

Spatial Interaction Models

Lecture #25 | GEOG 510
GIS & Spatial Analysis in Public Health
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Outline

- Spatial Accessibility
 - Gravity models (spatial interaction)
 - Floating Catchment Areas
 - Calculation

Spatial Accessibility

- Merges measures of accessibility and availability
- Why do we need it?
 - Accessibility does not capture differences in the opportunities available (e.g., magnitude)
 - Container-based Availability has known issues (travel outside of container, MAUP)

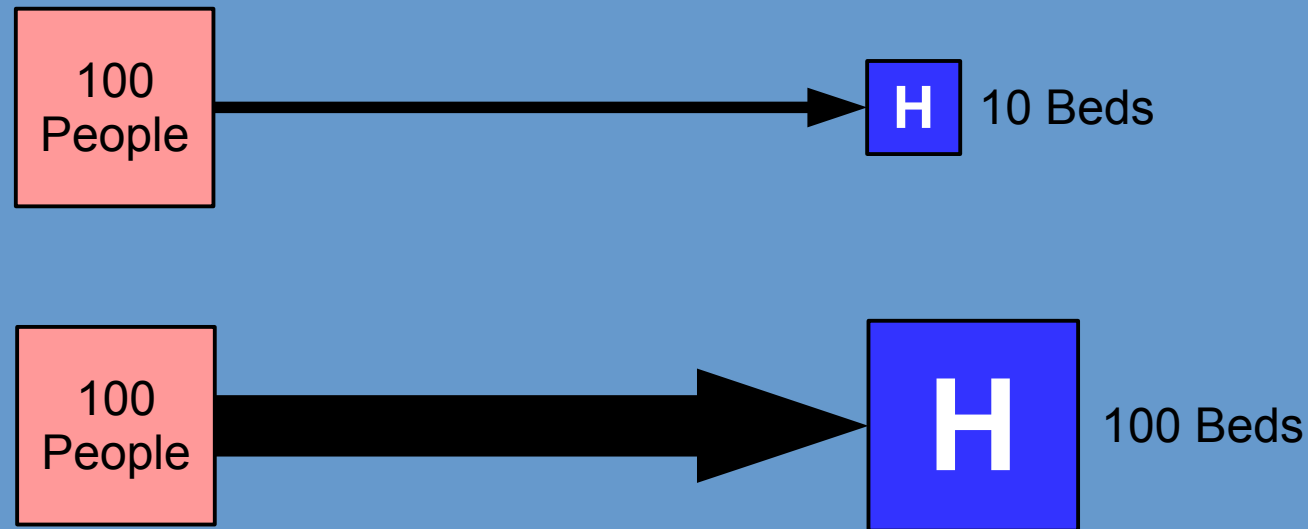
Spatial Accessibility

- How do we measure it?
 - Floating Catchment Area (FCA) metrics
 - Simultaneously incorporates distance, supply, and potential demand
 - Based on a Gravity Model
 - Forces pulling people toward facilities
 - Attractive force conceptualized as potential spatial accessibility

Gravity Model

- Basics

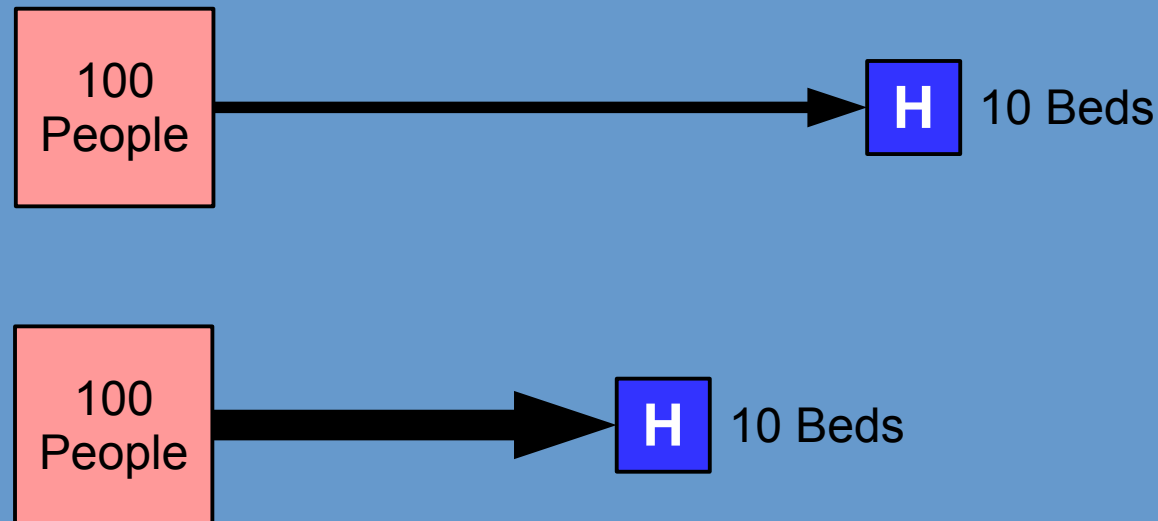
- Larger facilities will have a greater attraction (with constant distance)



Gravity Model

- Basics

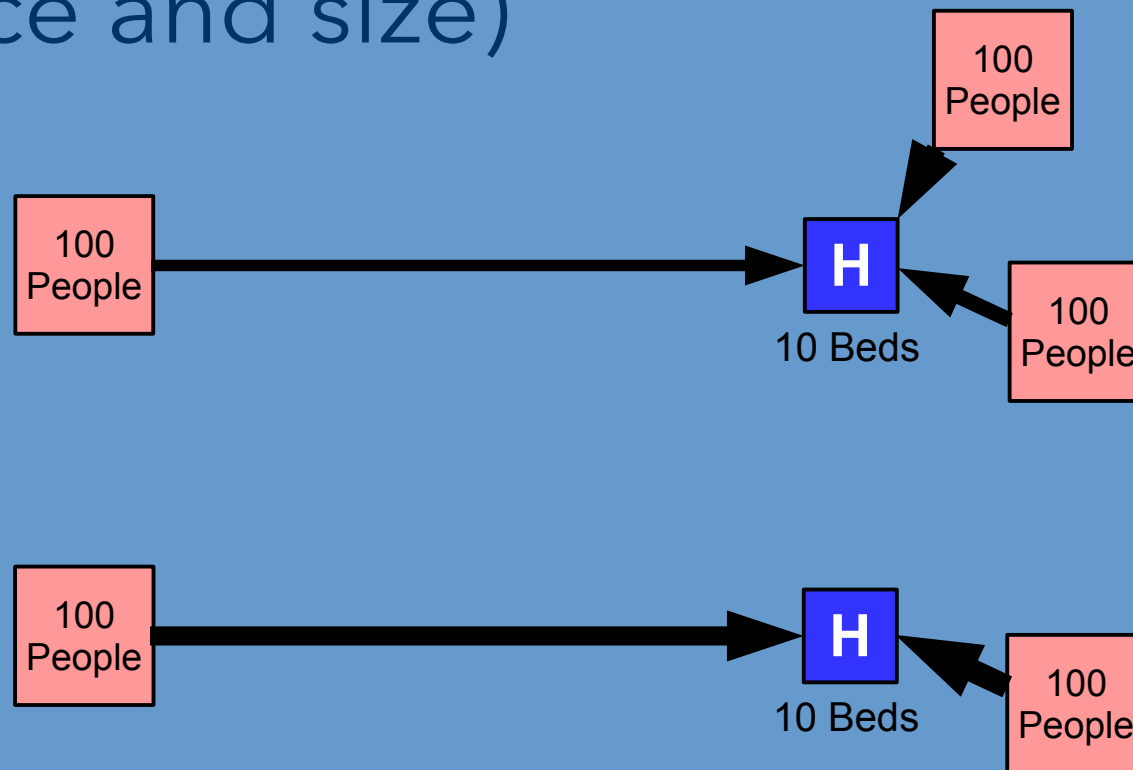
- Attraction increases with decreasing distance (and constant size)



(Modified) Gravity Model

- Basics

- Attraction decreases with increasing competition for services (with constant distance and size)



Floating Catchments

- Catchments based on distance from facilities, rather than predetermined (admin) boundaries
 - Alleviates the problem of people's ability to access services outside of their spatial unit

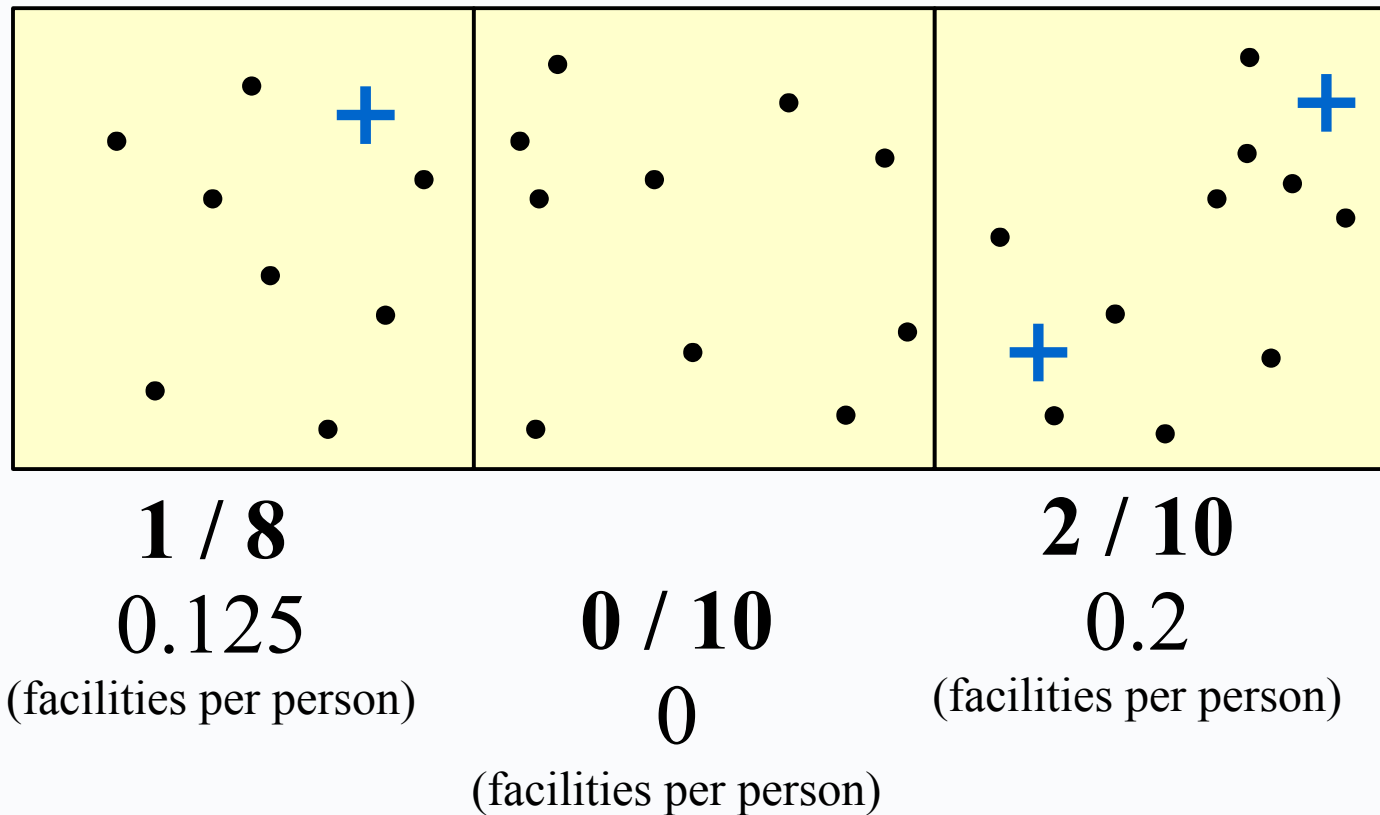
FCA Metrics

- Provide a measurement of spatial accessibility
 - Combination of accessibility and availability
 - Output is a measurement for each population unit
 - e.g., for a county or zip code
 - Output is opportunities / person
 - Just like container-based methods, e.g., hospital beds / person

Two-Step FCA (2SFCA)

- Original methodology
 - Applied approach that built on theoretical gravity models of previous researchers
 - Reflection of the “time”
 - Simply allowed the boundaries to float
 - Two steps
 - Calculate demand at facilities
 - Calculate supply available to populations

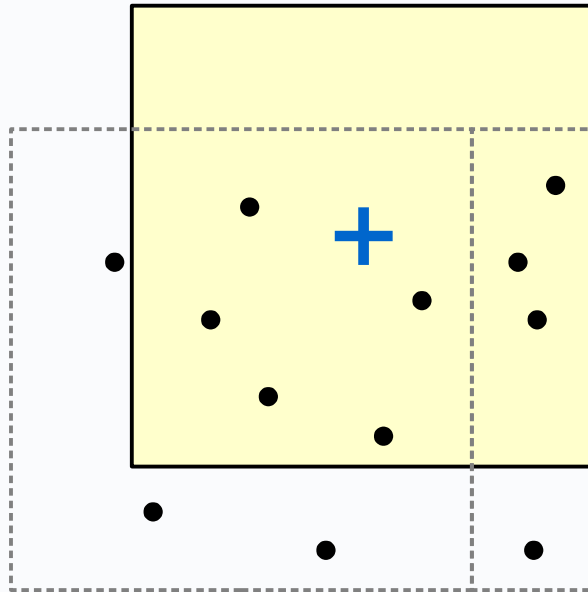
Container approach



Catchments

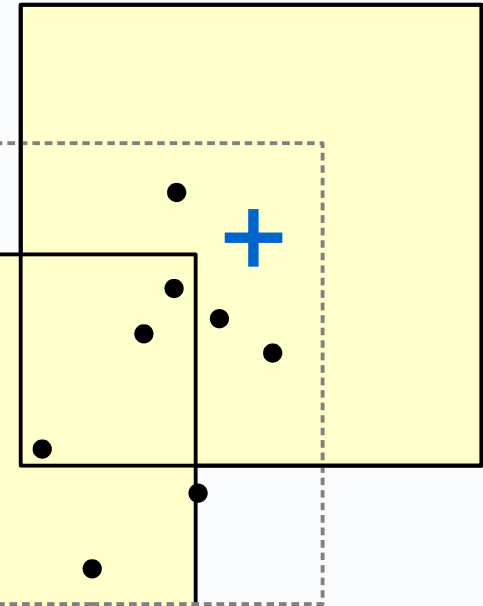
1 / 8

(facilities per person)



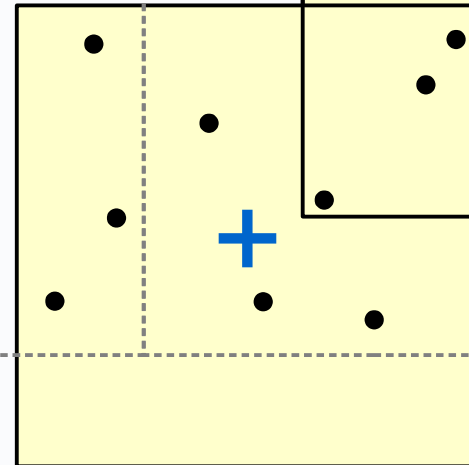
1 / 6

(facilities per person)



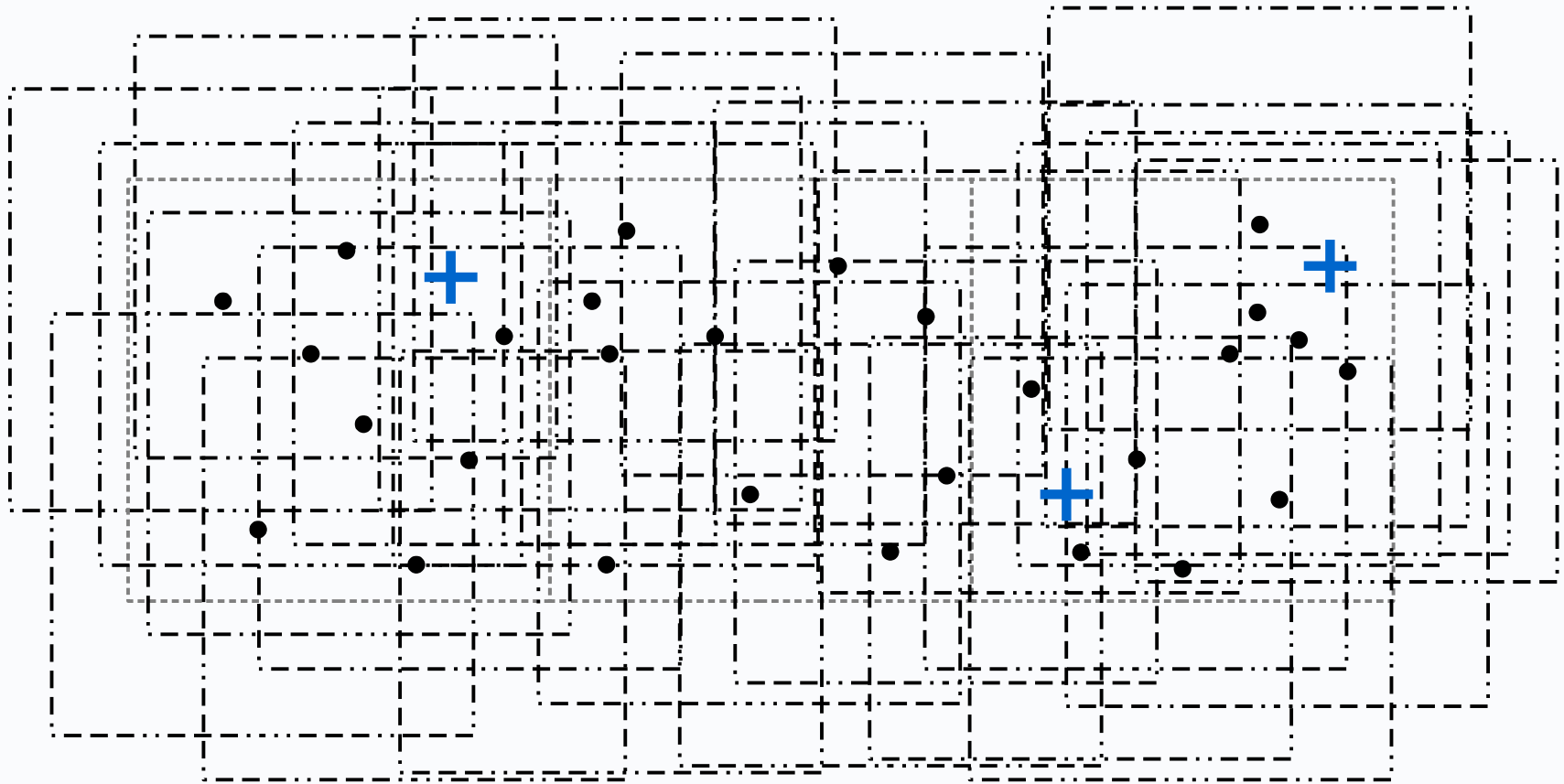
1 / 10

(facilities per person)



2SFCA, Step 1

Catchments



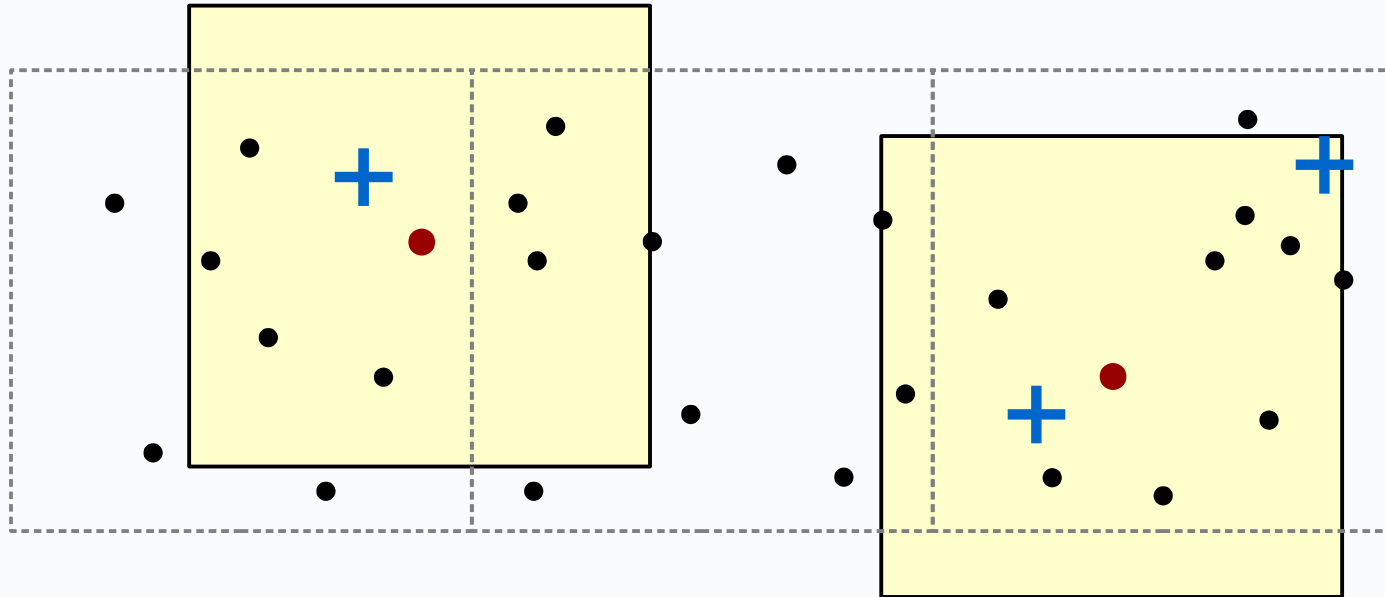
2SFCA, Step 2

Catchments

0.125

1 / 8

(facilities per person)



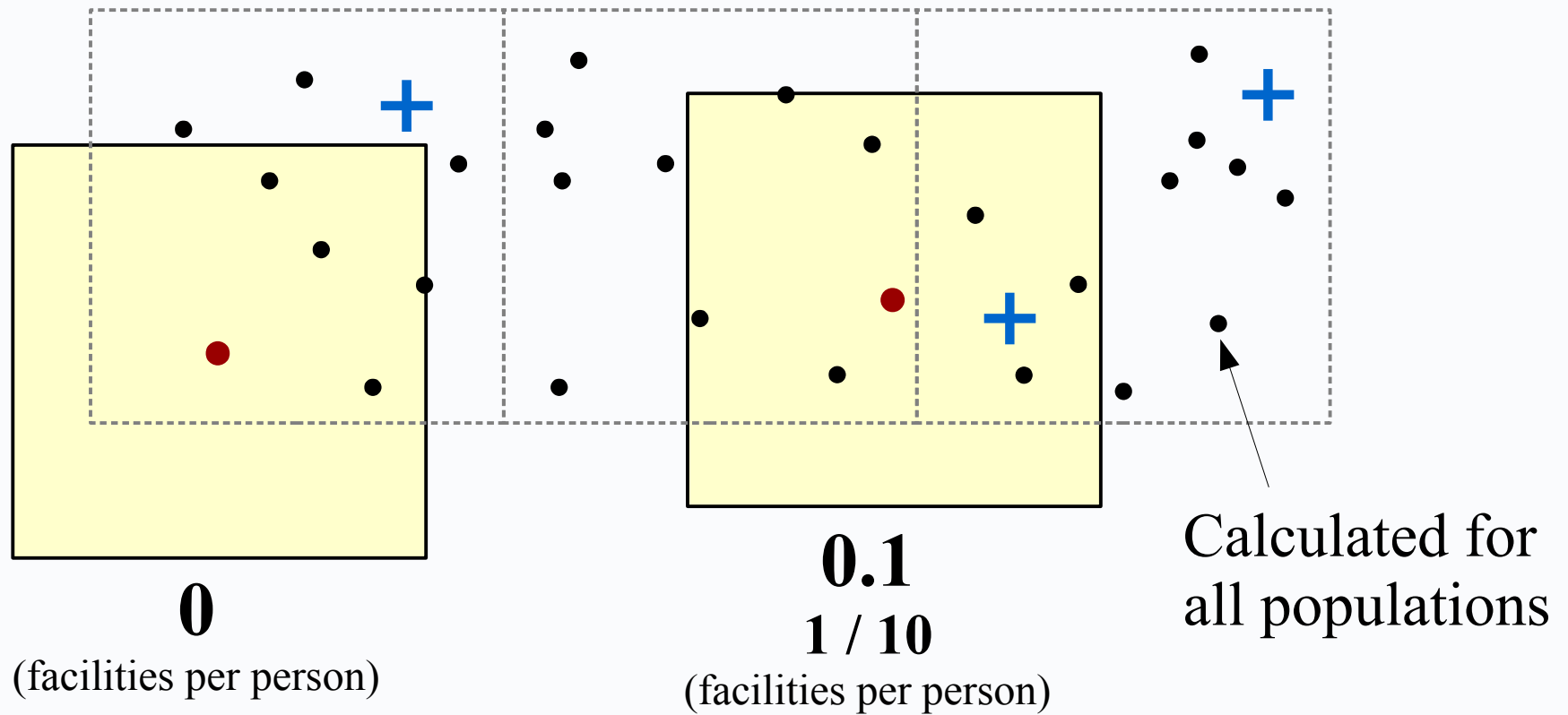
0.267

1 / 10 + 1 / 6

(facilities per person)

2SFCA, Step 2

Catchments



2SFCA, Step 2

2 Step Floating Catchment Area

$$A_i^G = \frac{\sum_{j=1}^m S_j * f(d_{i,j})}{\sum_{i=1}^k P_i * f(d_{i,j})} \quad \begin{array}{l} \text{Modified} \\ \text{Gravity} \\ \text{Formula} \end{array}$$

Step 1

$$D_j = \frac{S_j}{\sum_{i \in [d_{i,j} < d]} P_i}$$

For each facility

Step 2

$$A_i = \sum_{j \in [d_{i,j} < d]} D_j$$

For each region

Catchments

0.078

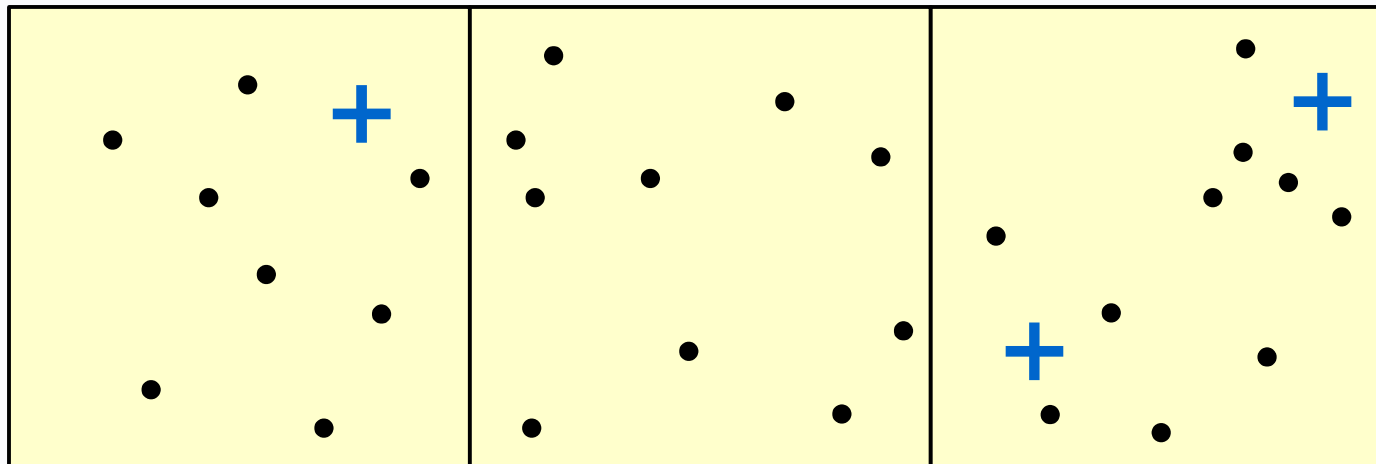
(facilities per person)

0.068

(facilities per person)

0.17

(facilities per person)



0.125

(facilities per person)

0

(facilities per person)

0.2

(facilities per person)

Containers

Distance Decay

- Enhanced 2SFCA (E2SFCA)
- Approach is similar, but integrate a distance decay function
 - Accessibility is not consistent within a catchment
 - Used a series of service area rings
 - Define distance decay function
 - Converts distance to a weight

Distance Decay

- We know the concept
 - How to apply?
 - As a distance decay function
 - A mathematical representation of the decrease in interaction with increasing distance

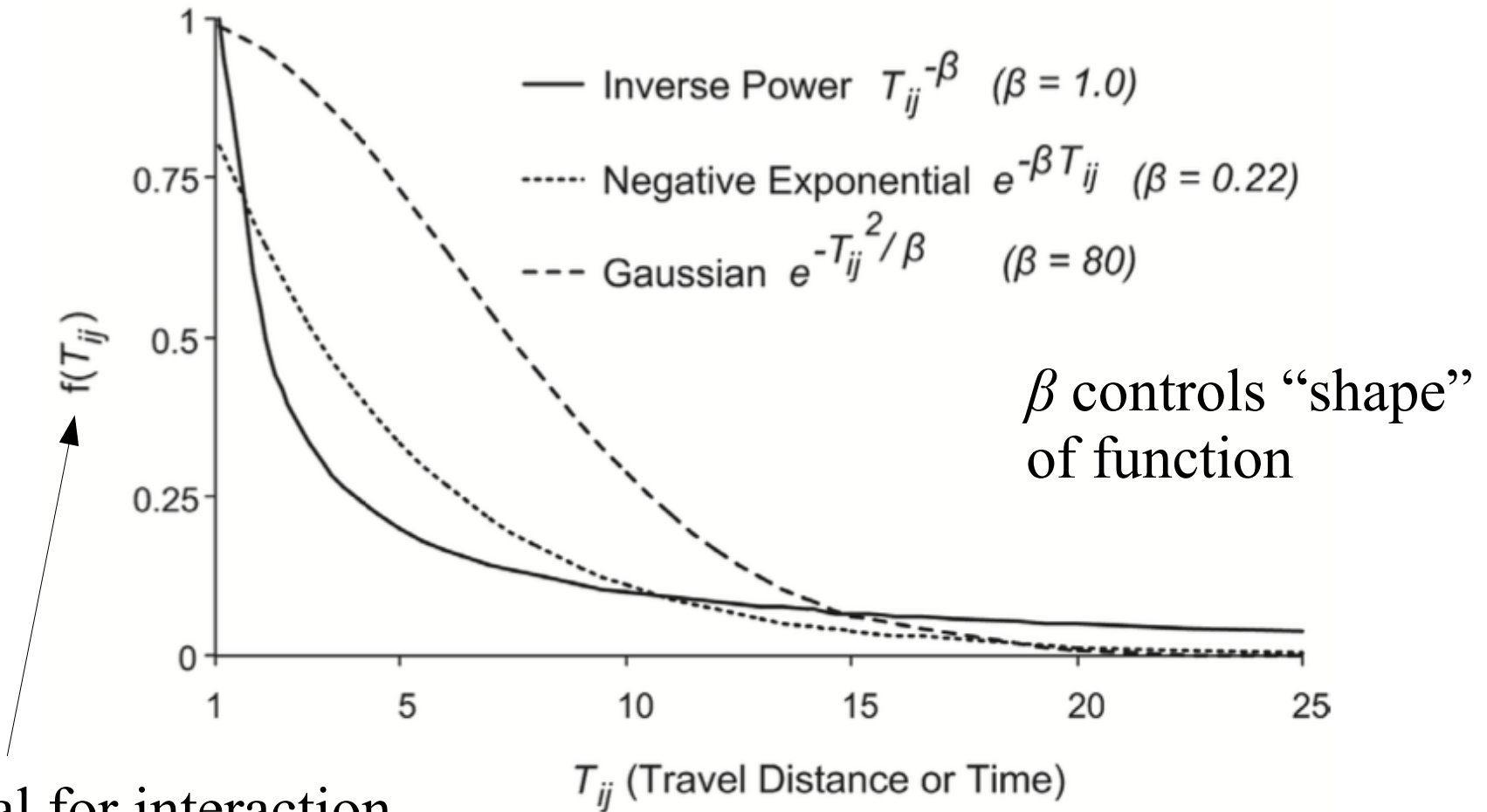


FIGURE 9.11. Different spatial impedance functions. T_{ij} is a measure of travel time or distance.

2 Step Floating Catchment Area

$$A_i^G = \frac{\sum_{j=1}^m S_j * f(d_{i,j})}{\sum_{i=1}^k P_i * f(d_{i,j})} \quad \begin{array}{l} \text{Modified} \\ \text{Gravity} \\ \text{Formula} \end{array}$$

Step 1

$$D_j = \frac{S_j}{\sum_{i \in [d_{i,j} < d]} P_i}$$

For each facility

Step 2

$$A_i = \sum_{j \in [d_{i,j} < d]} D_j$$

For each region

Enhanced 2 Step Floating Catchment Area

$$A_i^G = \sum_{j=1}^m \frac{S_j * f(d_{i,j})}{\sum_{i=1}^k P_i * f(d_{i,j})} \quad \begin{array}{l} \text{Modified} \\ \text{Gravity} \\ \text{Formula} \end{array}$$

Step 1

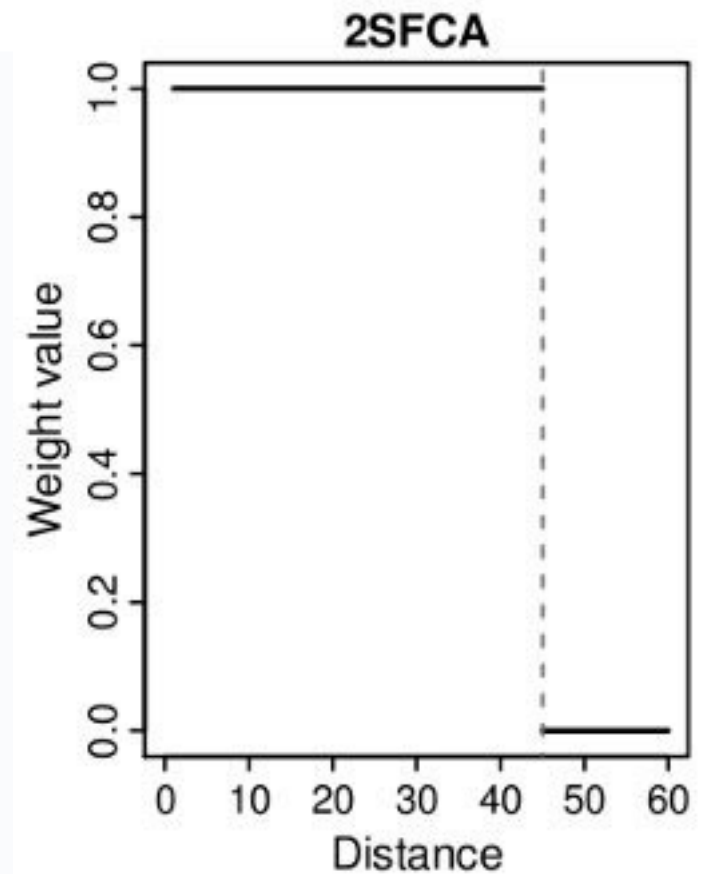
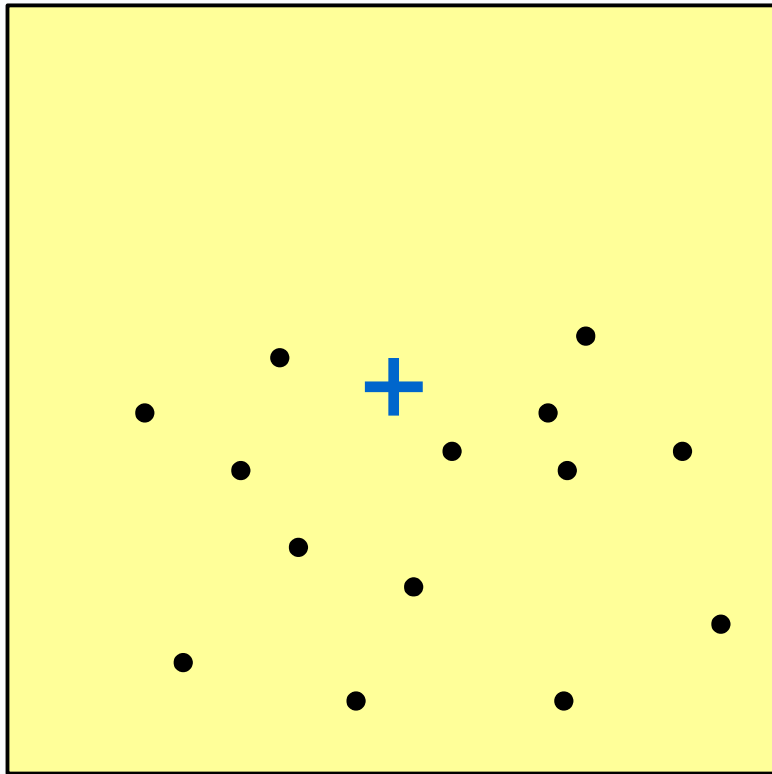
$$D_j = \frac{S_j}{\sum_{i \in [d_{i,j} < d]} P_i * W_{i,j}}$$

For each facility

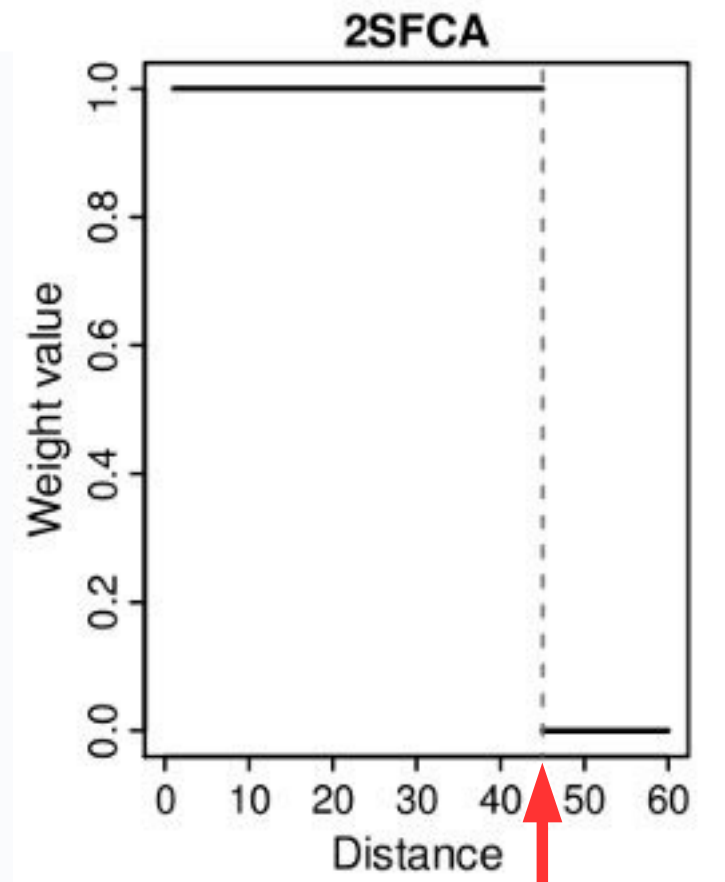
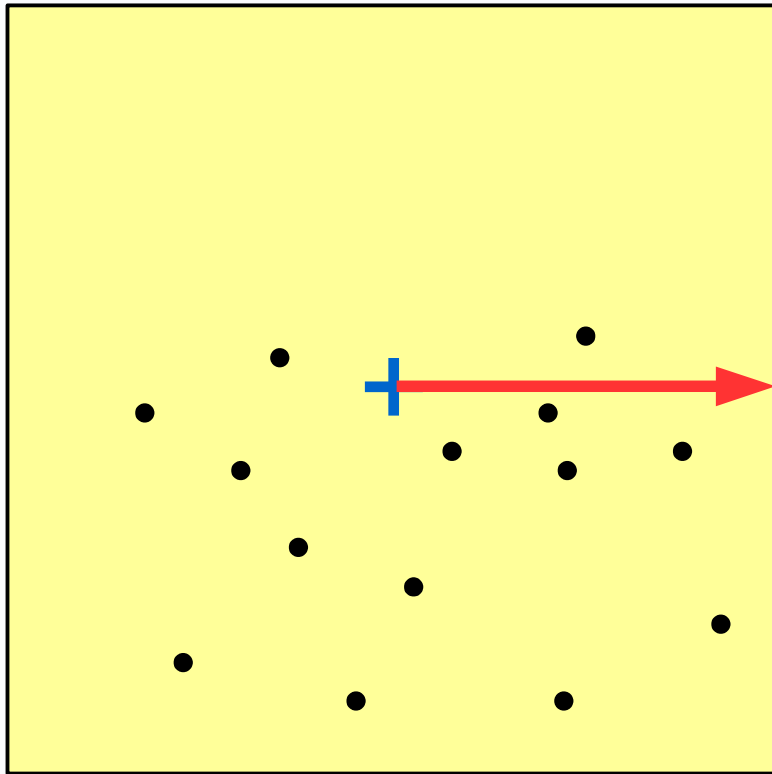
Step 2

$$A_i = \sum_{j \in [d_{i,j} < d]} D_j * W_{i,j}$$

For each region

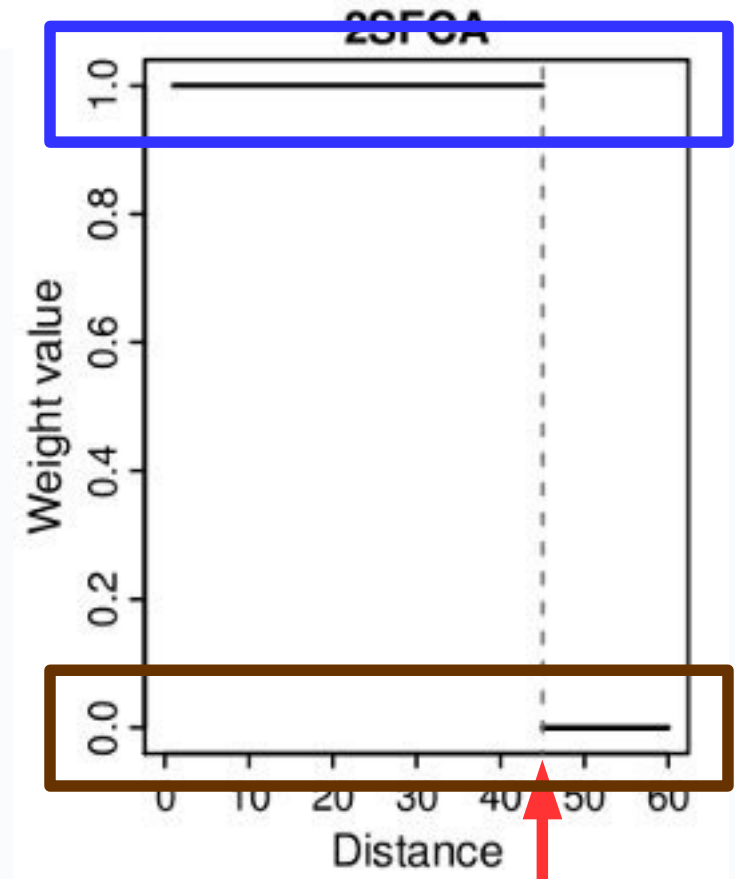
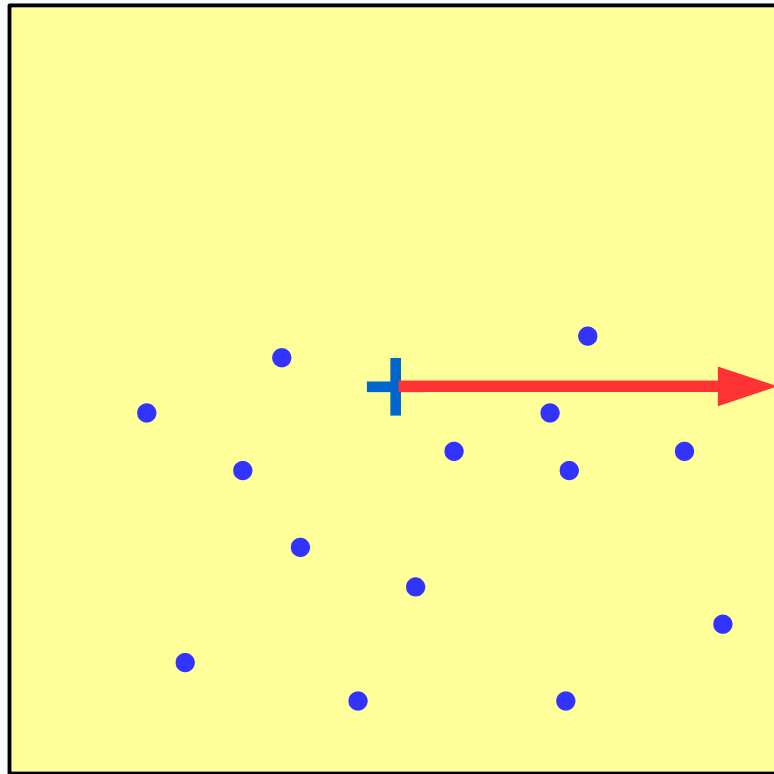


Catchment without Distance Decay

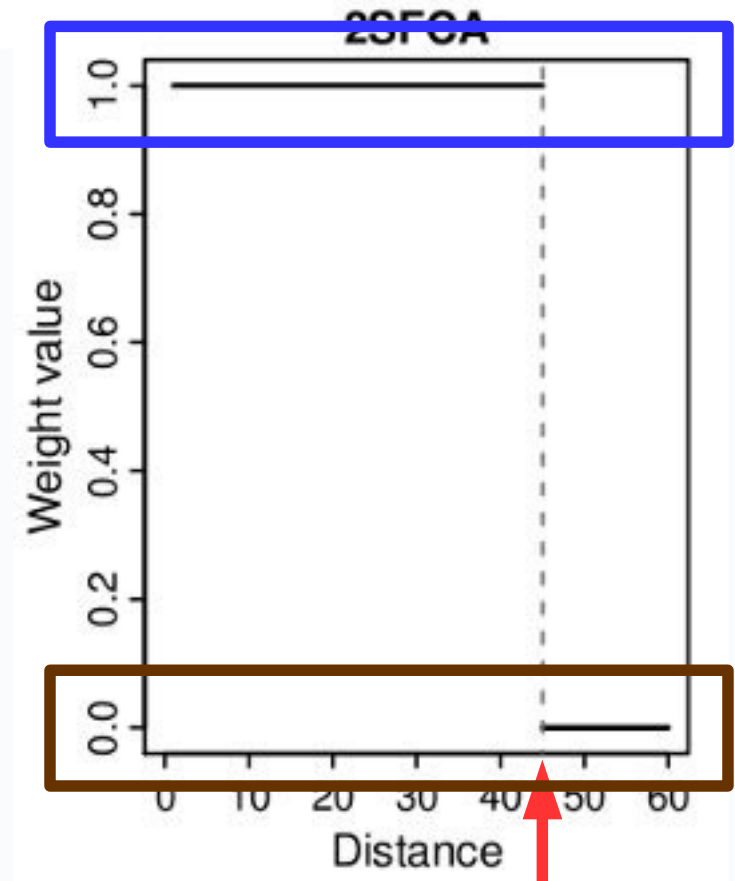
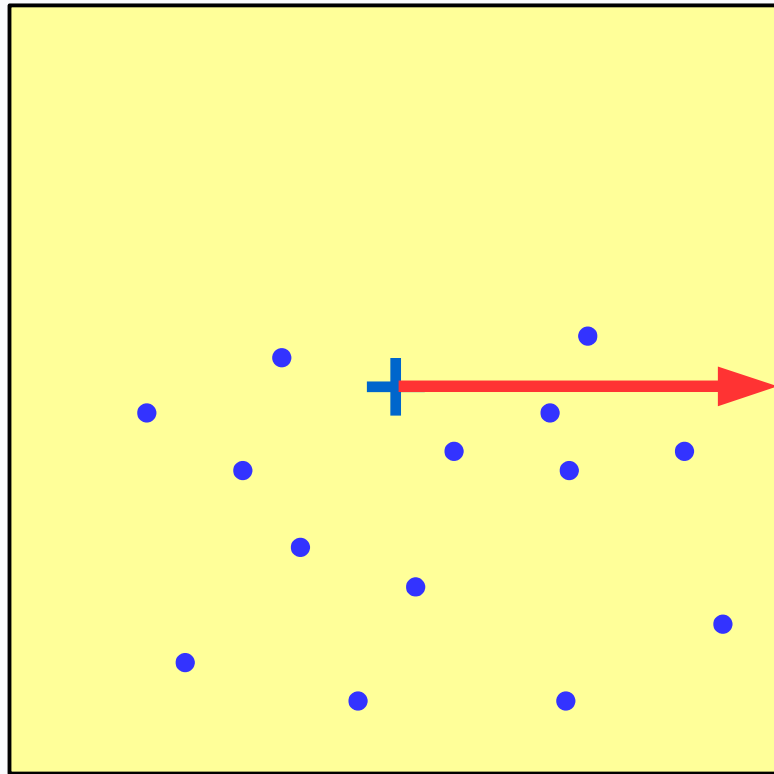


45 Minutes

Catchment without Distance Decay

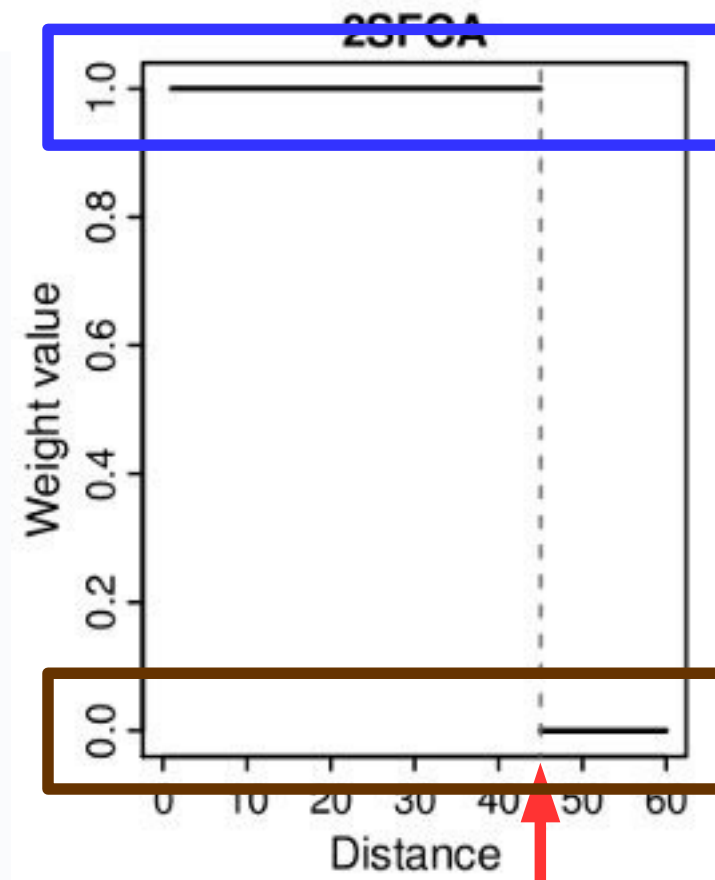
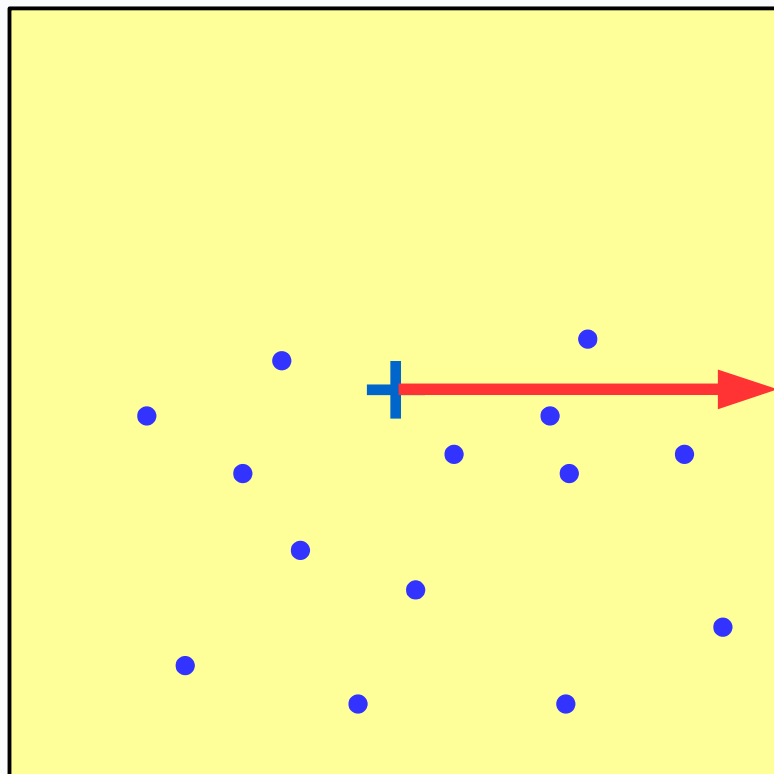


Catchment without Distance Decay



Step 1

$$D_j = \frac{S_j}{\sum_{i \in [d_{i,j} < d]} P_i}$$

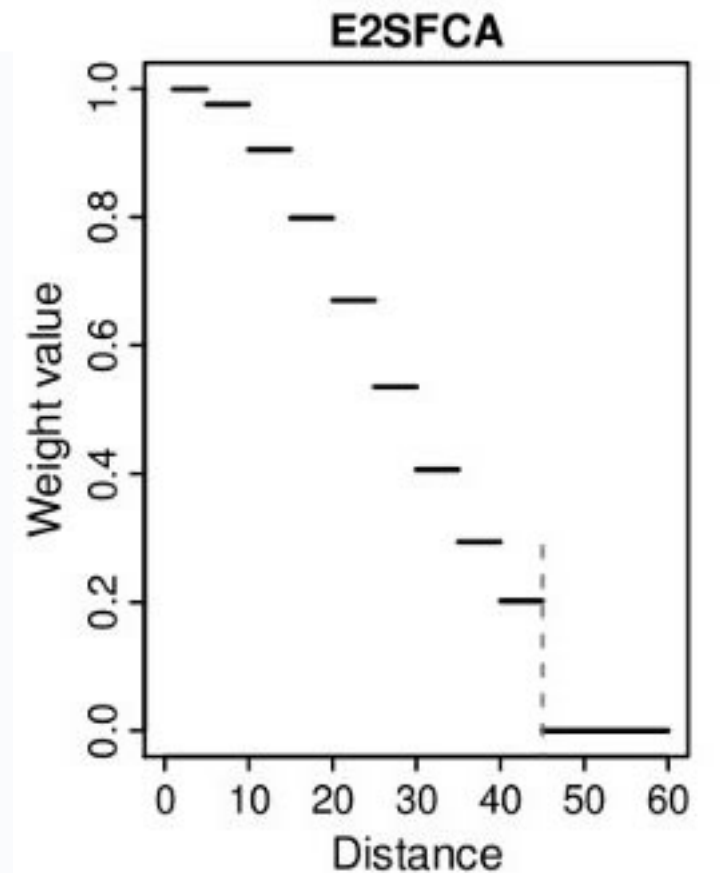
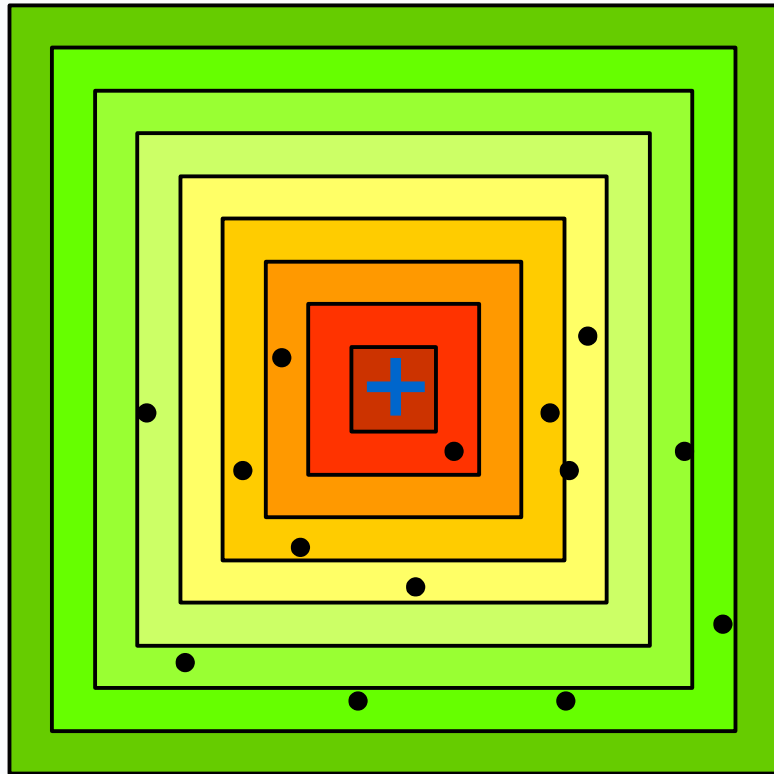


45 Minutes

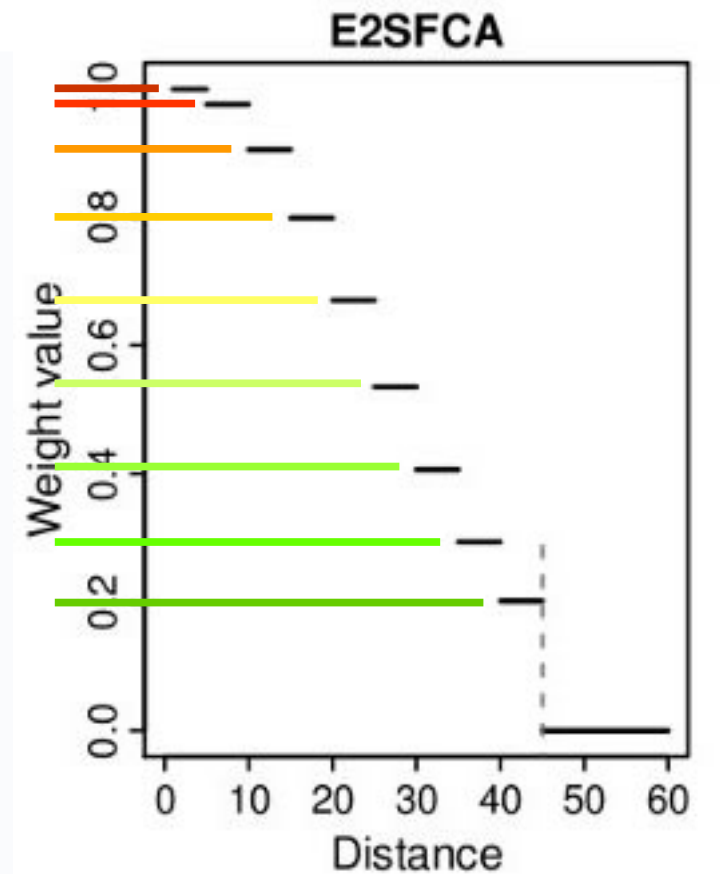
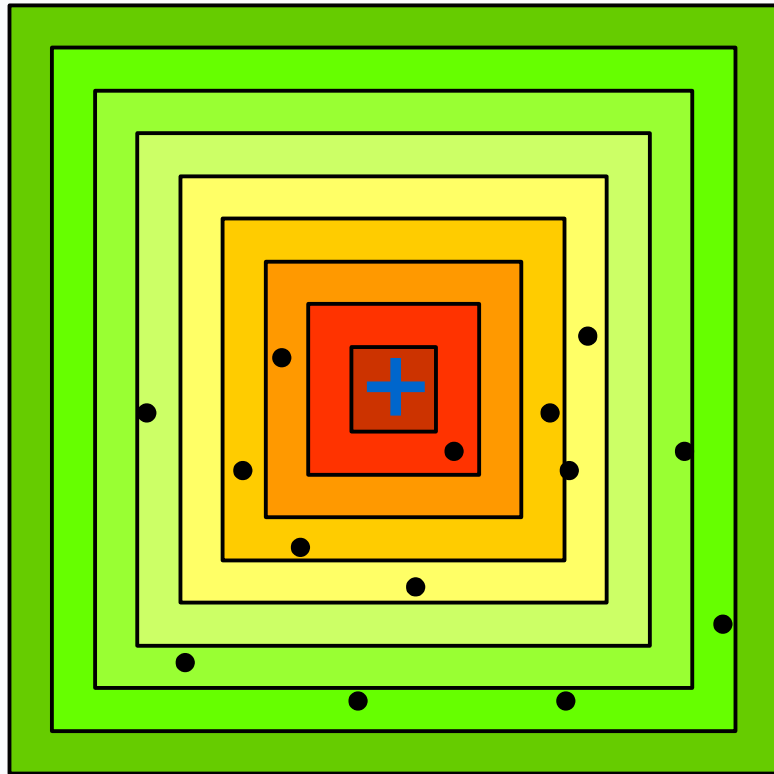
Step 1

$$D_j = \frac{1}{14}$$

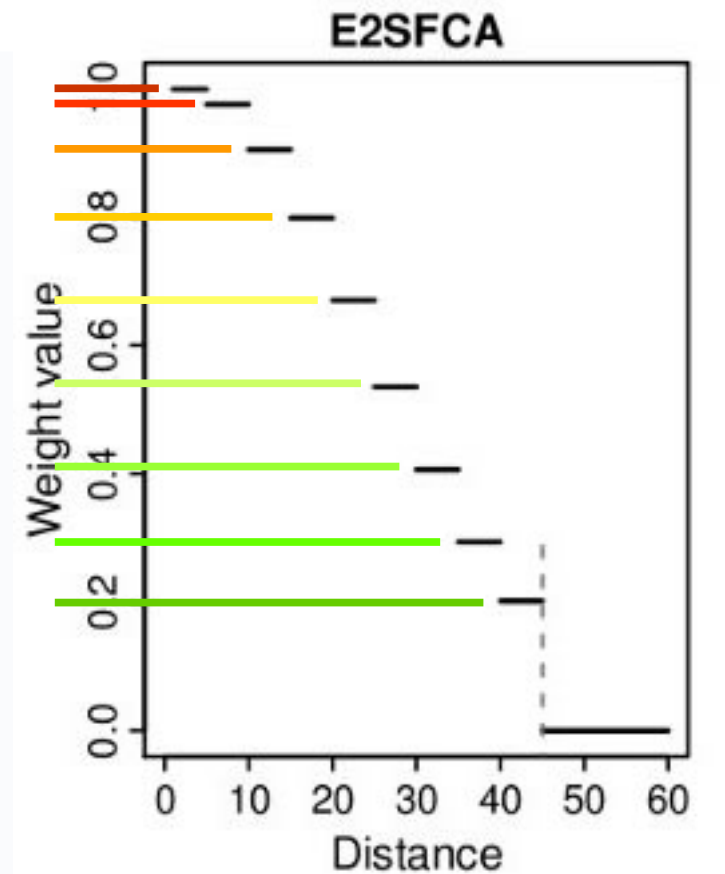
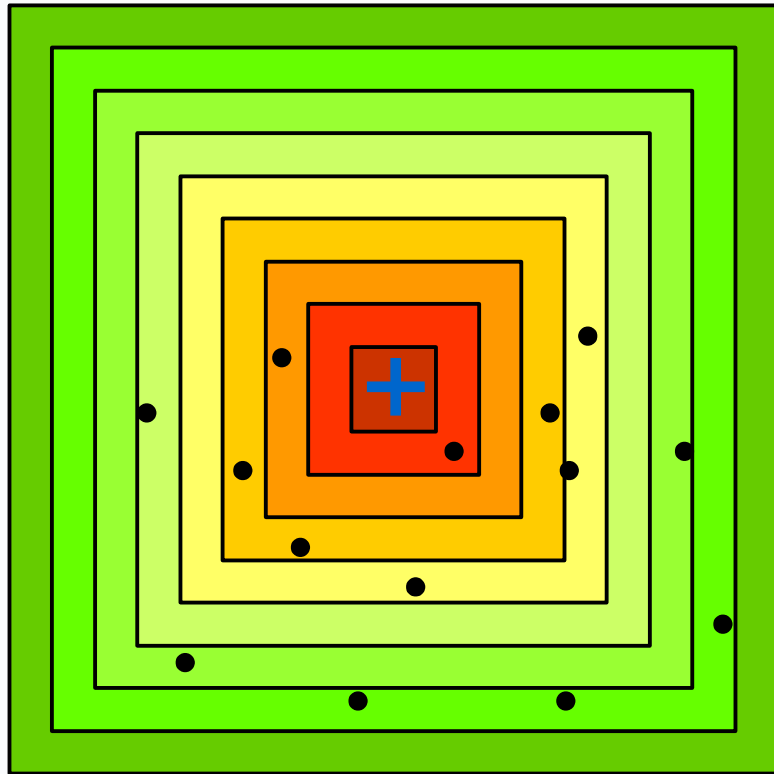
(facilities per person)



Catchments with Distance Decay

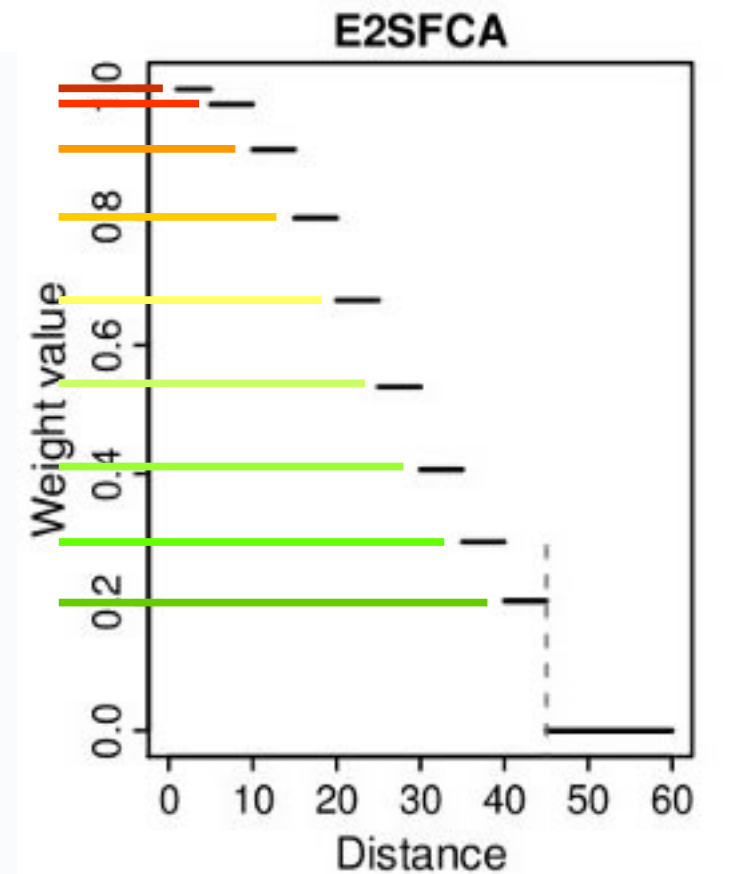
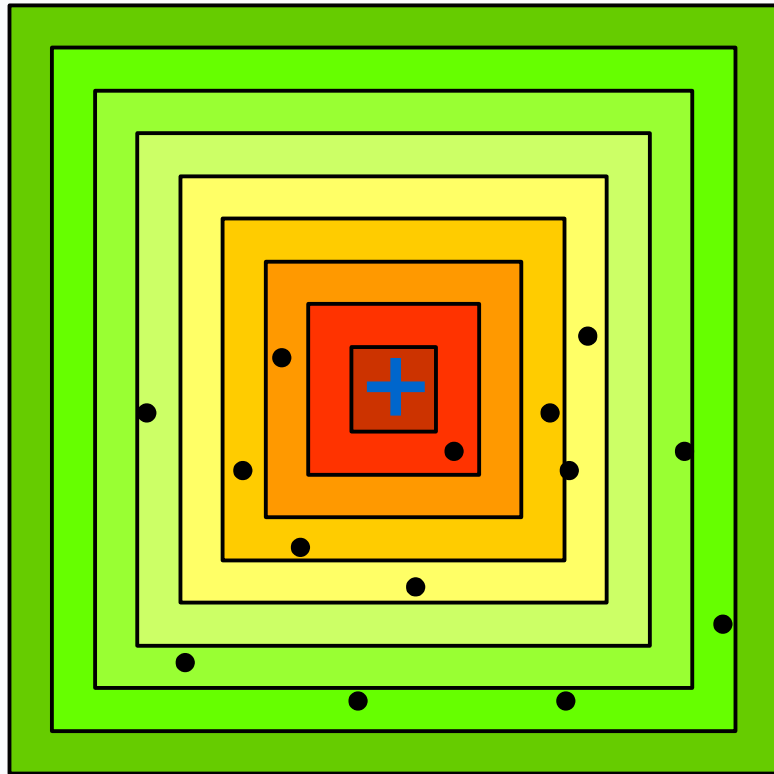


Catchments with Distance Decay



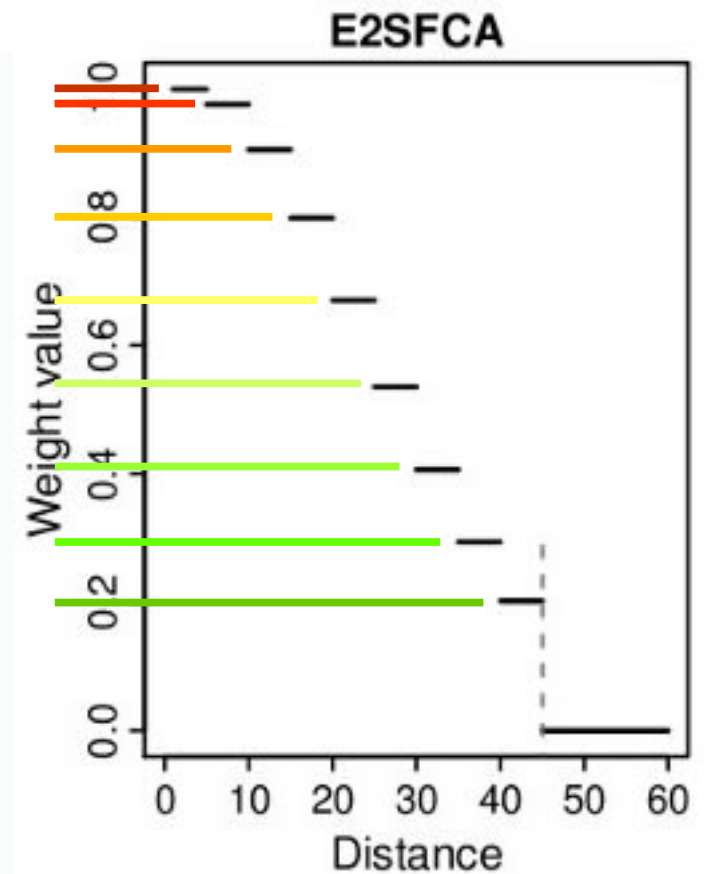
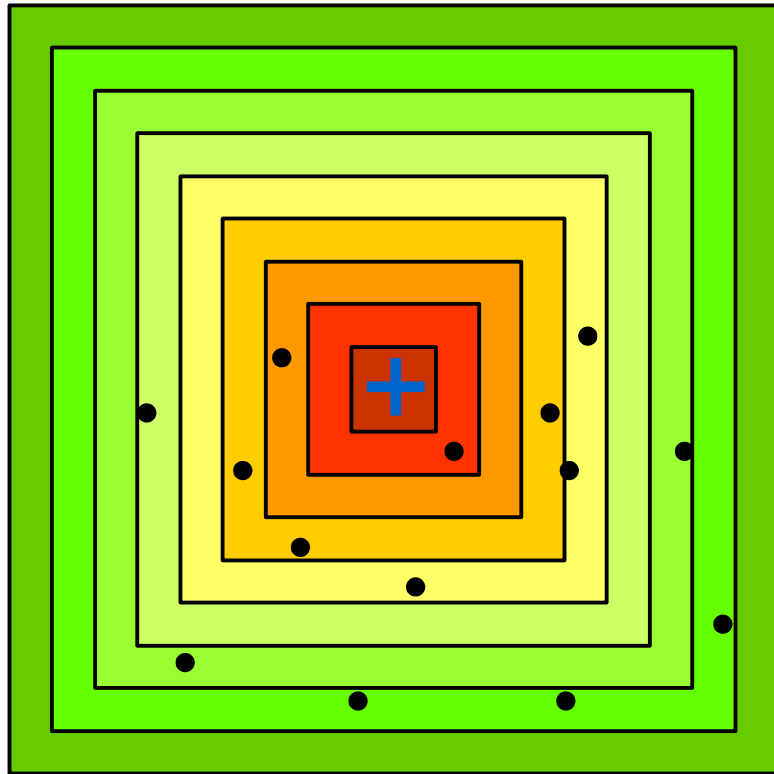
Step 1

$$D_j = \frac{S_j}{\sum_{i \in [d_{i,j} < d]} P_i * W_{i,j}}$$



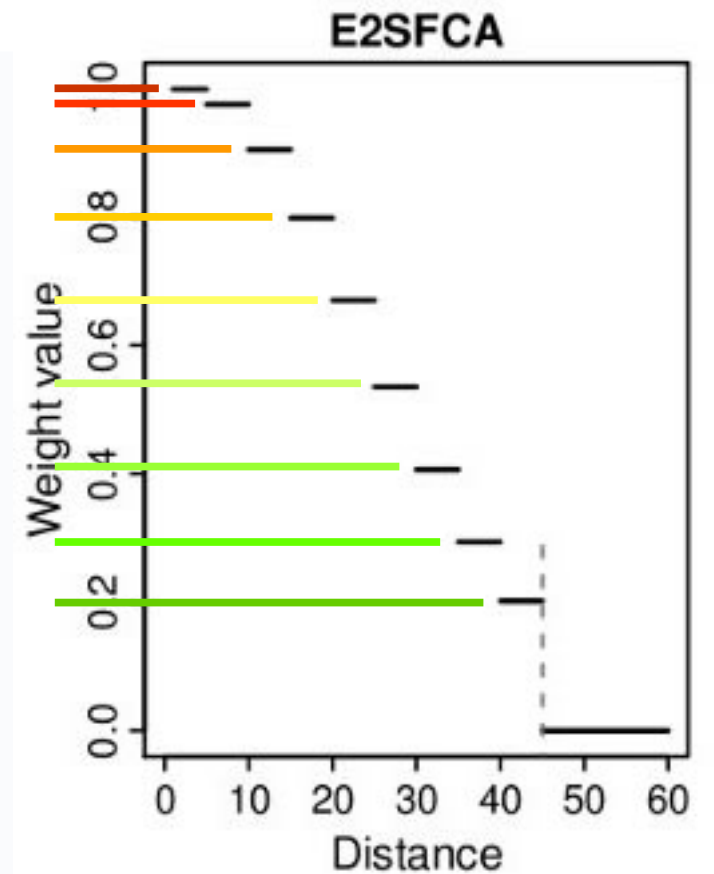
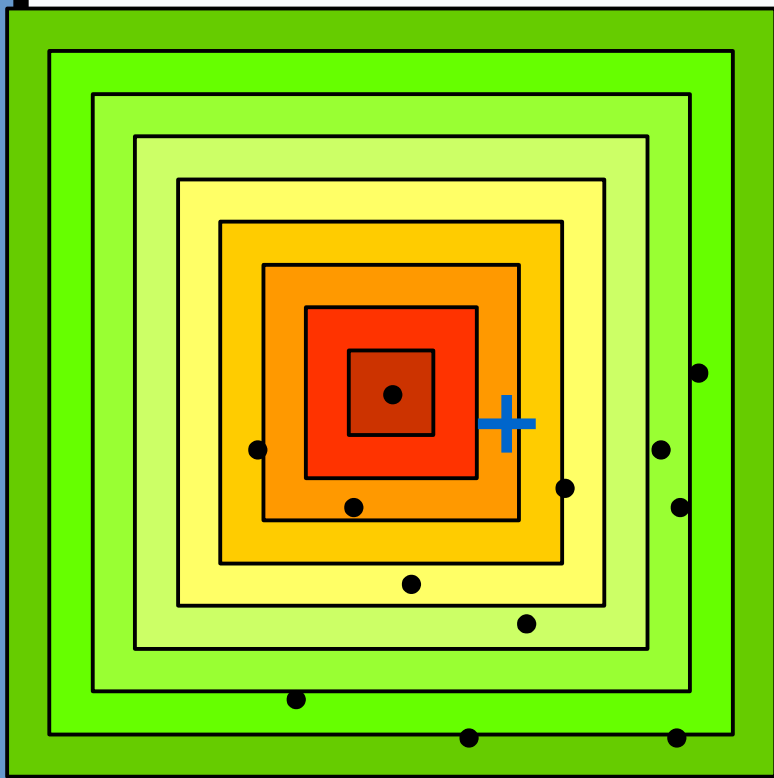
Step 1

$$D_j = \frac{1}{(1 * 0.98) + (1 * 0.9) + (3 * 0.8) + \dots}$$

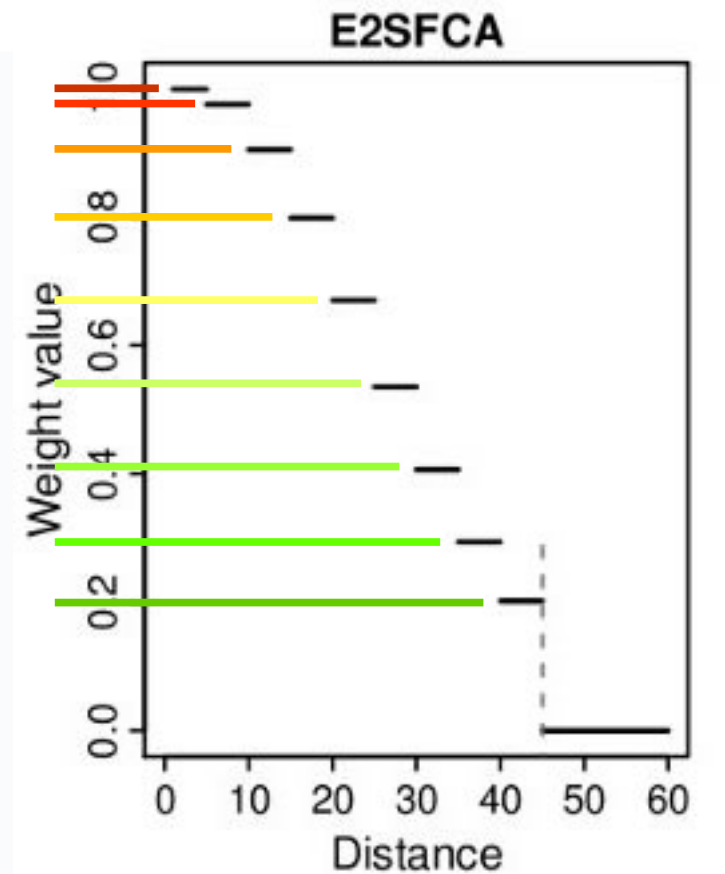
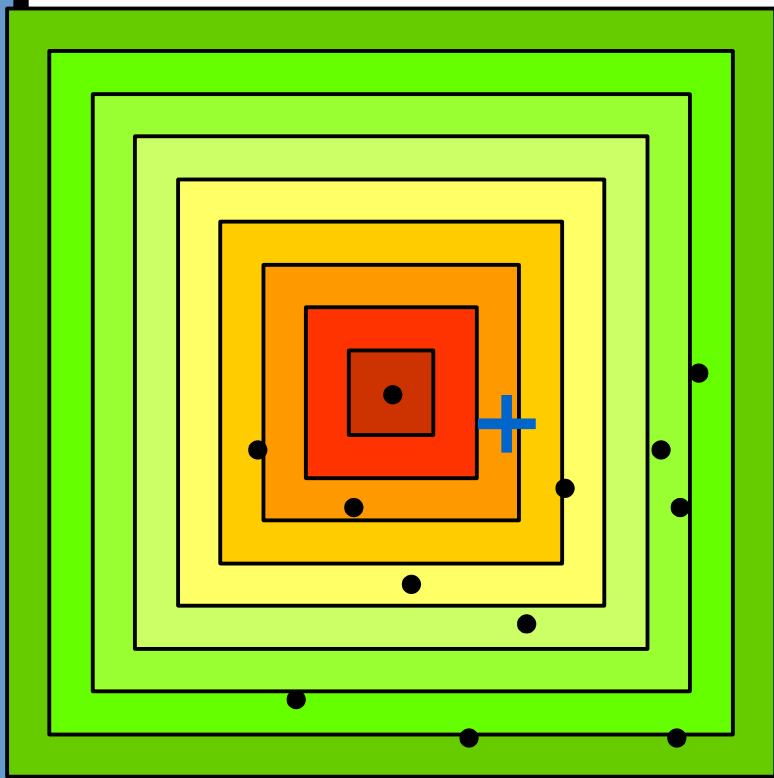


Step 1
$$D_j = \frac{1}{8.57}$$

(facilities per person)

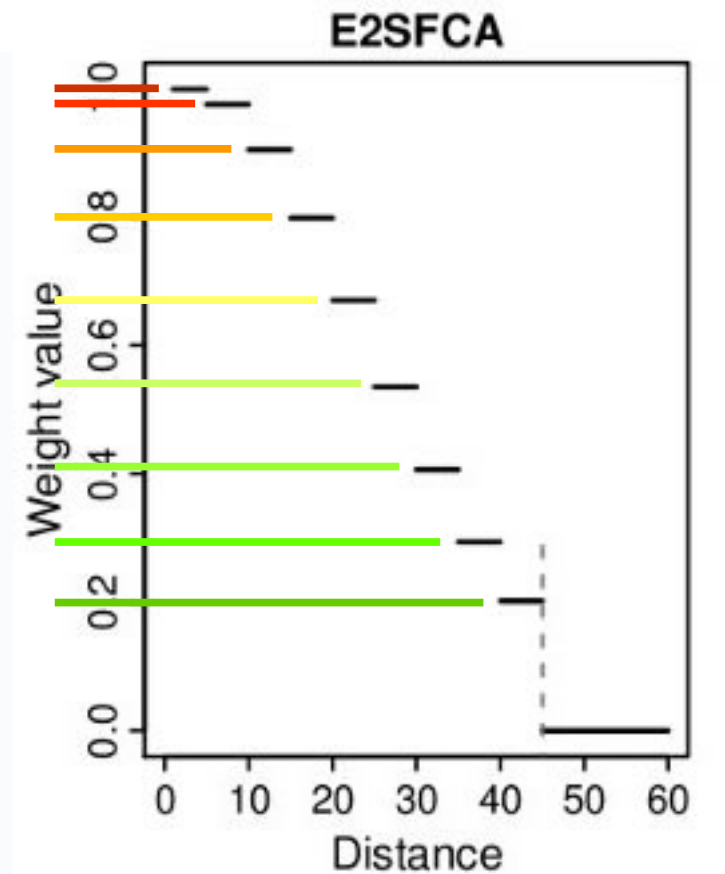
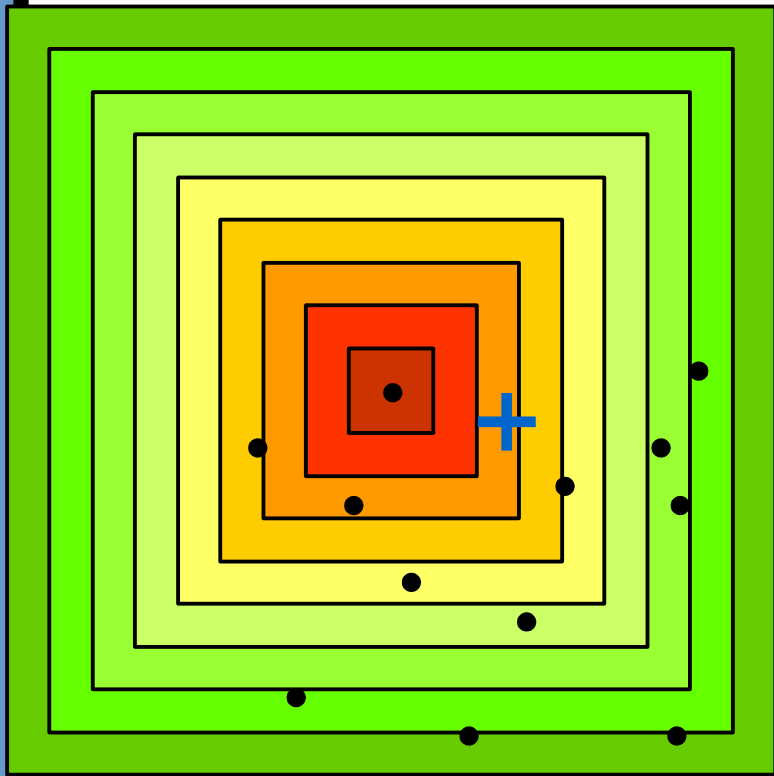


Step 2 $A_i = \sum_{j \in [d_{i,j} < d]} D_j * W_{i,j}$



Step 2

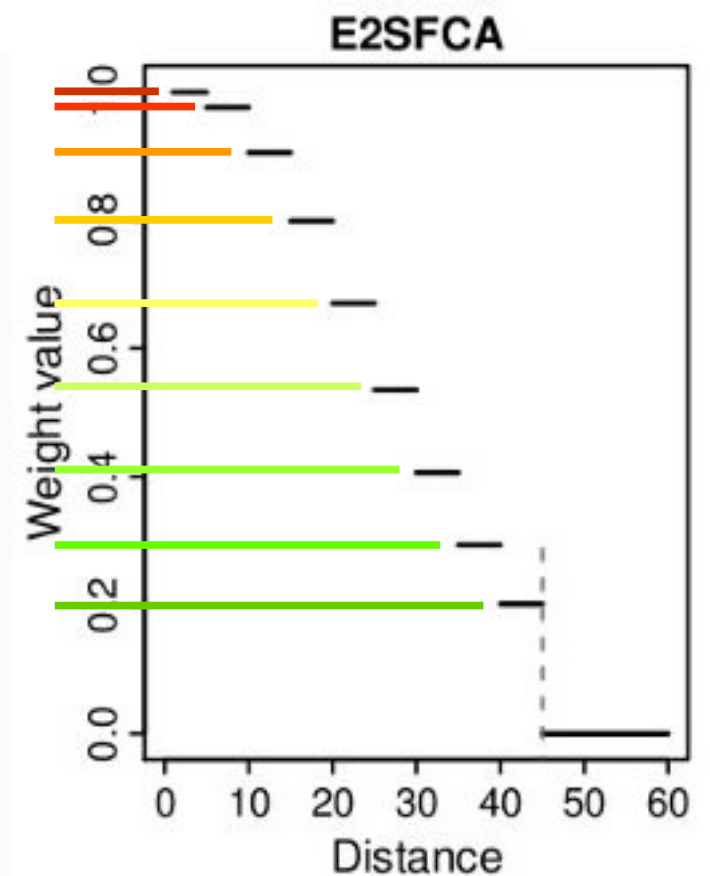
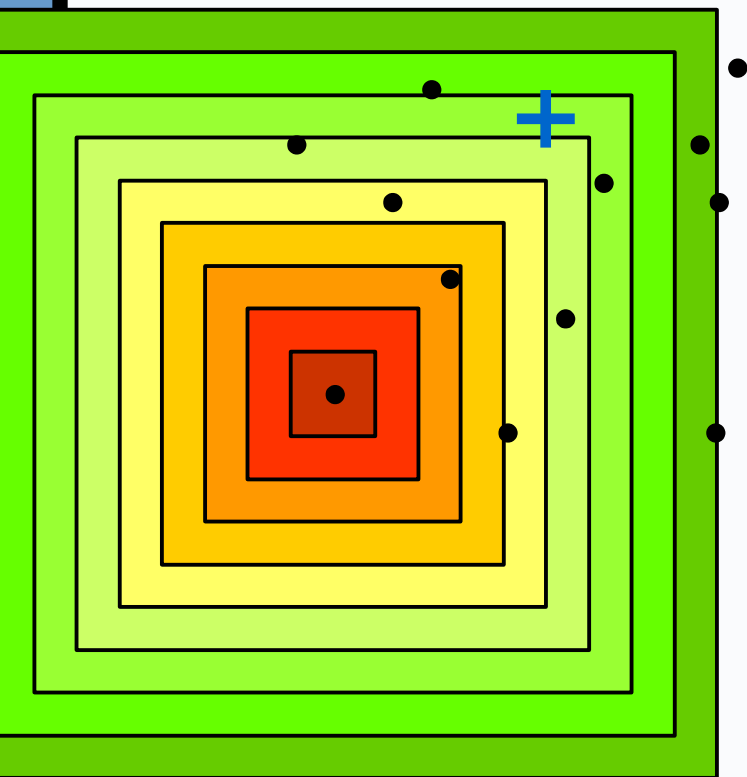
$$A_i = \frac{1}{8.57} * 0.9$$



Step 2

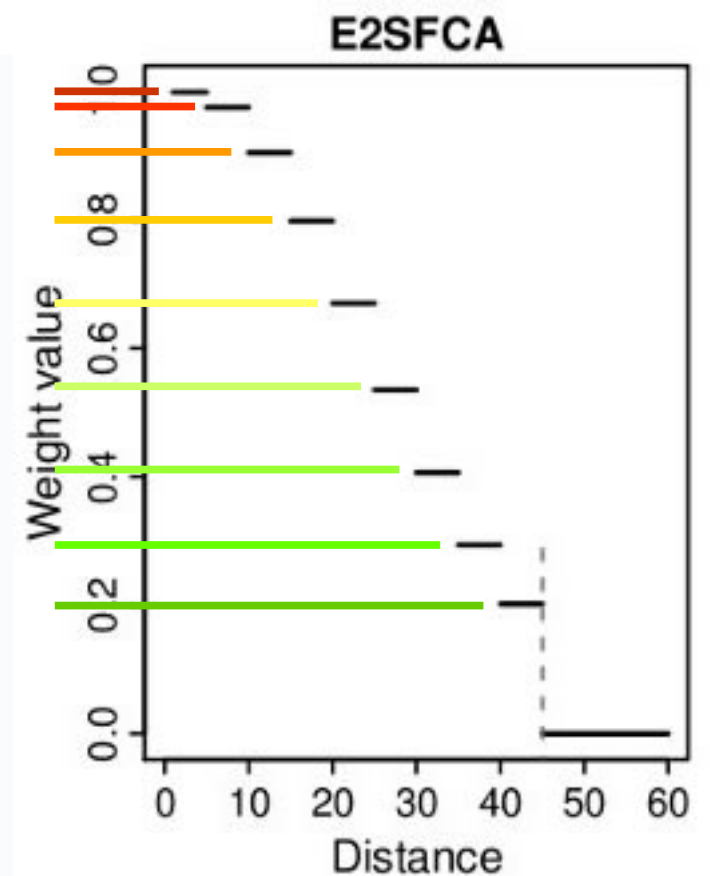
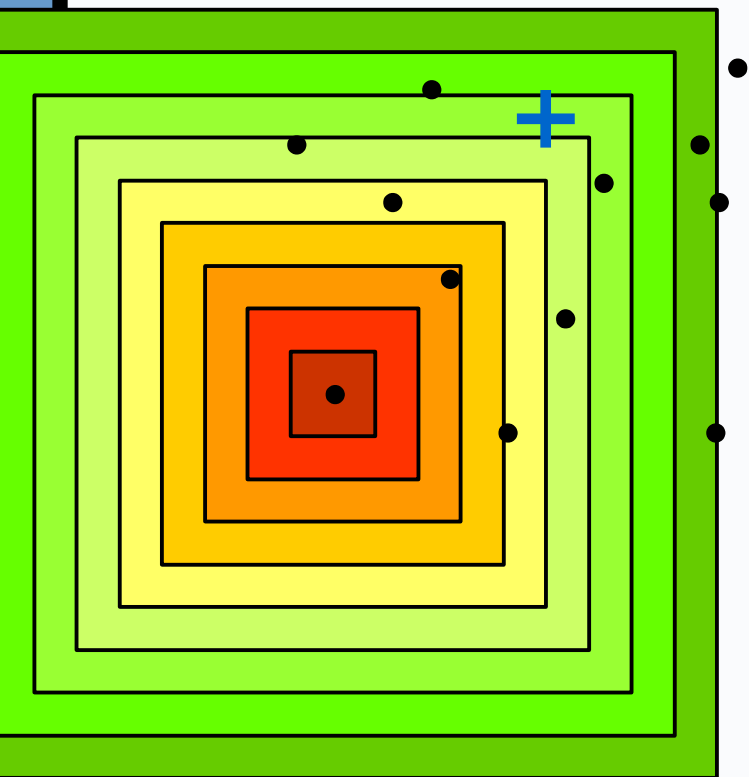
$$A_i = \frac{1}{9.52}$$

(facilities per person)



Step 2

$$A_i = \frac{1}{8.57} * 0.4$$



Step 2

$$A_i = \frac{1}{21.43}$$

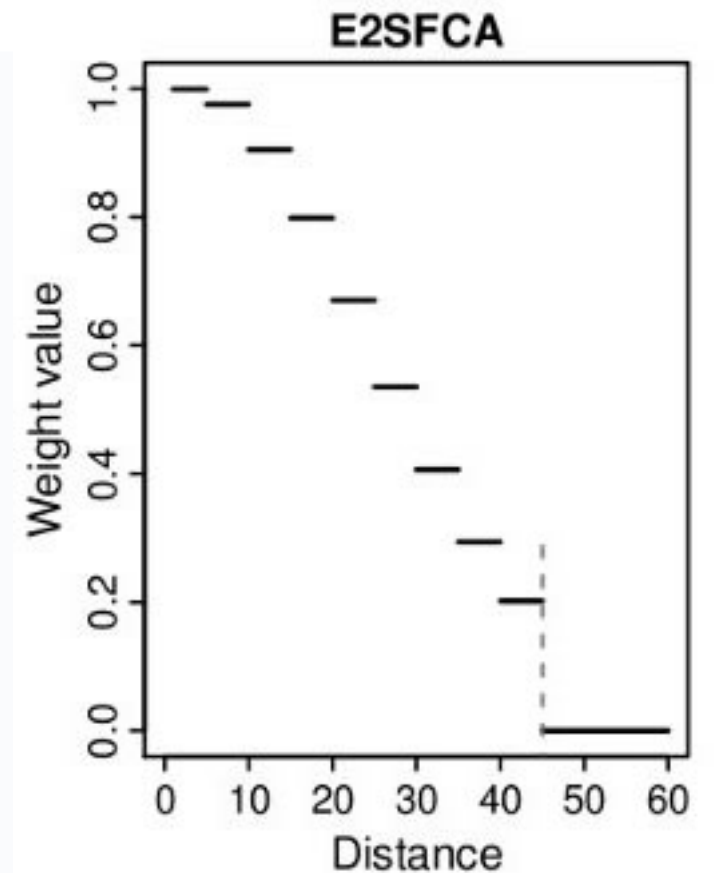
(facilities per person)

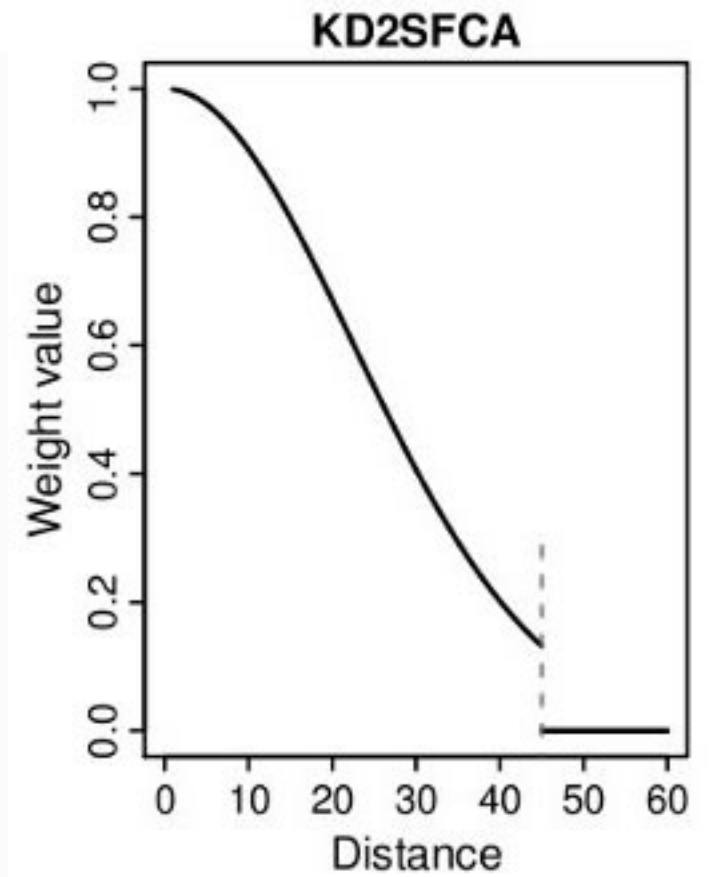
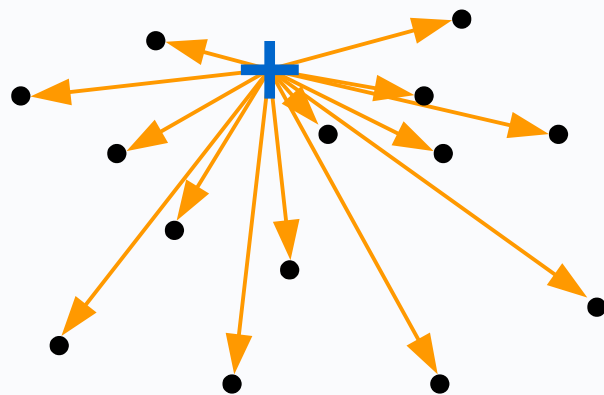
$$A_i = \frac{1}{9.52}$$

(facilities per person)

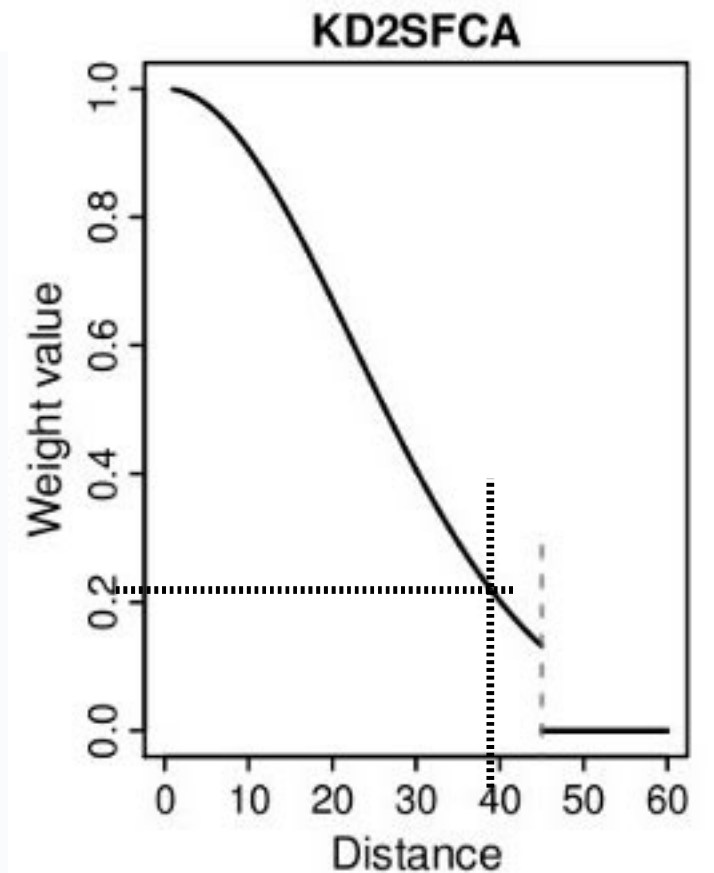
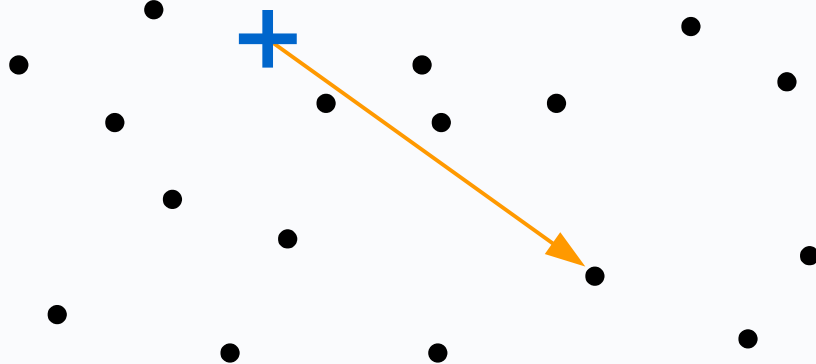
$$A_i = \frac{1}{21.43}$$

(facilities per person)

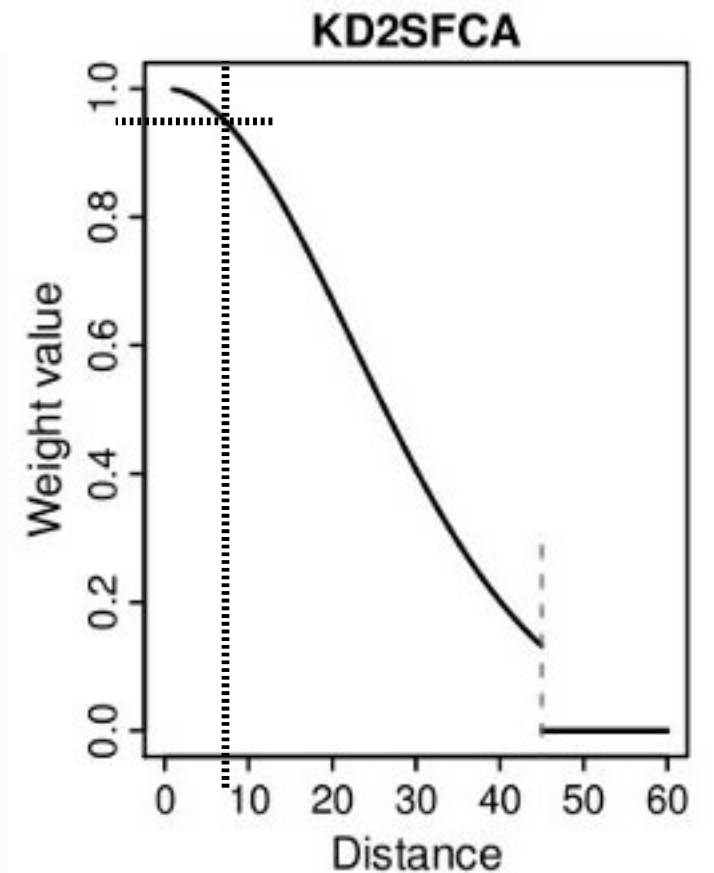
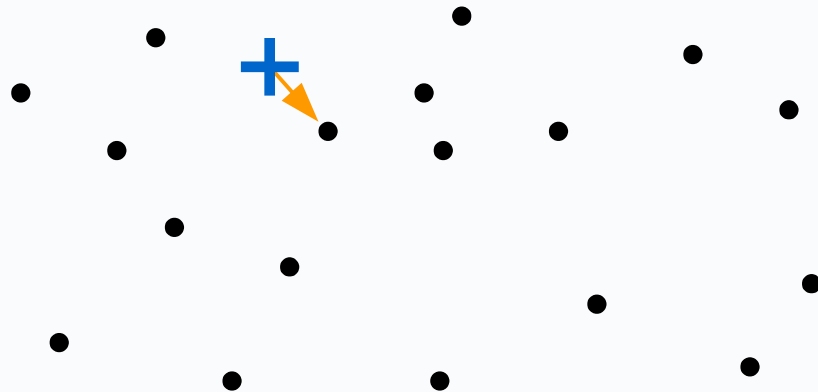




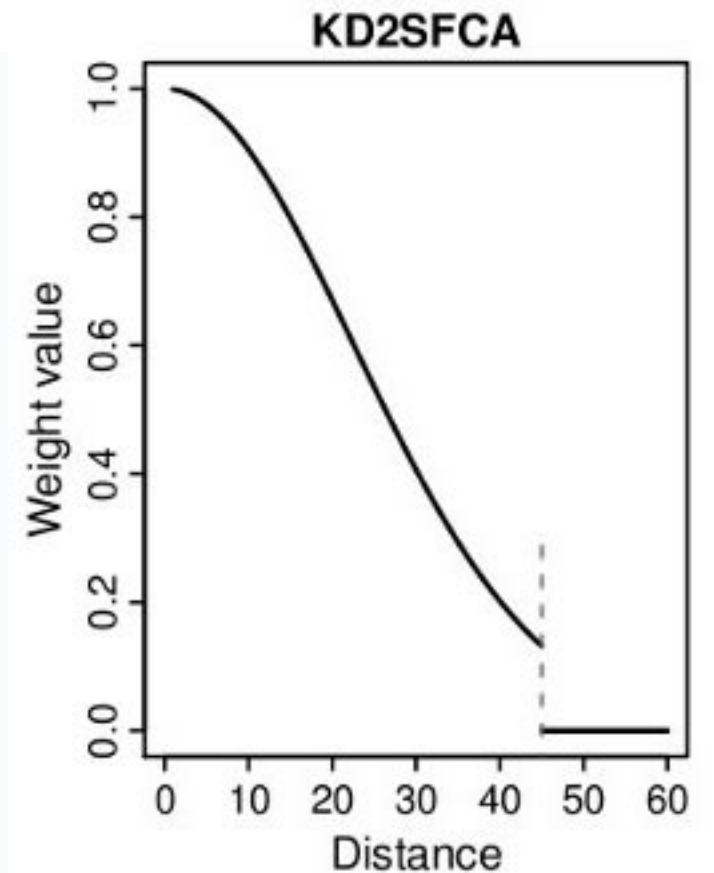
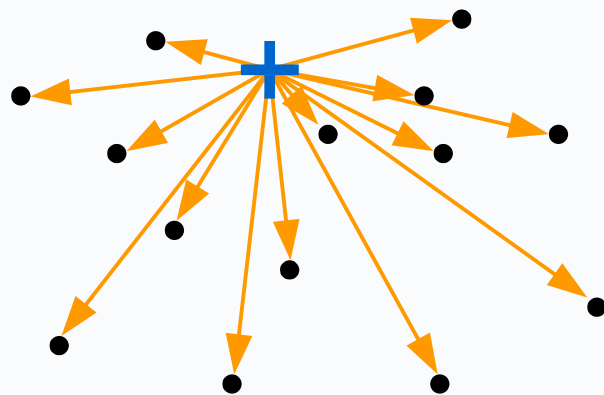
Catchments with continuous Distance Decay



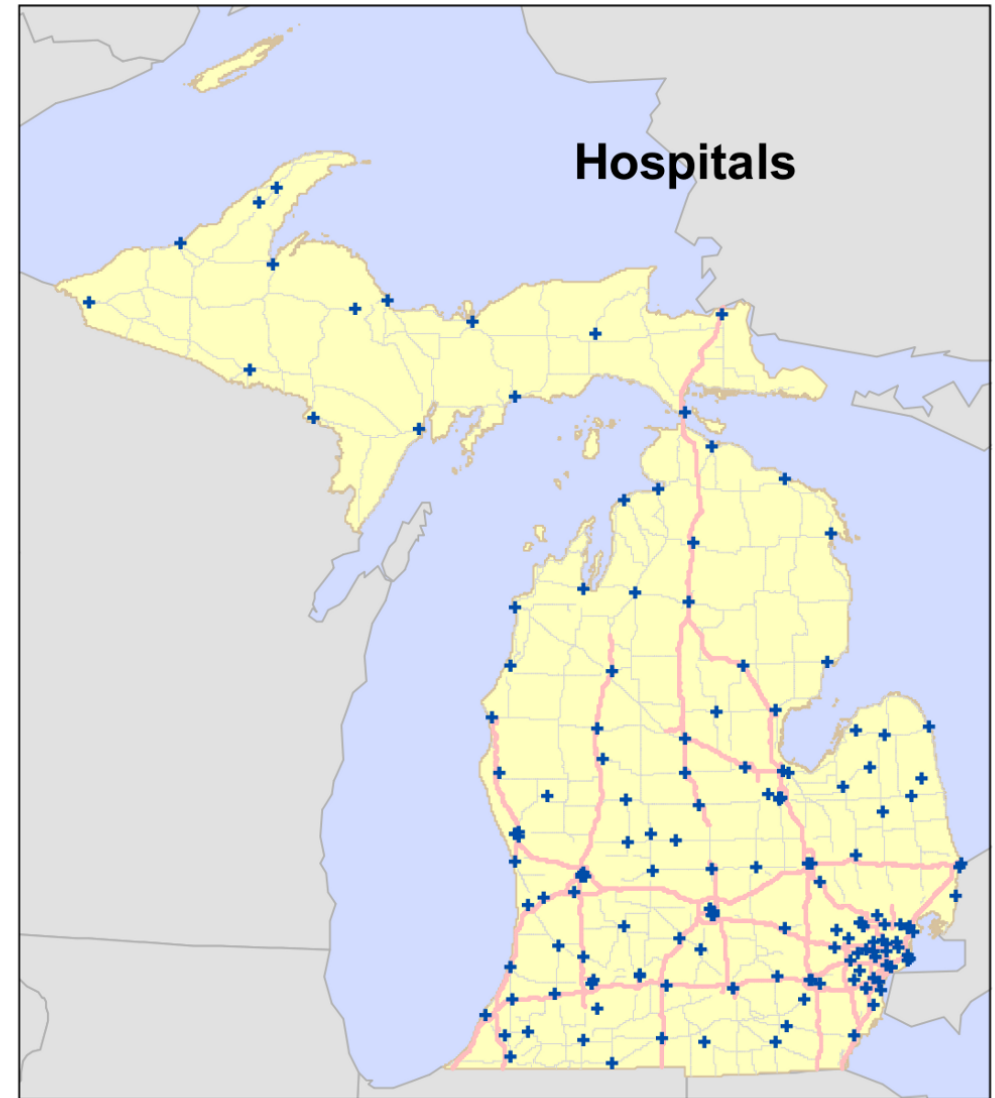
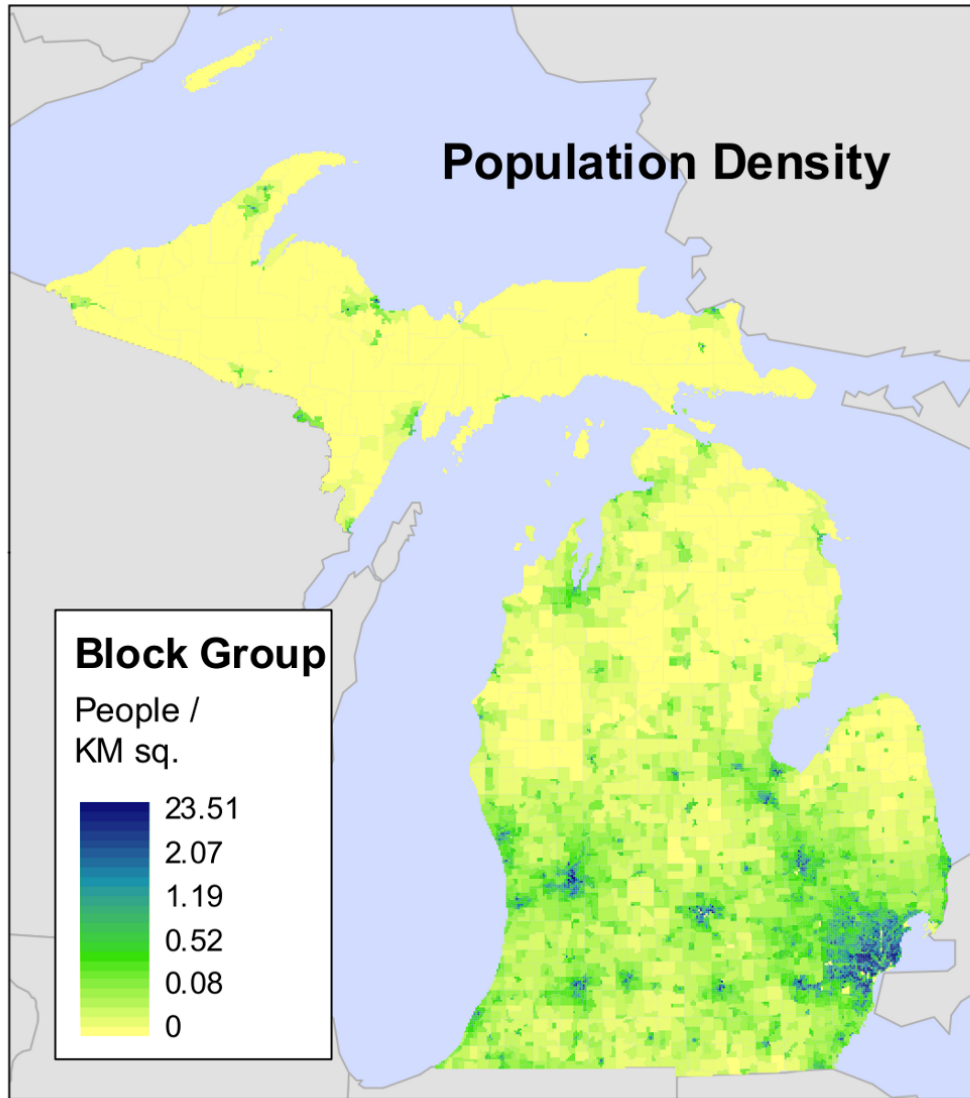
Catchments with continuous Distance Decay



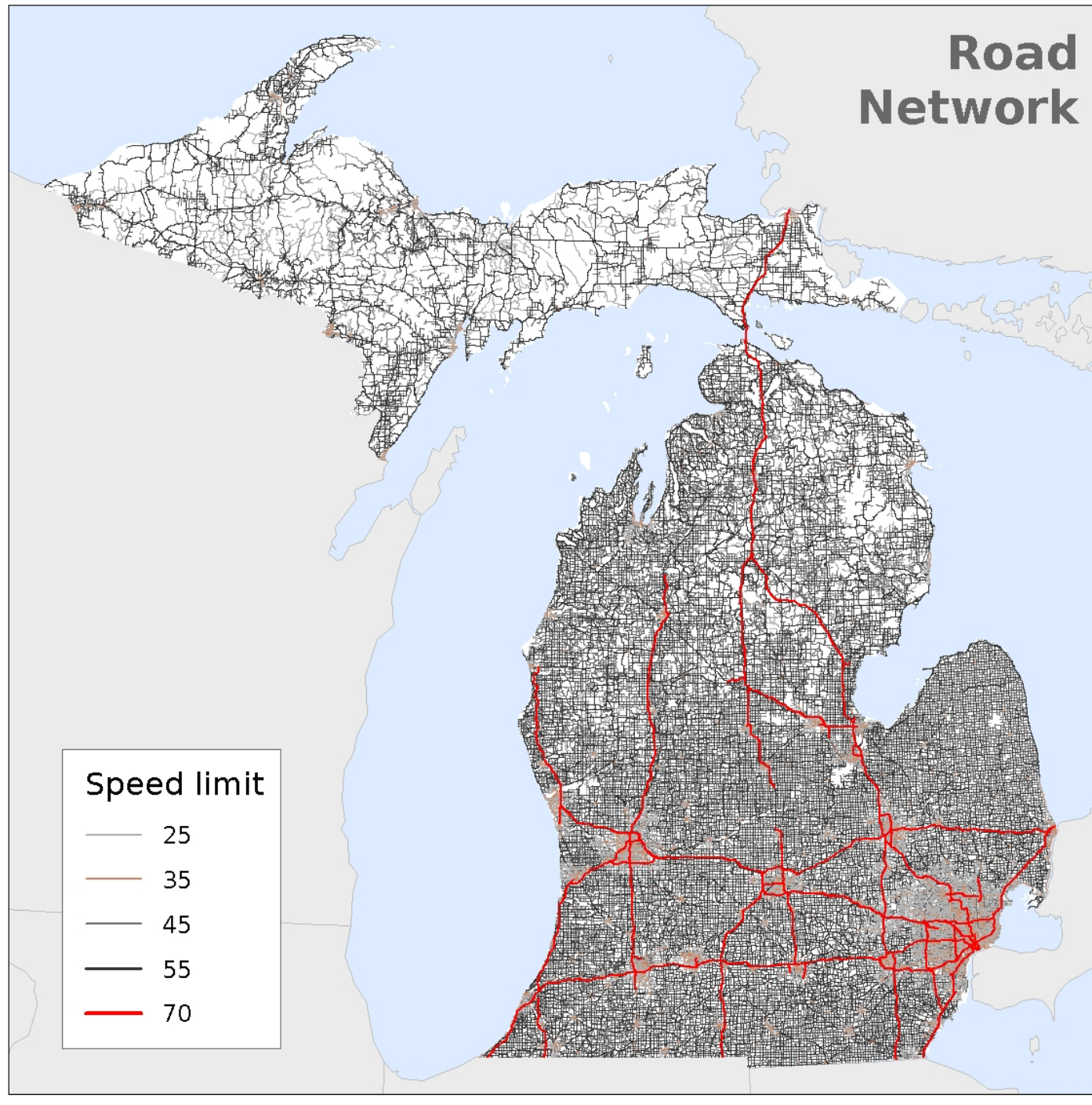
Catchments with continuous Distance Decay

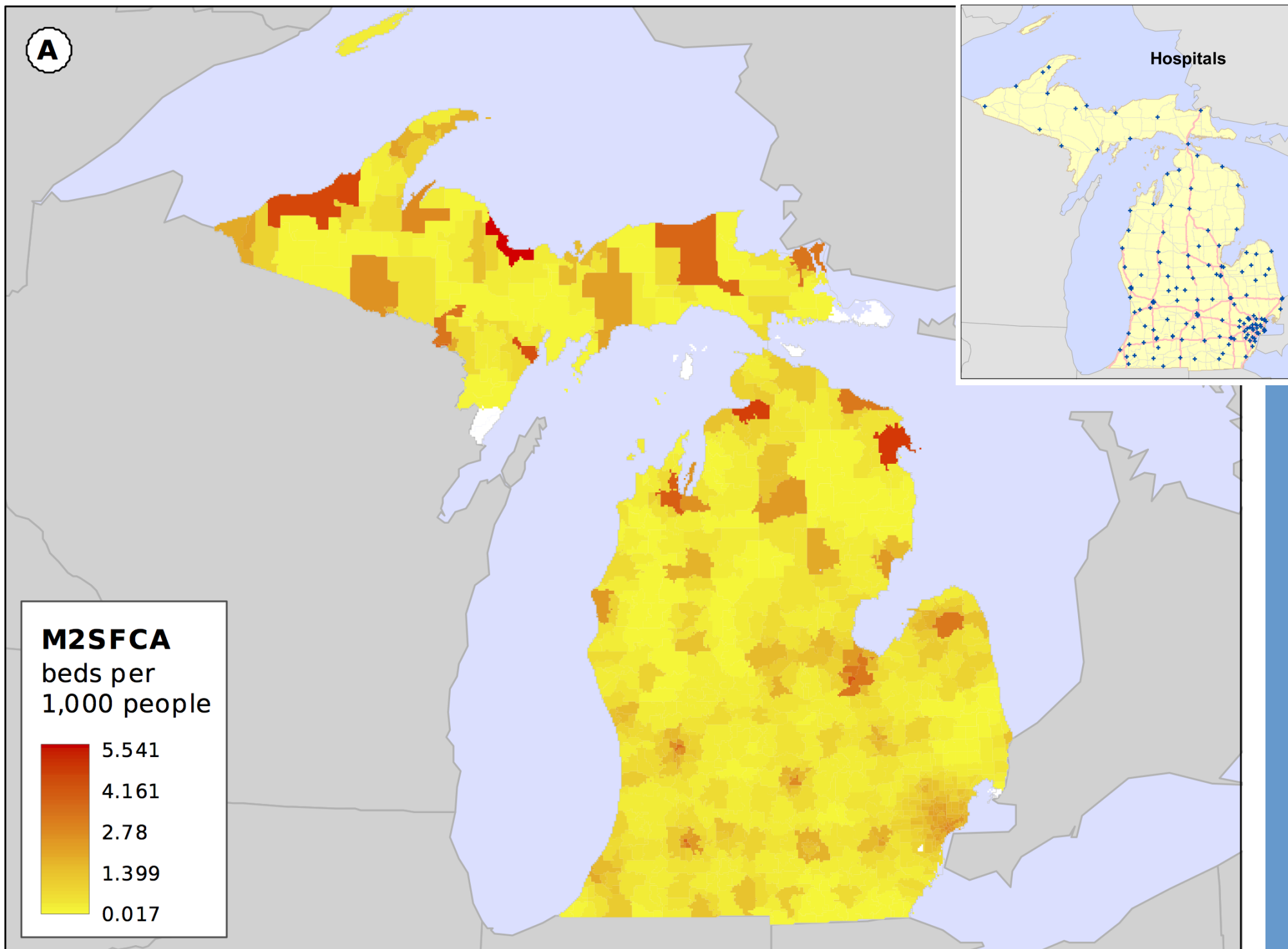


Catchments with continuous Distance Decay



Road Network





FCAs (recent advances)

- Competition
 - When assigning people to facilities in Step 1
- Suboptimal facility configuration
 - M2SFCA, Delamater, 2013
 - Considers suboptimal configurations
- Variable catchment sizes
 - Larger facilities will likely attract people from greater distances

FCAs (recent advances)

- Travel modes
 - Integrates varying travel modes (driving, public transit, walking)
- Health needs and Mobility
 - Modifies population by need estimates
 - Incorporates ability to overcome space
- Commuting patterns
 - Considers distance away from general commute to access services

FCA issue

- Biggest hurdle for potential spatial accessibility: *there is no ground truth information*
 - Evaluation of new or improved FCA metrics is difficult
 - Requires strong theoretical and mathematical foundation

Keywords

- Spatial Accessibility
- Gravity model
- Floating Catchment Area (FCA)
- Distance decay function