

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

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## 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.

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

subject to:

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

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

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

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

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

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

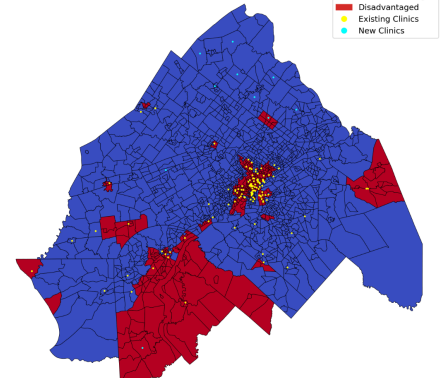
- Extend to regions with different geographic aspects.
- Compare with models using alternative fairness notions.

## Experiments and Results

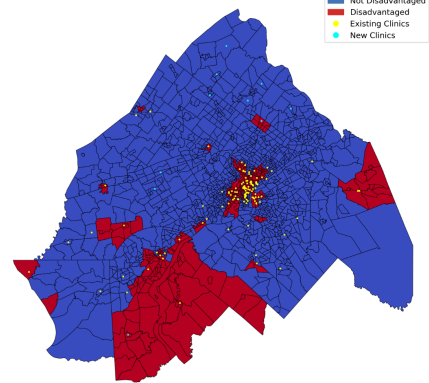
### Data Preparation

- 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  $\lambda$ , increasing  $\lambda$  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



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Weighted Average Distance vs Fairness CVaR Across  $\lambda$

