Lesson 11: Modelling Geographical Accessibility

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- Accessibility Models
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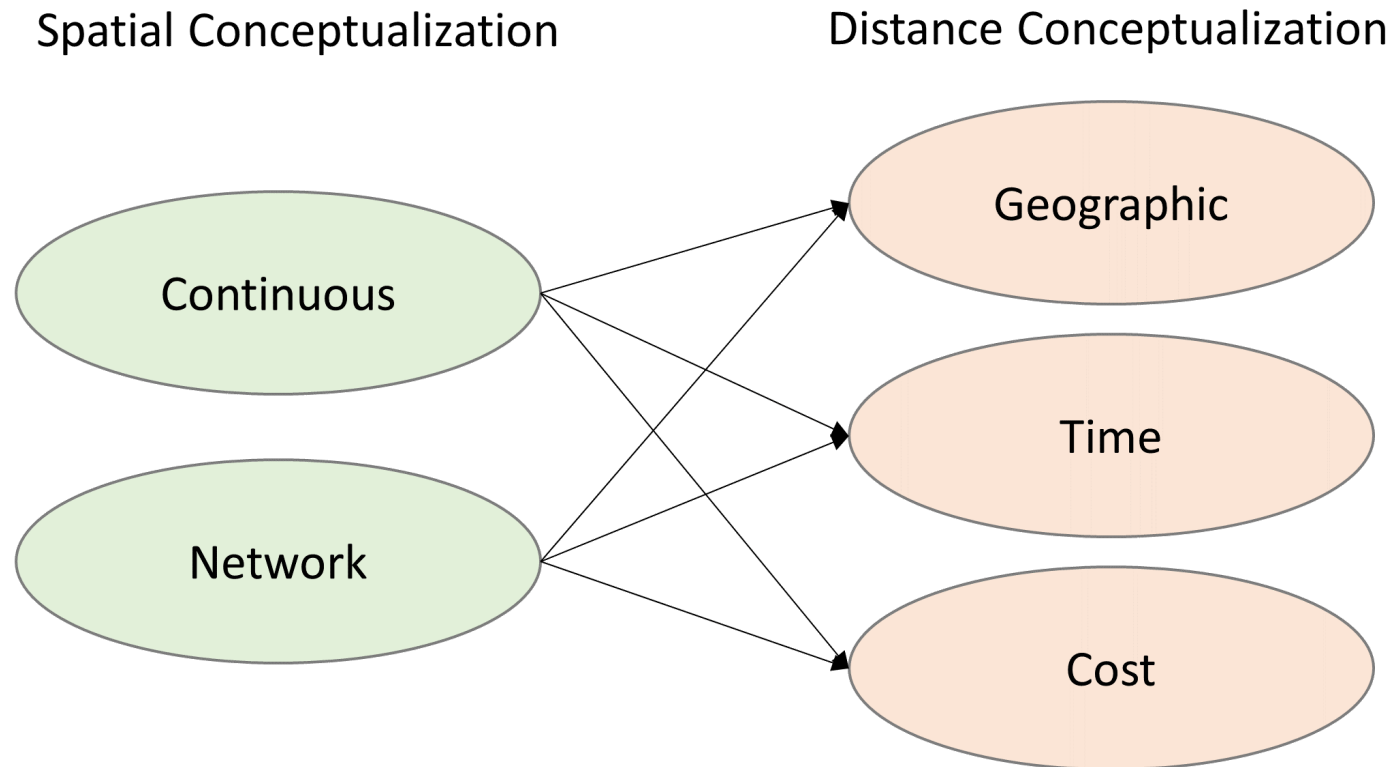
What is Geography of Accessibility?

- Accessibility is the measure of **the capacity of a location to be reached from, or to be reached by, different locations**. Therefore, the capacity and the arrangement of transport infrastructure are key elements in the determination of accessibility.

Why Model Geography of Accessibility?

- Questions that can be answered by accessibility models:
    - Which part of the geographical areas are deprived from getting access to a social service, facility or job opportunity?
    - Which part of the geographical areas will be affected by a public policy or business decision such as merging JCs, secondary and primary schools.
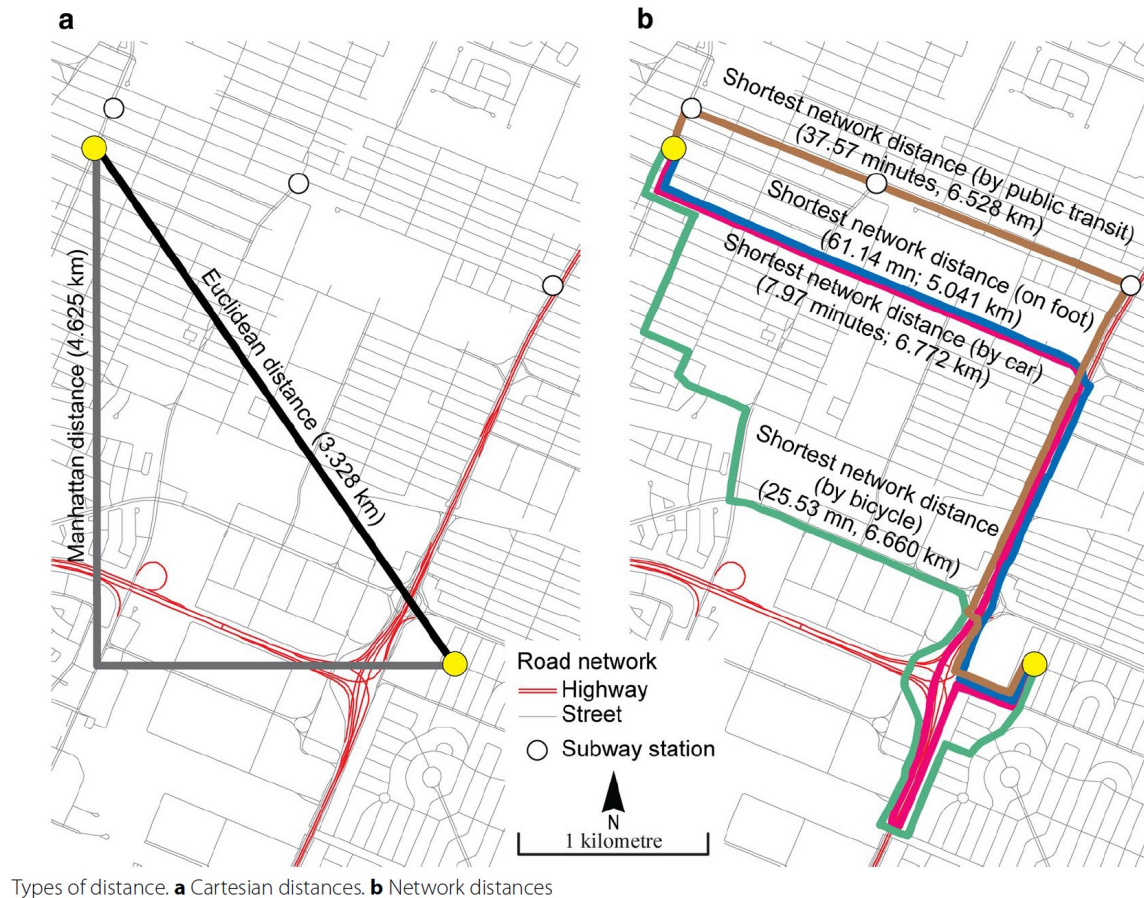
Measuring Distances

- Different spatial and distance conceptualizations that are commonly employed when measuring and modelling accessibility.

Spatial Conceptualization

Distance Conceptualization

Continuous

Network

Geographic

Time

Cost

Distance Consideration

Cartesian distance versus Network distance

Types of distance. **a** Cartesian distances. **b** Network distances

Reference: Philippe Apparicio et. al. (2017) "The approaches to measuring the potential spatial access to urban health services revisited: distance types and aggregation-error issues. *International Journal of Health Geographics*, pp. 16:32
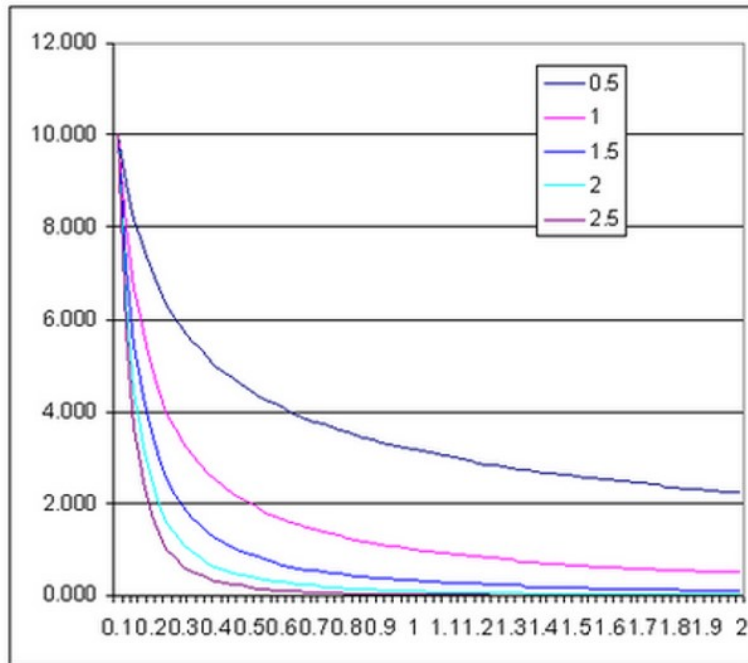
The distance friction

- Modeling spatial interactions implies quantifying the **distance friction** or **impedance**.
- The role of the distance can be interpreted as a disincentive to access desired destinations or opportunities (e.g. jobs, shops).
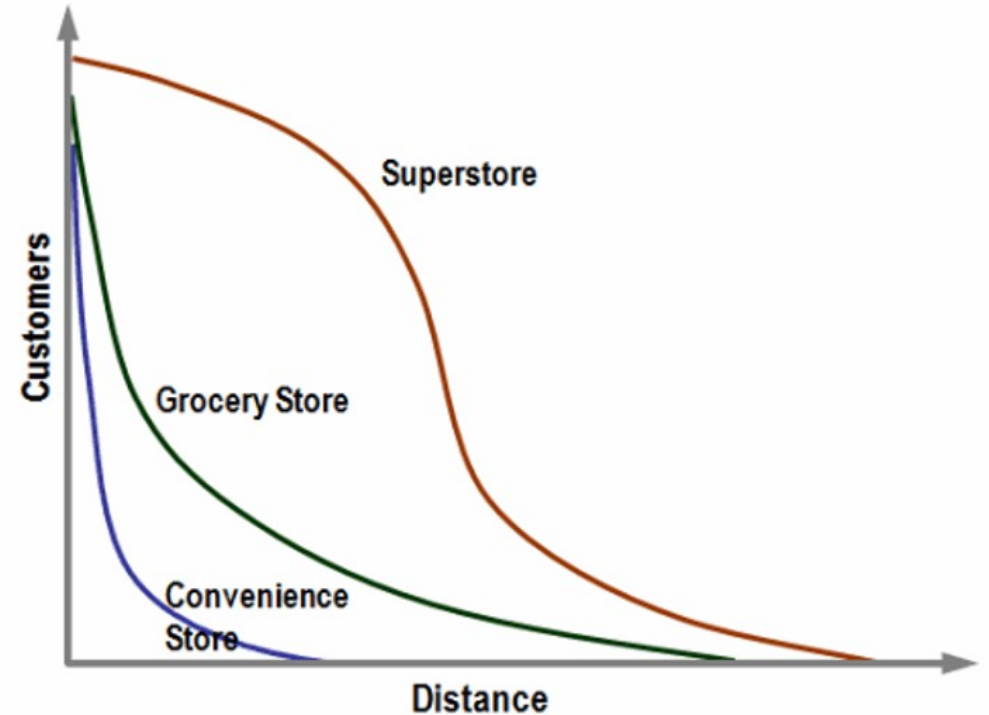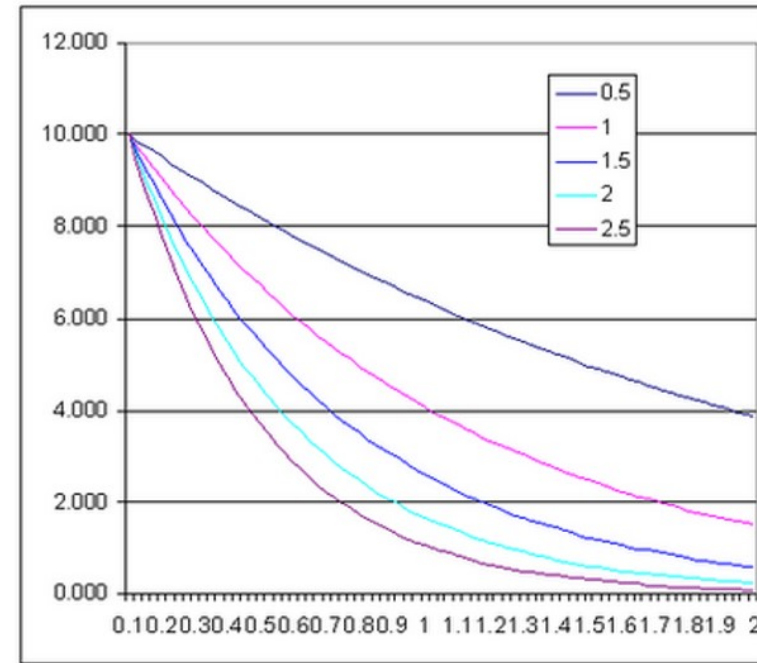
Distance Decay function.

Inverse distance decay, α/d_β

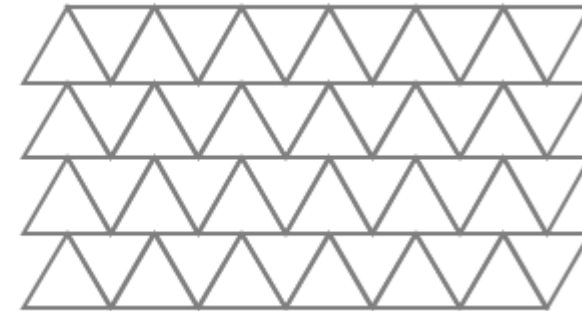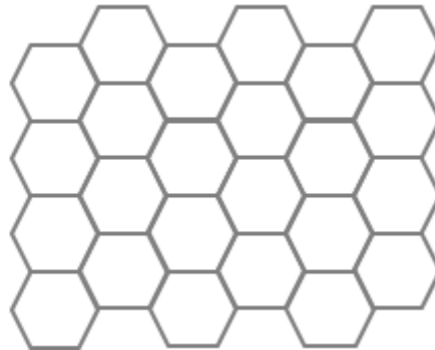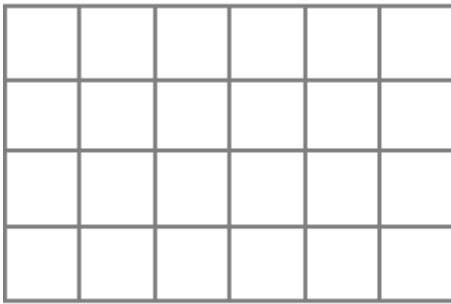Exponential distance decay, $\alpha e\verb|^|(-\beta d)$

The Geographical Unit

- This issue of irregularly shaped polygons created arbitrarily (such as county boundaries or block groups that have been created from a political process).
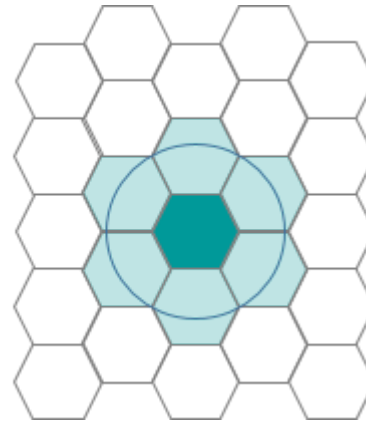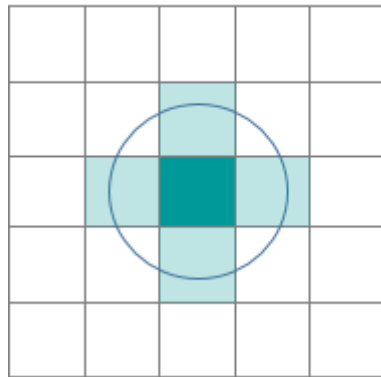
The Geographical Unit

- Using regular shaped geometry such as square, hexagon or triangle to define geographical unit.

The Geographical Unit

- Hexagons reduce sampling bias due to edge effects of the grid shape, this is related to the low perimeter-to-area ratio of the shape of the hexagon.
- A circle has the lowest ratio but cannot tessellate to form a continuous grid. Hexagons are the most circular-shaped polygon that can tessellate to form an evenly spaced grid.

The Geographical Unit

- An example of 250m radius hexagons covering Singapore main island.

Distance to Nearest Location

The formula:

$$A_{ij} = min(d_{ij})$$

A_{ij} = Accessibility of zone i to location of type j
d_{ij} = the distance between i and j

Limitation of the method:

- Does not consider the size/attractiveness of the closest location, thereby implicitly treating all locations as being equally attractive.
- Does not consider the cumulative effect of multiple accessible locations (e.g. is a zone that is within 1.1 km of two MRT stations inferior to one that is within 1.0 km of a single station?

The Potential Model

The classic model

$$P_i = \sum_j \frac{M_j}{d_{ij}^{\alpha}}$$

P_i = potential at point i
M_j = The size (attraction) of centre j
d_{ij}= the distance between i and j
α= a parameter, usually between 1 and 2, reflecting the rate of increase of the friction of distance

The Modified Potential Formula

$$P_i = \frac{\sum_j \left(\dfrac{M_j}{d_{ij}^{\alpha-1}} \right)}{\sum_k \left(\dfrac{M_k}{d_{ij}^{\alpha}} \right)}$$
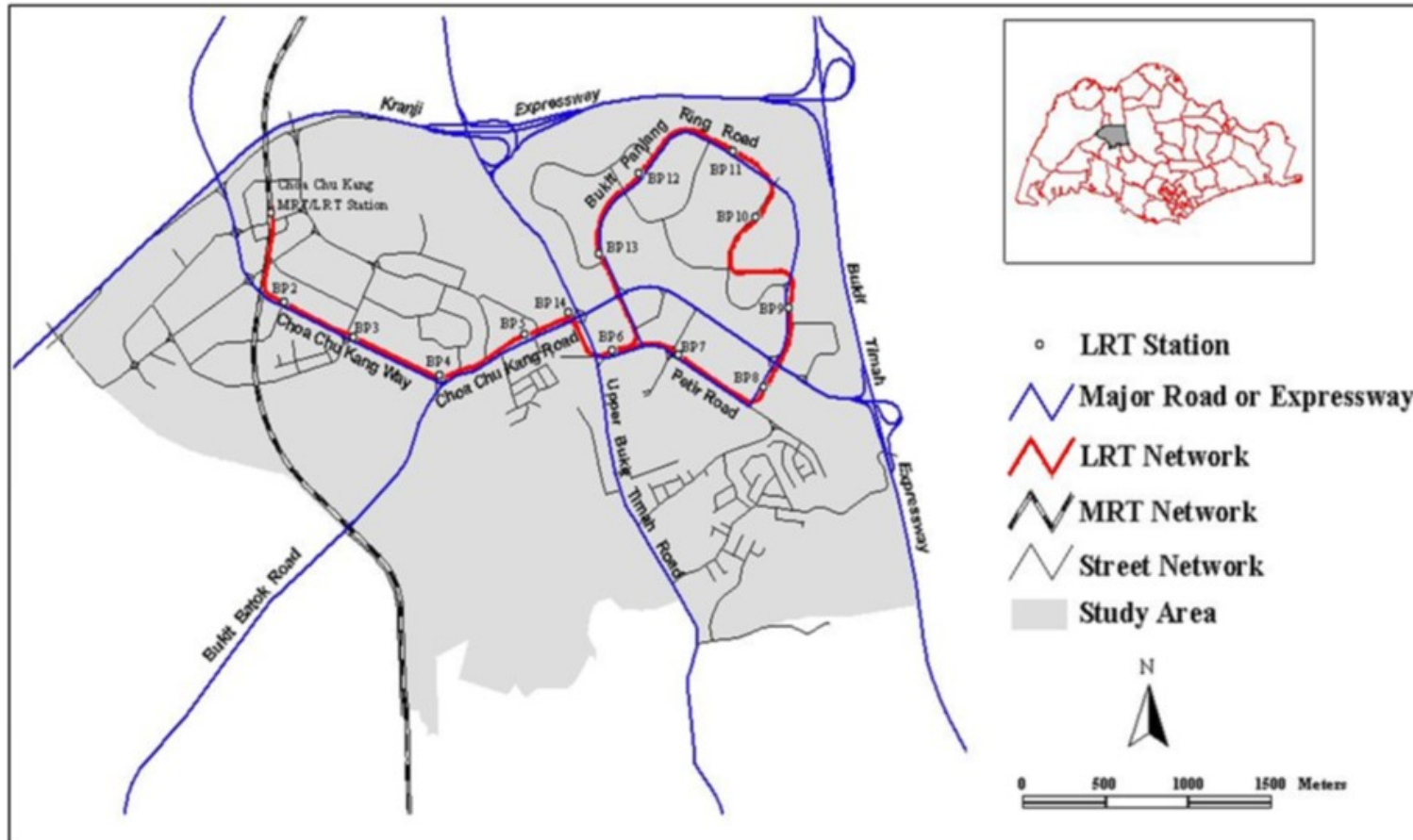
P_i = potential at point i

M_j = The size (attraction) of centre j

d_{ij} = the distance between i and j

α = a parameter, usually between 1 and 2, reflecting the rate of increase of the friction of distance
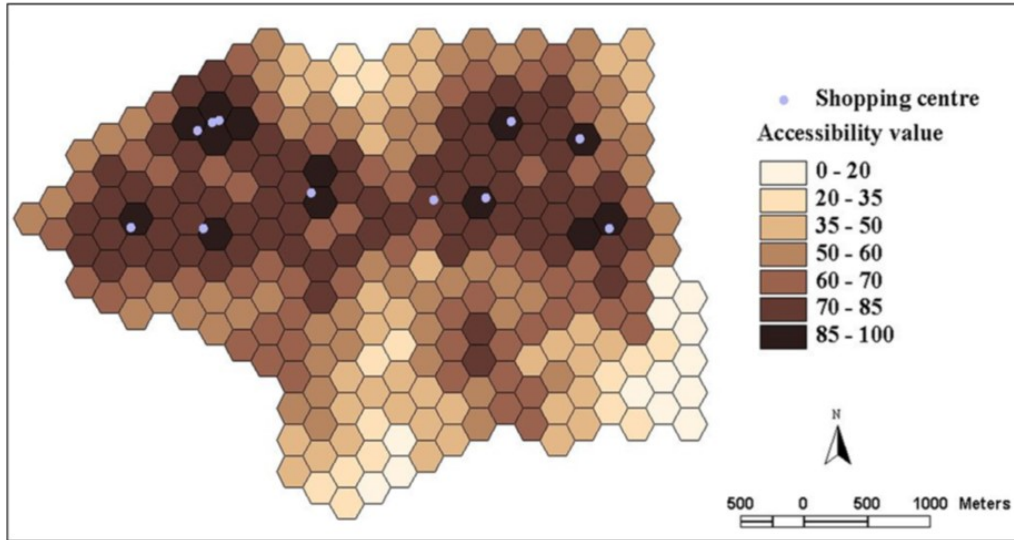
Real world application of potential model

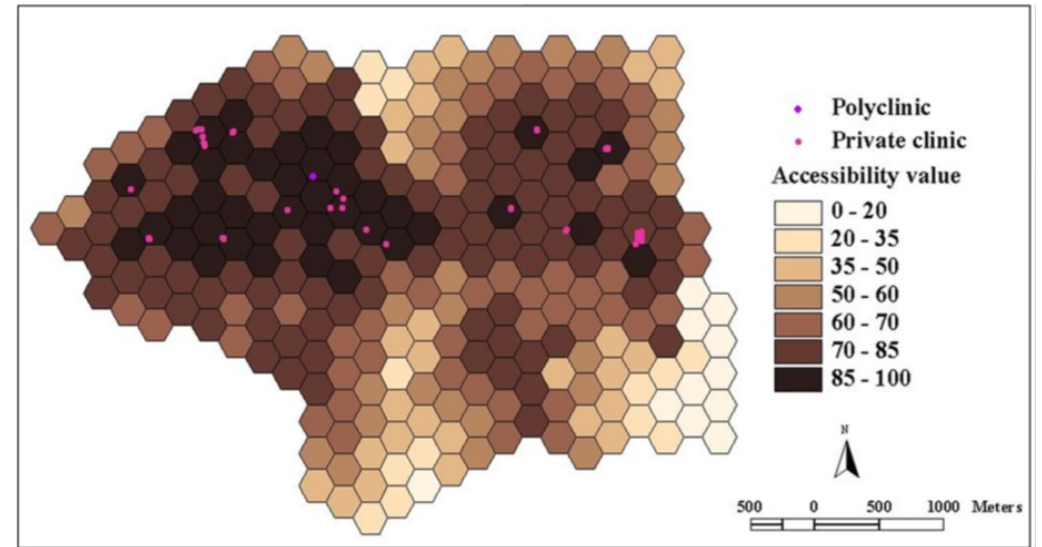- Accessibility to urban functions study

Real world application of potential model
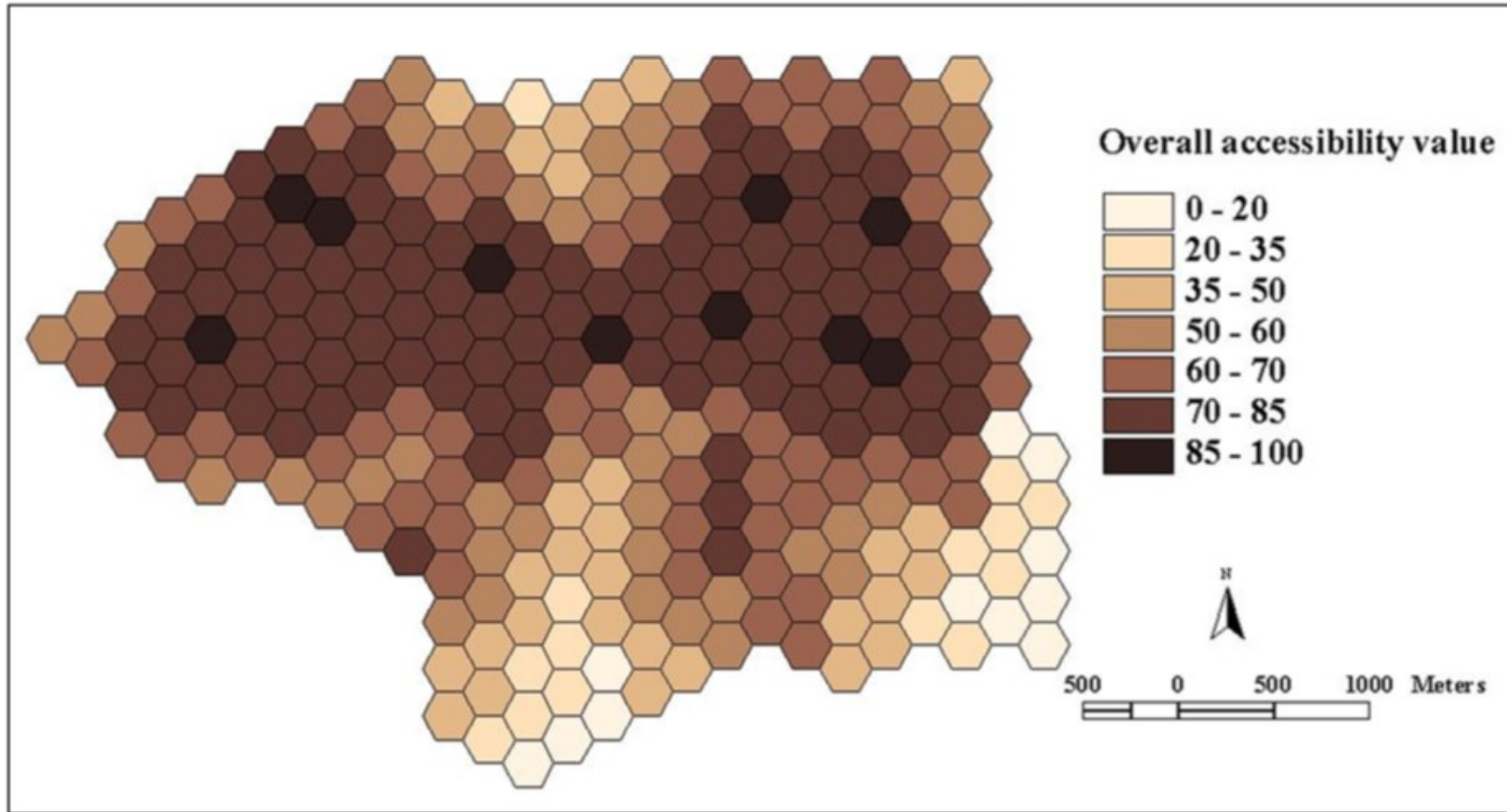
Accessibility to shopping centres

Accessibility to health services

Real world application of potential model
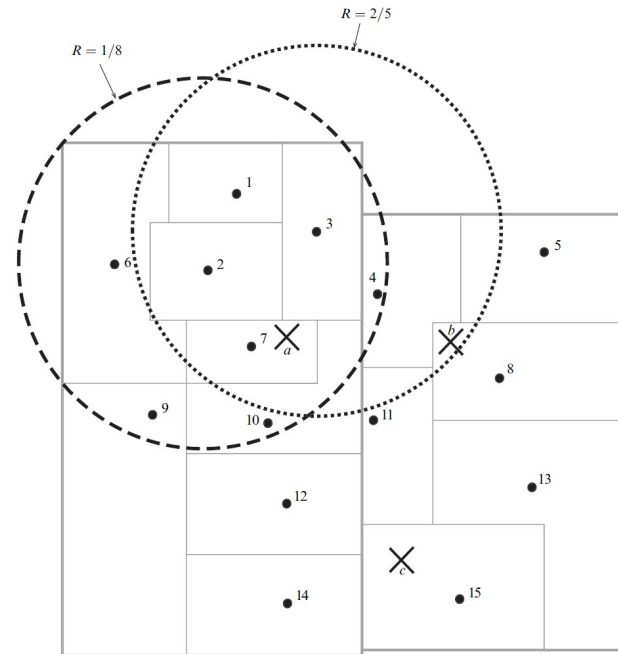
- Overall accessibility

Two-step floating catchment area method (2SFCA)

- A special case of a potential model for measuring spatial accessibility to primary social services and public facilities.
- It was inspired by the spatial decomposition idea first proposed by Radke and Mu (2000).

Reference: Luo, W.; Wang, F. (2003b). "Measures of spatial accessibility to health care in a GIS environment: synthesis and a case study in the Chicago region". *Environment and Planning B: Planning and Design*. 30 (6): 865–884.

An earlier version of 2SFCA

- - - - 15-mile catchment area for tract 2
- - - - - 15-mile catchment area for tract 3
  •¹ Census tract centroid and identifier
  ✕ Physician location and identifier
  a
  —— County boundary
  —— Census tract boundary

Two-step floating catchment area method (2SFCA)

Step 1: For each physician location j, search all population locations (k) that are within a threshold travel time ($d0$) from location j (that is, catchment area j), and compute the physician-to-population ratio, Rj, within the catchment area:

$$R_j = \frac{S_j}{\sum_{k \in \{d_{kj} \le d_0\}} P_k}$$

An earlier version of 2SFCA
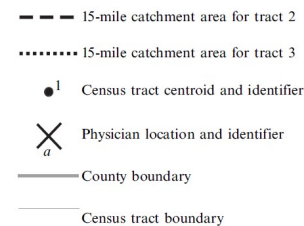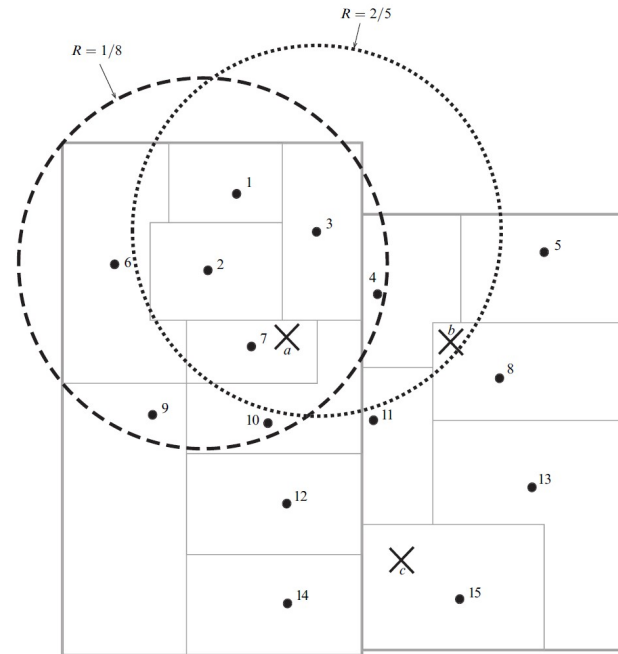

- - - 15-mile catchment area for tract 2

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•¹ Census tract centroid and identifier

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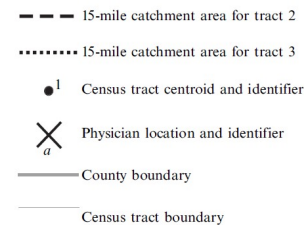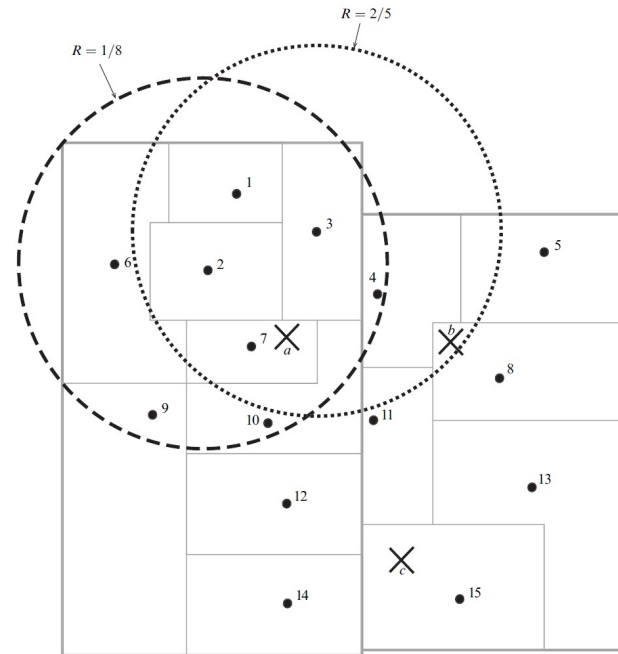
Two-step floating catchment area method (2SFCA)

Step 2: For each population location i, search all physician locations (j) that are within the threshold travel time ($d0$) from location i (that is, catchment area i), and sum up the physician-to-population ratios, Rj, at these locations:

$$A_i^F = \sum_{j \in \{d_{ij} \leqslant d_0\}} R_j = \sum_{j \in \{d_{ij} \leqslant d_0\}} \frac{S_j}{\sum_{k \in \{d_{kj} \leqslant d_0\}} P_k}$$

An earlier version of 2SFCA

- – – – 15-mile catchment area for tract 2
- ······· 15-mile catchment area for tract 3
- •¹   Census tract centroid and identifier
- ✕ₐ   Physician location and identifier
- —— County boundary
- —— Census tract boundary

Enhanced Two-step Floating Catchment Area (E2SFCA)

Step1: The catchment of physician location j is defined as the area within 30-min driving zone(Lee, 1991). Within each catchment, compute three travel time zones with minute breaks of 0–10,10–20 and 20–30min(zones1–3,respectively). Search all population locations(k) that are within a threshold travel time zone (Dr) from location j (this is catchment area j), and compute the weighted physician-to-population ratio, Rj, within the catchment area as follows:

$$R_j = \frac{S_j}{\sum\limits_{k \in \{d_{kj} \in D_r\}} P_k W_r}$$

$$= \frac{S_j}{\sum\limits_{k \in \{d_{kj} \in D_1\}} P_k W_1 + \sum\limits_{k \in \{d_{kj} \in D_2\}} P_k W_2 + \sum\limits_{k \in \{d_{kj} \in D_3\}} P_k W_3}$$

Step2: For each population location i, search all physician locations (j) that are within the 30min travel time zone from location i (that is,catchment area i), and sum up the physician-to-population ratios (calculated in step1), Rj, at these locations as follows:

$$A_i^F = \sum_{j \in \{d_{ij} \in D_r\}} R_j W_r$$

$$= \sum_{j \in \{d_{ij} \in D_1\}} R_j W_1 + \sum_{j \in \{d_{ij} \in D_2\}} R_j W_2 + \sum_{j \in \{d_{ij} \in D_3\}} R_j W_3$$
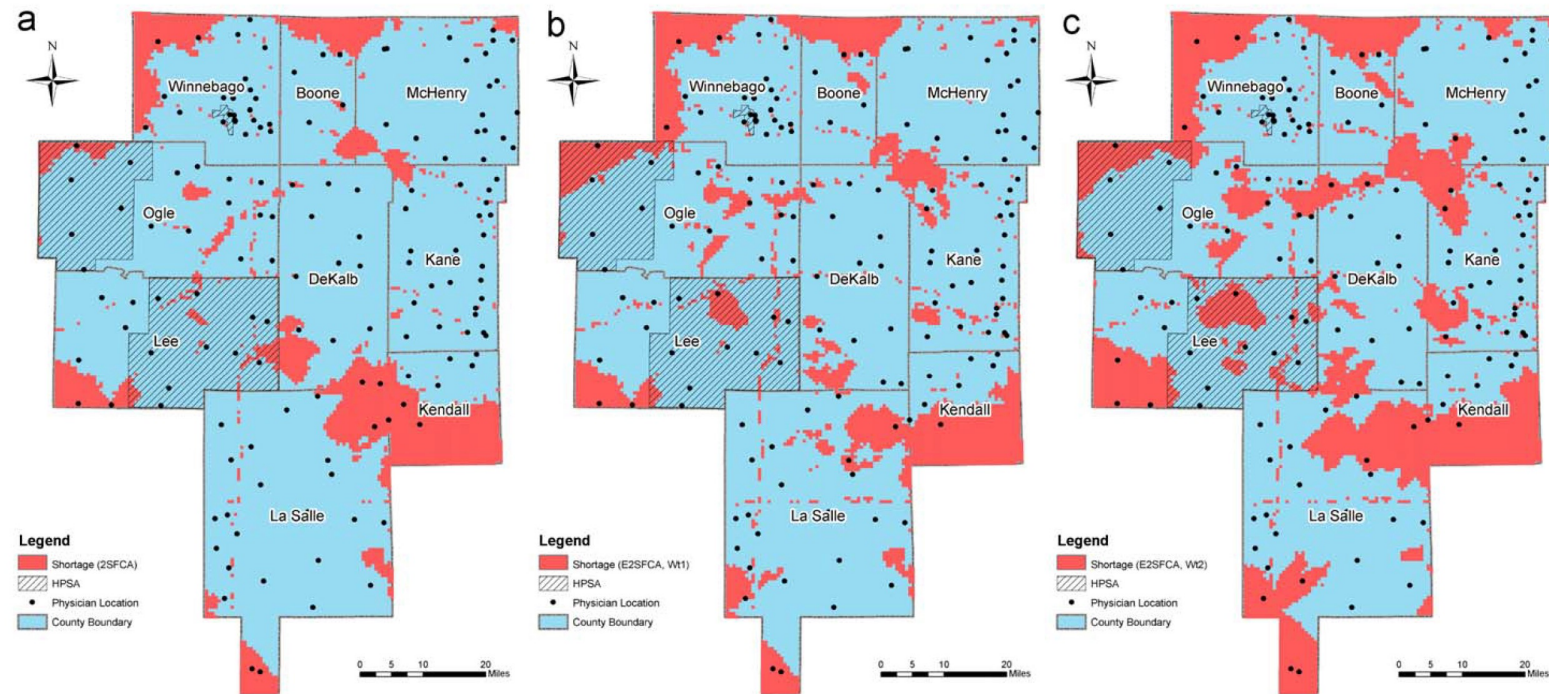
Comparing 2SFCA and E2SFCA

Fig. 6. Spatial distribution of shortage areas identified with 2SFCA (a), E2SFCA with weight1 (b), and weight 2 (c), along with published HPSA of 2000 by DHHS.

Reference: Luo, Wei., Qi, Yi. (2009) "An enhanced two-step floating catchment area (E2SFCA) method for measuring spatial accessibility to primary care physicians", *Health & Place*, 2009, Vol.15 (4), p.1100-1107.

Spatial Accessibility Measure (SAM)

The formula:

$$A_{ai} = 1 / p_i \sum_j \frac{n_j}{p_i * d_{ij}^2}$$

where

- *Aai* is the accessibility in ED *i*,
- *nj* is the capacity of the target facility *j*.
- *pi* is the demand of this ED, and
- *dij* is the network distance between the *EDi* and each facility *j*.

Reference: Stamatis Kalogirou & Ronan Foley (2006) "Health, place and Hanly: Modelling accessibility to hospitals in Ireland", *Irish Geography*, Volume 39(1), 2006, 52-68.