# Vaccine and Antibiotic Model

In this setup, a breakout has occurred. Some in the population need treatment. The rest we will give vaccinations to. To prevent further outbreak, we do not want to provide prevention and treatment in the same locations. In this problem we use multi-objective programming to balance the distance infected and uninfected people have to travel while staying within budget.

## Minimizing Average Total Distance

**Decision Variables:**

*First-stage:*

$\mathbf{y}_{47x1}$ : Binary, wether or not to open a point of dispense at each site

$T_{47x1}$ : Binary, whether to use a site for therapeutics (0 means use for vaccination if y = 1)

*Second stage:*

$A_{97x47x97}$ : Binary, whether or not to assign zip-code i to site j

$S_{47x97}$ : Binary, wether or not to assign less than 10 medical professionals to a site

$M_{47x97}$ : Binary, wether or not to assign between 10 and 20 medical professionals to a site

$L_{47x97}$ : Binary, wether or not to assign more than 20 medical professionals to a site

$U_{47x25x97}$ : Binary, whether or not to utilize a site each day

$X_{47x25x97}$ : Integer, the number of medical professionals for each point of dispense for every time period for every scenario

$I_{47x25x97}$ : Integer, the amount of inventory to hold every day out of 25 days for each of 47 sites in 97 scenarios

**Parameters:**

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

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

$\mathbf{e}_{3x2}$ : efficiencies per medical professional for each dispense size (Small, Medium, Large) and for each treatment type

$o$ : First stage fixed cost (opening cost)

$v$ : Second stage variable cost

$f$ : Second stage daily fixed cost

$r$ : medical professional wage

$h$ : Per unit daily holding cost

$K$ : A constant serving as the budget constraint

$B_{97x97}$ : Binary, whether the population for a zipcode has an outbreak for each of the 97 scenarios

$C$ : The number of available medical professionals

**Helping Functions**

Average Total Distance to get therapeutics $= z_1 = \sum_{k=1}^{97}\sum_{i=1}^{97}\sum_{j=1}^{47}\frac{1}{97}p_i B_{ik} D_{ij} A_{ijk}$

Average Total Distance to get vaccination $= z_2 = \sum_{k=1}^{97}\sum_{i=1}^{97}\sum_{j=1}^{47}\frac{1}{97}p_i(1-B_{ik}) D_{ij} A_{ijk}$

Average Total Cost $= \sum_{j=1}^{47} o y_j + \sum_{k=1}^{97}\sum_{j=1}^{47}\sum_{i=1}^{97}\frac{1}{97} v A_{ijk} p_i + \sum_{k=1}^{97}\sum_{j=1}^{47}\sum_{t=1}^{25}\frac{1}{97}(r X_{jtk} + h I_{jtk} + f U_{jtk})$

## Formulation

Minimize $\alpha z_1 + (1-\alpha) z_2$

subject to

*Average Total Cost* $\leq K$

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

$A_{ijk} \leq y_j, \forall i \in \{1, 2, \ldots, 97\}, \forall j \in \{1, 2, \ldots, 47\}$

$A_{ijk} + (B_i - T_j) \leq 1$

$A_{ijk} + (T_j - B_i) \leq 1$

> Zipcode $i$ can only be assigned to site $j$ if breakout matches therapeutics value

$S_{jk} + M_{jk} + L_{jk} \leq y_j$

$10M_{jk} + 20L_{jk} - 20(1 - U_{jtk}) \leq X_{jtk} \leq 10S_{jk} + 20M_{jk} + 1{,}000L_{jk}$

$\sum_{t=1}^{25} e_S X_{jtk} \geq \sum_{i=1}^{97} A_{ijk} p_i - (1 - S_{jk})(\text{Total Population})$

$\sum_{t=1}^{25} e_M X_{jtk} \geq \sum_{i=1}^{97} A_{ijk} p_i - (1 - M_{jk})(\text{Total Population})$

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

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

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

$U_{jtk} \leq S_{jk} + M_{jk} + L_{jk}$

$I_{jtk} + (1 - S_{jk})(\text{Total Population}) \geq \sum_{\mathrm{i}} \mathrm{A_{ijk} p_i} - \sum_1^{\mathrm{t}} \mathrm{e_S X_{jtk}}$

$I_{jtk} + (1 - M_{jk})(\text{Total Population}) \geq \sum_{\mathrm{i}} \mathrm{A_{ijk} p_i} - \sum_1^{\mathrm{t}} \mathrm{e_M X_{jtk}}$

$I_{jtk} + (1 - L_{jk})(\text{Total Population}) \geq \sum_{\mathrm{i}} \mathrm{A_{ijk} p_i} - \sum_1^{\mathrm{t}} \mathrm{e_L X_{jtk}}$

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

$y_j, T_j, S_{jk}, M_{jk}, L_{jk}, A_{ijk}, U_{jtk} \geq 0$, binary