# Mass Vaccination

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:**

$A_{96x47}$ : 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:**

$D_{96x47}$ : Travel distance from zipcode i to site j

$\mathbf{p}_{96x1}$ : 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 Distance $= \sum_{i=1}^{96}\sum_{j=1}^{47} p_i D_{ij} A_{ij}$

Total Cost $= \sum_{j=1}^{47} o(S_j + M_j + L_j) + \sum_{j=1}^{47}\sum_{i=1}^{96} vA_{ij}p_i + \sum_{j=1}^{47}\sum_{t=1}^{25}(rX_{jt} + hI_{jt} + fU_{jt})$

> This adds the opening cost for each site with the cost of the medical professionals hired

### Formulation

Minimize *Total Distance*

subject to

*Total Cost* $\leq K$

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

$A_{ij} \leq S_j + M_j + L_j, \forall i \in \{1, 2, \ldots, 96\}, \forall j \in \{1, 2, \ldots, 47\}$

$S_j + M_j + L_j \leq 1$

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

$\sum_{t=1}^{25} e_S X_{jt} \geq \sum_{i=1}^{96} A_{ij}p_i - (1 - S_j)(\text{Total Population})$

$\sum_{t=1}^{25} e_M X_{jt} \geq \sum_{i=1}^{96} A_{ij}p_i - (1 - M_j)(\text{Total Population})$

$\sum_{t=1}^{25} e_L X_{jt} \geq \sum_{i=1}^{96} A_{ij}p_i$

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

$X_{jt} \leq CU_{jt}$

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

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

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

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

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

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

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

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

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

## Minimizing Max Distance

## Minimizing Total Distance

**Decision Variables:**

$A_{92x47}$ : 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)

$U_{47x100}$ : Binary, whether or not to utilize a site each day

$X_{47x100}$ : Integer, the number of medical professionals for each point of dispense for every time period

$I_{47x100}$ : Integer, the amount of inventory to hold every day out of 100 days for each of 47 sites

**Parameters:**

$D_{92x47}$ : Travel distance from zipcode i to site j

$\mathbf{p}_{92x1}$ : 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 $= \sum_i A_{ij}p_i$

$D^*$: Maximum distance traveled

Total Cost $= \sum_{j=1}^{47} o(S_j + M_j + L_j) + \sum_{j=1}^{47}\sum_{i=1}^{92} vA_{ij}p_i + \sum_{j=1}^{47}\sum_{t=1}^{100}(rX_{jt} + hI_{jt} + fU_{jt})$

> This adds the opening cost for each site with the cost of the medical professionals hired

### Formulation

Minimize *D**

subject to

$D^* \geq D_{ij}A_{ij}$

*Total Cost* $\leq K$

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

$A_{ij} \leq S_j + M_j + L_j, \forall i \in \{1, 2, \ldots, 92\}, \forall j \in \{1, 2, \ldots, 47\}$

$S_j + M_j + L_j \leq 1$

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

$\sum_{t=1}^{100} e_S X_{jt} \geq \sum_{i=1}^{92} A_{ij}p_i - (1 - S_j)1{,}000{,}000$

$\sum_{t=1}^{100} e_M X_{jt} \geq \sum_{i=1}^{92} A_{ij}p_i - (1 - M_j)1{,}000{,}000$

$\sum_{t=1}^{100} e_L X_{jt} \geq \sum_{i=1}^{92} A_{ij}p_i$

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

$X_{jt} \leq 1{,}000{,}000U_{jt}$

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

$I_{jt} + (1 - S_j)1{,}000{,}000 \geq \sum_i A_{ij}p_i - \sum_1^t e_S X_{jt}$

$I_{jt} + (1 - M_j)1{,}000{,}000 \geq \sum_i A_{ij}p_i - \sum_1^t e_M X_{jt}$

$I_{jt} + (1 - L_j)1{,}000{,}000 \geq \sum_i A_{ij}p_i - \sum_1^t e_L X_{jt}$

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

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