manage each fire station and the limit of resources that each station demands.

Section 2: Formulation of an optimization model:

Our goal in this project is to minimize the distance from each node to the nearest fire station. We will choose 9 facility locations from among the candidates facility locations and attempt to minimize the total distance from each demand node to its facility. For this, we will use the P-Median model that will be described below.

Indices

$i = 1, \ldots, I,$ Demand Nodes $\longrightarrow$ Highest population demand
$j = 1, \ldots J,$ Candidate facility sites $\longrightarrow$ Potential facility fire station location

Parameters

$j = distance\ from\ demand\ node\ i\ to\ candidate\ site\ j, \quad i = 1, \ldots, I, \quad j = 1, \ldots, J$
$i = demand\ at\ node\ i, i = 1, \ldots, I$
$p = number\ of\ faciliies$

For our project the values are as follow:

J = 37. We decided to have 37 nodes.
I=11. We want to have 11 alternatives on where to locate the facilities.
P = 9. We want to locate exactly 9 fire stations

Variables

$$xj = \begin{cases} 1 & \text{if a facility is located at candidate side j, j = } 1, \ldots. \text{J} \\ 0 & \text{otherwise} \end{cases}$$

$$\text{yij} = \begin{cases} 1 & \text{if demand node i is assigned to a facility at site j} \quad \text{i} = 1, \ldots, \text{I}, \quad \text{j} = 1, \ldots, \text{J} \\ 0 & \text{otherwise} \end{cases}$$

$w =$ *objective value* $\longrightarrow$ *minimize the maximum distance from node i to its assigned facility*

Constraints

Locate exactly P facilities w

$\sum_{j=1}^{J} xj = p$ $\longrightarrow$ Locate exactly 11 facilities

Assign every demand node to a facility

$\sum_{j=1}^{J} yij = 1 \quad \forall i = 1, \ldots, I.$ $\longrightarrow$ All demand nodes are covered by a fire station

If we assign any demand node to a candidate facility site, we must build a facility at that site

$yij \leq xj \ \forall i = 1, \ldots, I \ \forall j = 1, \ldots, J$
xj binary, $\forall i = 1, \ldots, I$

yij binary, $\forall i = 1, \ldots, I \ \forall j = 1, \ldots, J$

Section 3: Gather and synthesize data:

To gather our data, we started by calculating the exact point on which we want to locate our facilities with their corresponded latitude and longitude coordinates. Using calc maps we locates the coordinates and set up the radius to be 1.5miles. This part of the data should be very accurate because the tool locates the center of the circle in the exact coordinate, and from there calculates the radios. This again just to set the number of possible facility locations. We repeated this step for every candidate facility. Next, we calculated the distances between node j to its assigned facility. We used calc maps as well and calculated these distances with straight lines. A good thing of using the same tool for both radius and distance is that we do not need to think about any error in the scale it was calculated.

To gather data about our demand vector, we based our data on the ranges that figure 1 provides. For this we did not use accurate data. We used random data.

Section 4: Solve and analyze the model:

After gathering data and setting the parameters we wanted to, we came up with the following result. The nodes that ampl suggested to set as permanent are nodes 1,2,5,6,7,8,9,10,11. we found an approximate location of this fire stations show in the table below:

node	**coordinates**
1	29.763194, -82.394333
2	29.722361, -82.366139
5	29.693359, -82.333793
6	29.673788, -82.397365
7	29.669164, -82.291732
8	29.682804, -82.229470
9	29.658760, -82.334837
10	29.634148, -82.411599
11	29.630548, -82.370529

With these coordinate points we can try out the radius we previous found and double check if the solution is feasible. We plotted the coordinates and added a circle with radius of 1.5

miles. The solution is optimal. However, we noticed that if we change the parameter of a possible number of potential facilities, we could potentially get another feasible solution. We changed parameter I to be set to 15 instead of 11, as we started at the beginning. This is as well an optimal solution. We would need to compare various changes into the constraints to find the most accurate. When analyzing the result ampl gave, we believe it is reasonable. We referenced the actual fire stations in Gainesville, and multiple of our nodes are in a close location to what we got.

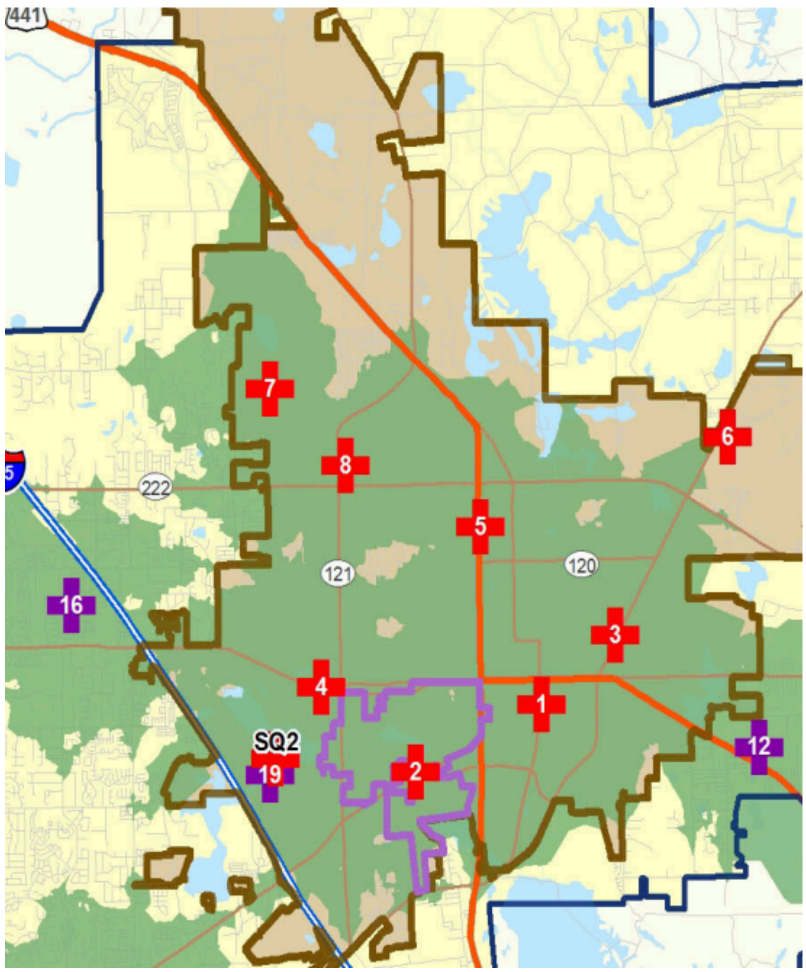

Figure 5

Figure 5 shows the current locations of fire stations in Gainsville. Our output showed that we should locate our facilities at the top half of the map. Which is not wrong, but we could extend our model and figure out why is not considering the nodes in the bottom of the map. A factor is definitely our population data that was calculated randomly.

Reference

Gainesville, FL population density map by neighborhoods. (n.d.). Retrieved December 10, 2021, from https://www.newborhood.com/moving-guide/population_density/FL/gainesville.

Principles and applications of Operations Research. (n.d.). Retrieved December 10, 2021, from https://sites.pitt.edu/~jrclass/or/or-intro.html.

Metterhausen, F. (n.d.). *Draw a circle - create a circle on a google map using a point and a radius. Draw a circle with a radius on a map.* Retrieved December 10, 2021, from https://www.mapdevelopers.com/draw-circle-tool.php.