Vaccine Distribution Strategy

Sets

I	Set of Import Depots (IDs)
J	Set of Local Vaccination Centres (LVCs)
K	Set of Census Collection (CCDs)
T	Set of Weeks

Data

c_i	Cost (\$) per dose for each ID $i \in I$
P_k	Population for each CCD $k \in K$
$IDtoLVC_ij$	Distances (km) from IDs $i \in I$ to LVCs $j \in J$
$PtoLVC_kj$	Distance (km) from CCDs $k \in K$ to LVCs $j \in J$
α	Cost per km (\$/km) per dose for delivering vaccinces from IDs to LVCs
β	Cost per km (\$/km) per citizen for a citizen from $k \in K$ travelling to an LVC $j \in J$
$MaxID$	Maximum doses imported to IDs
$MaxLVC$	Maximum doses administered at LVCs
$WeekMax$	Maximum number of doses administered per week per LVC
δ	Cost in delaying vaccination (\$/person/week)
$DiffRatio$	The max difference between the max and min cumulative fraction vaccinated

Variables

x_{ij}	Number of vaccines going from $i \in I$ to $j \in J$
y_{jkt}	Number of people $k \in K$ getting vaccinated at centre $j \in J$ in week $t \in T$
z_i	Total number of vaccines imported to each $i \in I$
u_t	Number of people left to be vaccinated at the end of week $t \in T$
r_{kt}	The cumulative fraction vaccinated for $k \in K$ at $t \in T$
min_ratio_t	The minimum cumulative fraction vaccinated $\forall k \in K$ at the end of week $t \in T$
max_ratio_t	The maximum cumulative fraction vaccinated $\forall k \in K$ at the end of week $t \in T$

$$z_i = \sum_{j \in J} x_{ij} \quad \forall i \in I$$

$$u_t = u_{t-1} - \sum_{j \in J} \sum_{k \in K} y_{jkt} \quad \forall t \in T > 0$$

$$u_0 = \sum_{k \in K} P_k - \sum_{j \in J} \sum_{k \in K} y_{jkt}$$

$$r_{kt} = r_{k,t-1} + \sum_{j \in J} y_{jkt} \quad \forall k \in K, \forall t \in T > 0$$

$$r_{k,0} = \frac{\sum_{j \in J} y_{j,k,0}}{P_k} \quad \forall k \in K$$

Objective

$$\min \sum_{i \in I} c_i * z_i + \sum_{i \in I} \sum_{j \in J} \alpha * IDtoLVC_{ij} * x_{ij} + \sum_{j \in J} \sum_{k \in K} \sum_{t \in T} \beta * PtoLVC_{kj} * y_{jkt} + \sum_{t \in T} \delta * u_t$$

Constraints

$$\sum_{i\in I} x_{ij} = \sum_{k\in K}\sum_{t\in T} y_{jkt} \qquad \forall j \in J \tag{1}$$

$$\sum_{j\in J'}\sum_{t\in T} y_{jkt} \geq P_k \qquad where J' \subset J where PtoLVC_{kj} \neq 0, \forall k \in K \tag{2}$$

$$\sum_{i\in I} x_{ij} \leq MaxLVC \qquad \forall j \in J \tag{3}$$

$$\sum_{j\in J} x_{ij} \leq MaxID \qquad \forall i \in I \tag{4}$$

$$\sum_{k\in K} y_{jkt} \leq WeekMax \qquad \forall j \in J, \forall t \in T \tag{5}$$

$$min\_ratio_t \leq r_{kt} \qquad \forall k \in K \forall t \in T \tag{6}$$

$$max\_ratio_t \geq r_{kt} \qquad \forall k \in K \forall t \in T \tag{7}$$

$$max\_ratio_t - min\_ratio_t \leq DiffRatio \qquad \forall t \in T \tag{8}$$

$$x_{ij} \geq 0 \qquad \forall i \in I, \forall j \in J \tag{9}$$

$$y_{jkt} \geq 0 \qquad \forall j \in J, \forall k \in K, \forall t \in T \tag{10}$$

Constraints (1) say that the flow of vaccines into each LVCs must be equal to the doses administered at each LVC, and constraints (2) ensure that there are sufficient vaccines to satisfy the demand given by the population. Constraints (3-4) enforce the maximum capacities and maximum number of doses administered at each ID and LVC respectively. Constraints (5) enforce the weekly maximum number of doses that can be delivered to each LVC. Constraints (6-8) ensure the difference between the maximum and minimum cumulative fraction vaccinated is no greater than maximum allowable difference. Constraints (9-10) enforce non-negativity for the variables.