Appendix 2

Vaccine-only Model

In this setup, the breakout has not yet occurred and we want to get everyone vaccinated to prevent major breakout. Our goals are minimizing cost and minimizing distance traveled. We assume everyone will come get a vaccine. This is unlikely to be the case, but at least we will be prepared to give vaccines to as many as want them.

Minimizing Total Distance

Decision Variables:

A_{97x47} : Binary, whether or not to assign zip-code i to site j

S_{47x1} : Binary, whether or not to open a small site (less than 10 medical professionals)

M_{47x1} : Binary, whether or not to open a medium site (10 to 20 medical professionals)

L_{47x1} : Binary, whether or not to open a large site (more than 20 medical professionals)

U_{47x25} : Binary, whether or not to utilize a site each day

X_{47x25} : Integer, the number of medical professionals for each point of dispense for every time period

I_{47x25} : Integer, the amount of inventory to hold every day out of 25 days for each of 47 sites

Parameters:

D_{97x47} : Travel distance from zipcode i to site j

$\mathbf{p}_{97x1}$: population of each zipcode

$\mathbf{e}_{3x1}$: efficiencies per medical professional for each dispense size (Small, Medium, Large)

o : Fixed cost (opening cost)

v : Variable cost

f : Daily fixed cost

r : medical professional wage

h : Per unit daily holding cost

K : A constant serving as the budget constraint

C : The number of available medical professionals

Helping Functions

Total people served by a site $= \sum_i A_{ij} p_i$

Total Population $= \sum_{i=1}^{97} p_i$

Total Cost $= \sum_{j=1}^{47} o(S_j + M_j + L_j) + \sum_{j=1}^{47} \sum_{i=1}^{97} v A_{ij} p_i + \sum_{j=1}^{47} \sum_{t=1}^{25} (r X_{jt} + h I_{jt} + f U_{jt})$

> The total cost is a combination of variable and fixed costs

Formulation

Minimize *Total Distance*

subject to

Total Cost $\leq K$

$\sum_{j=1}^{47} A_{ij} = 1, \forall i \in \{1, 2, \ldots, 97\}$

> Each neighborhood must be assigned to one and only one POD (Point of Dispense)

$A_{ij} \leq S_j + M_j + L_j, \forall i \in \{1, 2, \ldots, 97\}, \forall j \in \{1, 2, \ldots, 47\}$

> A neighborhood can only be assigned to a POD if the POD is opened

$S_j + M_j + L_j \leq 1$

> If we open a site, it can only be one of the following site sizes: Small, Medium, or Large scale

$10M_j + 20L_j - 20(1 - U_{jt}) \leq X_{jt} \leq 10S_j + 20M_j + 1{,}000L_j$

> The number of medial professionals assigned to a site determines its scale-size. X must be within the appropriate range for the desired scale-size.

$\sum_{t=1}^{25} e_S X_{jt} \geq \sum_{i=1}^{97} A_{ij} p_i - (1 - S_j)(\text{Total Population})$

$\sum_{t=1}^{25} e_M X_{jt} \geq \sum_{i=1}^{97} A_{ij} p_i - (1 - M_j)(\text{Total Population})$

$\sum_{t=1}^{25} e_L X_{jt} \geq \sum_{i=1}^{97} A_{ij} p_i$

> Enough medical professionals must be assigned to a site over the time period to administer all of the vaccines. The number of medical professionals need depends on the scale-size of the site. The least restrictive of these three is the third constraint, which we make general to provide a minimum lower bound on X not provided elsewhere.

$\sum_{j=1}^{47} X_{jt} \leq C$

> Every day, no more medical professionals than the total available can be hired across the sites

$X_{jt} \leq C U_{jt}$

> A site can only be assigned medical professionals if it is "used" that day

$U_{jt} \leq S_j + M_j + L_j$

> A site can only be used if it has been opened

$I_{jt} + (1 - S_j)(\text{Total Population}) \geq \sum_{\mathrm{i}} \mathrm{A_{ij} p_i} - \sum_1^{\mathrm{t}} \mathrm{e_S X_{jt}}$

$I_{jt} + (1 - M_j)(\text{Total Population}) \geq \sum_{\mathrm{i}} \mathrm{A_{ij} p_i} - \sum_1^{\mathrm{t}} \mathrm{e_M X_{jt}}$

$I_{jt} + (1 - L_j)(\text{Total Population}) \geq \sum_{\mathrm{i}} \mathrm{A_{ij} p_i} - \sum_1^{\mathrm{t}} \mathrm{e_L X_{jt}}$

$I_{jt} - (1 - S_j)(\text{Total Population}) \leq \sum_{\mathrm{i}} \mathrm{A_{ij} p_i} - \sum_1^{\mathrm{t}} \mathrm{e_S X_{jt}}$

$I_{jt} - (1 - M_j)(\text{Total Population}) \leq \sum_{\mathrm{i}} \mathrm{A_{ij} p_i} - \sum_1^{\mathrm{t}} \mathrm{e_M X_{jt}}$

$I_{jt} - (1 - L_j)(\text{Total Population}) \leq \sum_{\mathrm{i}} \mathrm{A_{ij} p_i} - \sum_1^{\mathrm{t}} \mathrm{e_L X_{jt}}$

> The daily inventory is determined by the total number of vaccinations administered by that point, which is dependent on the scale-size of the site

$X_{jt}, I_{jt} \geq 0$, integer

$S_j, M_j, L_j, A_{ij}, U_{jt} \geq 0$, binary

Minimize Max Distance

This formulation uses the same model as above with the following changes

New Objective:

Minimize z

New Constraint:

$z \geq A_{ij} D_{ij}, \forall i, j$