

Multi-Objective Optimization of Healthcare Facility Access Equity and Efficiency Using a CVaR-Based Model

Caroline Yao, advised by Prof. Neil Lutz @ Swarthmore College

Introduction

- ♦ Healthcare facility allocation must balance population density, distance, and subgroup fairness.
- ♦ Constructed an MILP which optimizes clinic allocation subject to a convex combination of the twin objectives:
 - ♦ minimizing weighted average clinic distance,
 - ♦ optimizing a fairness metric based on Conditional Value at Risk (CVaR).

Methods

- ♦ Problem Definition
 - ♦ A tract is *disadvantaged* iff its centroid lies in a Medically Underserved Area/Population per HRSA.
 - ♦ Each tract centroid is a candidate site.

$$\min_{x, y, z} \lambda \frac{\sum_{i \in \mathcal{T}} w_i \sum_{j \in \mathcal{C}} d_{ij} x_{ij}}{\sum_{i \in \mathcal{T}} w_i} + (1 - \lambda) \left(\gamma + \frac{1}{2(1 - \alpha)} \left(\frac{1}{t_{dis}} \sum_{i \in \mathcal{T}_{dis}} z_i + \frac{1}{t_{adv}} \sum_{i \in \mathcal{T}_{adv}} z_i \right) \right)$$

subject to:

$$\sum_{j \in \mathcal{C}} x_{ij} = 1, \quad \forall i \in \mathcal{T}$$

$$x_{ij} < y_j, \quad \forall i \in \mathcal{T}, \forall j \in \mathcal{C}_{cand}$$

$$y_j = 1, \quad \text{if } j \in \mathcal{C}_{exist}$$

$$\sum_{j \in \mathcal{C}_{cand}} y_j = p, \quad z_i \geq \sum_{j \in \mathcal{C}} d_{ij} x_{ij} - \gamma, \quad \forall i \in \mathcal{T}$$

$$z_i \geq 0, \quad \gamma \in \mathbb{R}, \quad x_{ij} \in \{0, 1\} \quad \forall i \in \mathcal{T}, j \in \mathcal{C}, y_j \in \{0, 1\} \quad \forall j \in \mathcal{C}_{cand},$$

where $\alpha \in (0, 1)$ = confidence level; \mathcal{T} = tracts; \mathcal{C}_{cand} = candidate sites; \mathcal{C}_{exist} = existing sites; w_i = population in tract i ; d_{ij} = distance from tract i to clinic j ; \mathcal{T}_{dis} , \mathcal{T}_{adv} = two subgroups; $t_{dis} = |\mathcal{T}_{dis}|$, $t_{adv} = |\mathcal{T}_{adv}|$; p = number of new clinics; $x_{ij} \in \{0, 1\}$ = tract i assigned to clinic j ; $y_j \in \{0, 1\}$ indicates whether candidate j is chosen.

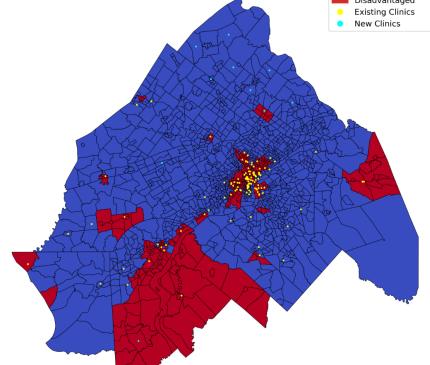
Future Work

- ♦ Extend to regions with different geographic aspects.
- ♦ Compare with models using alternative fairness notions.

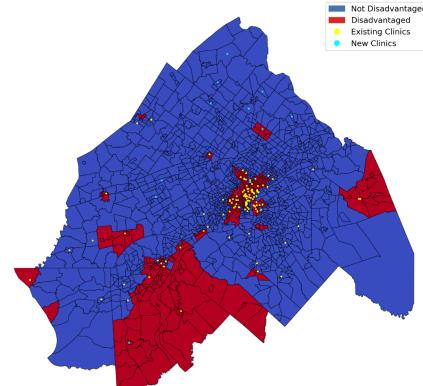
Experiments and Results

- ♦ Data Preparation
 - ♦ Study scope: *Philly Metro Area*.
 - ♦ Sources: census.gov, ACS 5-year data, HRSA.
- ♦ Ran experiments for different tradeoff parameters $\lambda \in [0, 1]$, $p = 5, 10, 15$, and $\alpha = 0.95$.
- ♦ Larger $p \rightarrow$ lower weighted distance. For all p , sharper decrease around $\lambda = 0.6$.
- ♦ For small λ , increasing λ can **improve average distance without impacting the fairness metric**.
- ♦ Mild tradeoff between fairness and distance.
- ♦ Allocation results for $p = 10$ with $\alpha = 0.95$ and $\lambda = 0.8$ (bottom) and $\lambda = 0.0$ (top).
- ♦ Similar allocation results but different fairness value: 16.387094 versus 16.526801.

Philly Metro Tracts: Disadvantaged Status + Clinics



Philly Metro Tracts: Disadvantaged Status + Clinics



Weighted Average Distance vs Fairness CVaR Across λ

