Data-Driven Patient Allocation Optimization with Epidemic and Vaccine Modeling

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Motivation

Since 2020, COVID-19 has infected and killed millions of individuals across the world. We develop a mathematical model that incorporates disease spread with patient travel dynamics to minimize unmet hospital demand. We test our model with a case study in Florida, using real-world data from [1].

Unmet Demand

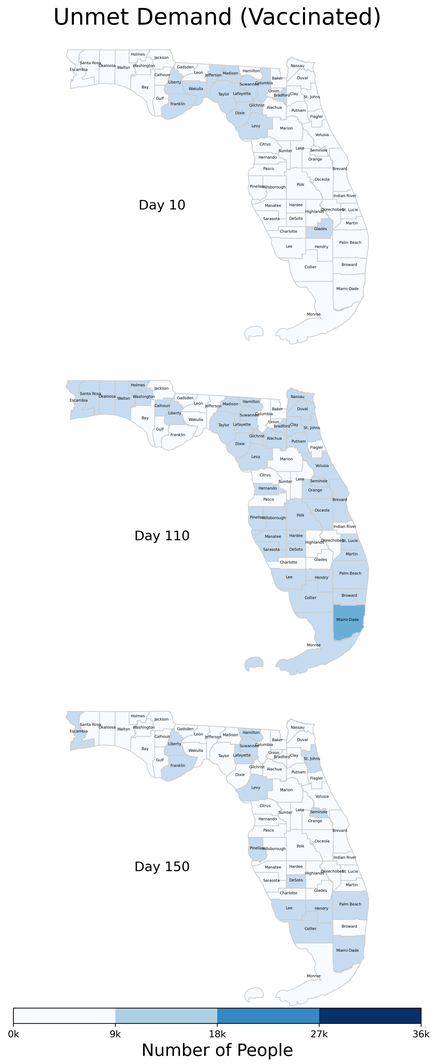

Figure 1: Heat Map of Unmet Hospital Demand Across Decision Periods

Mathematical Model

We formulate our mathematical model (as an extension of the one found in [2]) as follows:

$$\min \frac{1}{n} \sum_{i,t'} u_i^{t'} \tag{1}$$

subject to

$$S_i^{t+1} = S_i^t - \frac{\beta_i S_i^t I_i^t}{N_i} - \lambda_i S_i^t + \omega_i V_i^t + q_i R_i^t \qquad \forall i, t \tag{2}$$

$$I_i^{t+1} = I_i^t + \frac{\beta_i S_i^t I_i^t}{N_i} + \frac{\beta_i \ell_i V_i^{t'} I_i^t}{N_i} - \gamma_i I_i^t \qquad \forall i, t \tag{3}$$

$$I_i^{t'+1} = I_i^{t'} + \frac{\beta_i S_i^{t'} I_i^{t'}}{N_i} + \frac{\beta_i \ell_i V_i^{t'} I_i^t}{N_i} - \gamma_i I_i^{t'} + \sum_j (Z_{j,i}^{t'} - Z_{i,j}^{t'}) \qquad \forall i, t' \tag{4}$$

$$V_i^{t+1} = V_i^t + \lambda_i S_i^t - \omega_i V_i^t - \frac{\beta_i \ell_i V_i^t I_i^t}{N_i} \qquad \forall i, t \tag{5}$$

$$R_i^{t+1} = R_i^t + \gamma_i I_i^t - q_i R_i^t \qquad \forall i, t \tag{6}$$

$$u_i^{t'} = \sum_{t \in \{t'-\psi+1, \ldots, t'\}} \alpha_i^t I_i^t + \sum_{i \neq j} (Z_{j,i}^{t'} - Z_{i,j}^{t'}) - \phi_i^{t'} \qquad \forall i, t' \tag{7}$$

$$\phi_i^{t'} \leq \gamma_i C_i \qquad \forall i, t' \tag{8}$$

$$Z_{i,j}^{t'} \leq M \cdot A_{i,j}^{t'} \qquad \forall i, t' \tag{9}$$

$$A_{i,j}^{t'} \cdot d_{ij} \leq D \qquad \forall i, j, t' \tag{10}$$

$$Z_{i,j}^{t'} \geq A_{i,j}^{t'} \qquad \forall i, j, t' \tag{11}$$

$$S_i^t, I_i^t, R_i^t, V_i^t \geq 0 \qquad \forall i, t \tag{12}$$

$$u_i^{t'}, \phi_i^{t'} \geq 0 \qquad \forall i, t' \tag{13}$$

$$Z_{i,j}^{t'} \geq 0 \qquad \forall i, j, t' \tag{14}$$

Infection Comparison

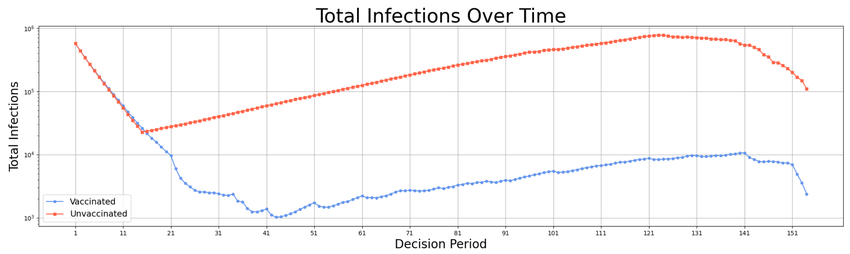

Figure 2: Total Infection Comparison Over Time

References

[1] Florida Department of Health. Florida covid-19 data, 2024. Accessed: 2024-02-15.

[2] Seyedreza Abazari, Onur Alisan, Omer Arda Vanli, and Eren Erman Ozguven. Data-driven patient allocation for healthcare facility optimization under uncertainty with sir dynamics. In *2024 IISE Annual Conference and Expo*. IISE, May 2024.

Patient Allocation

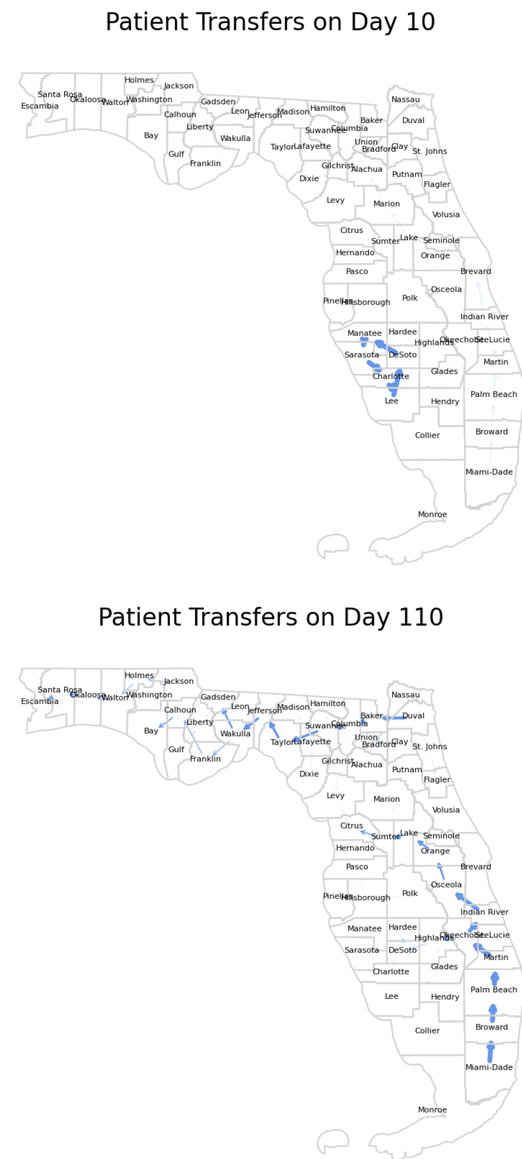

Figure 3: Patient Transfers Across Decision Periods

Links

QR Code 1: Full Model Description
QR Code 2: LinkedIn Profile