Lesson 11: Modelling Geographical Accessibility

Dr. Kam Tin Seong
Assoc. Professor of Information Systems

School of Computing and Information Systems,
Singapore Management University

2020-5-16 (updated: 2021-10-27)

Content

- Basic Concepts of Geography of Accessibility
- Accessibility Models
  - Stewart Potential model
  - Reilly model
  - Huff model

What is Geography of Accessibility?

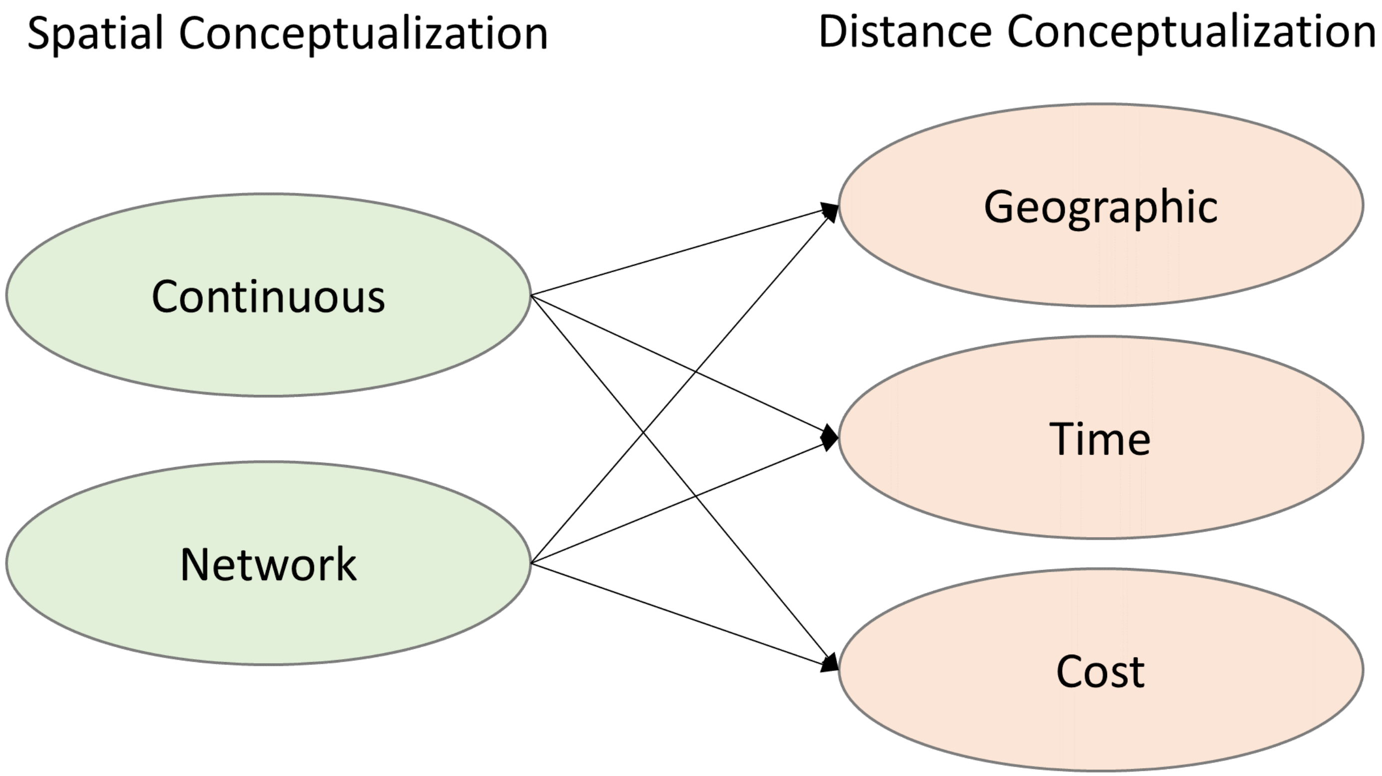
- Accessibility is the measure of **the capacity of a location to be reached from, or to be reached by, different locations**. Therefore, the capacity and the arrangement of transport infrastructure are key elements in the determination of accessibility.

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.

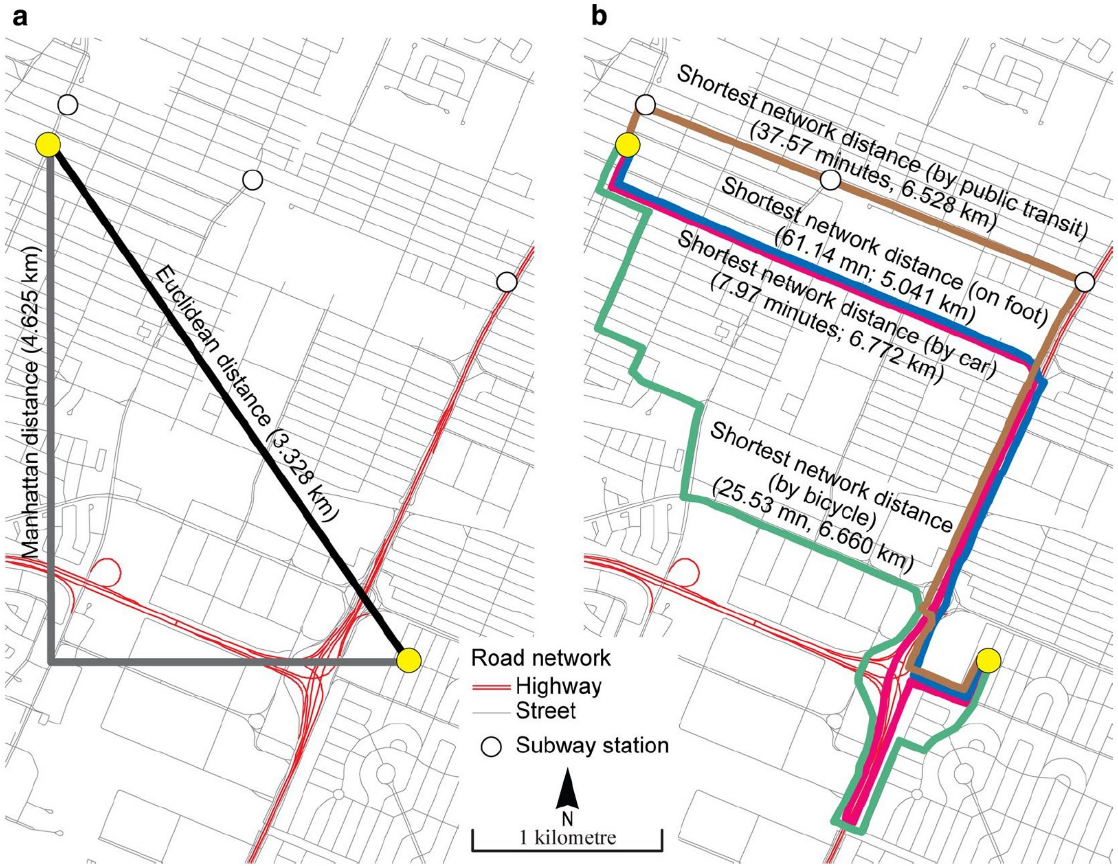
Measuring Distances

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



Distance Consideration

Cartesian distance versus Network distance

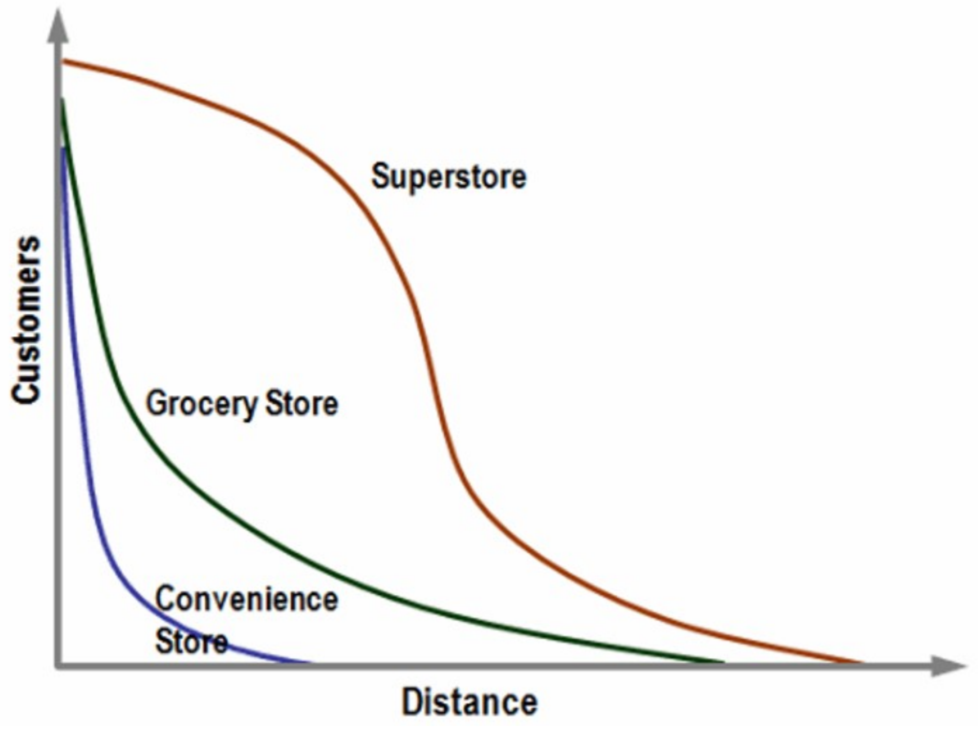


Types of distance. **a** Cartesian distances. **b** Network distances

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

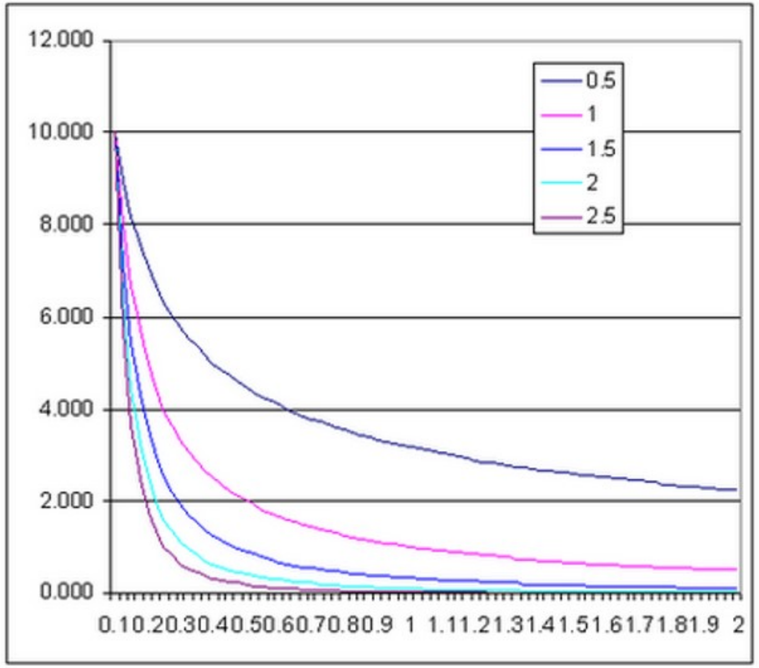
The distance friction

- 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).

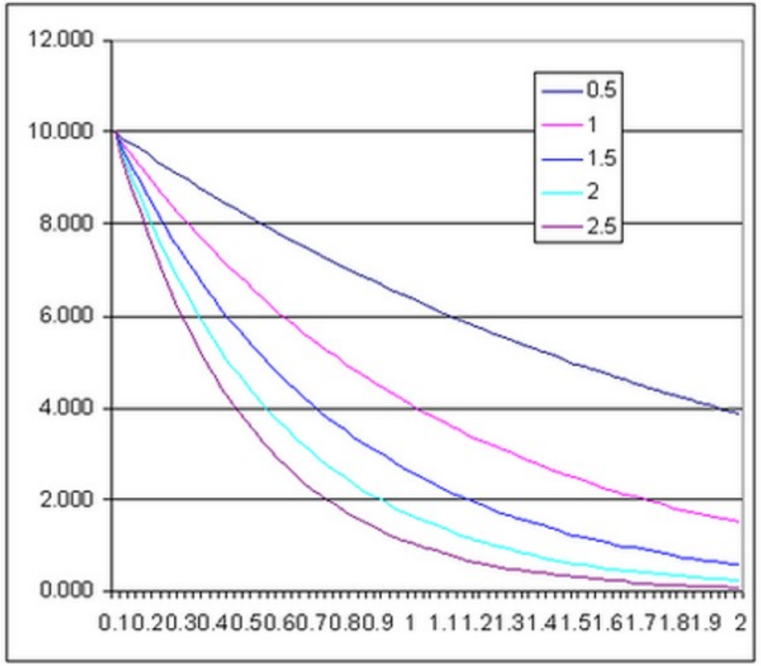


Distance Decay function.

Inverse distance decay, α/d_β



Exponential distance decay, αe^$(-\beta d)$

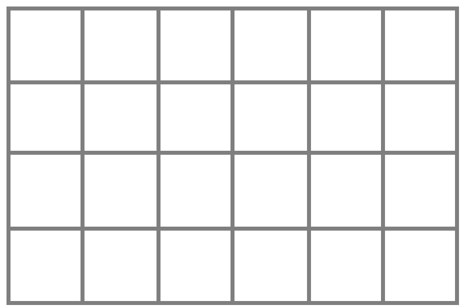
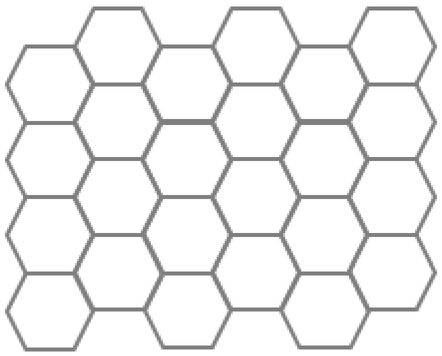
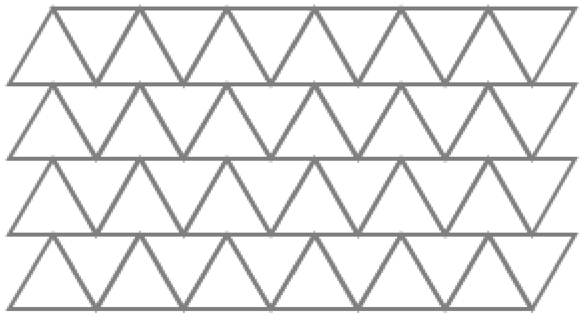


The Geographical Unit

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

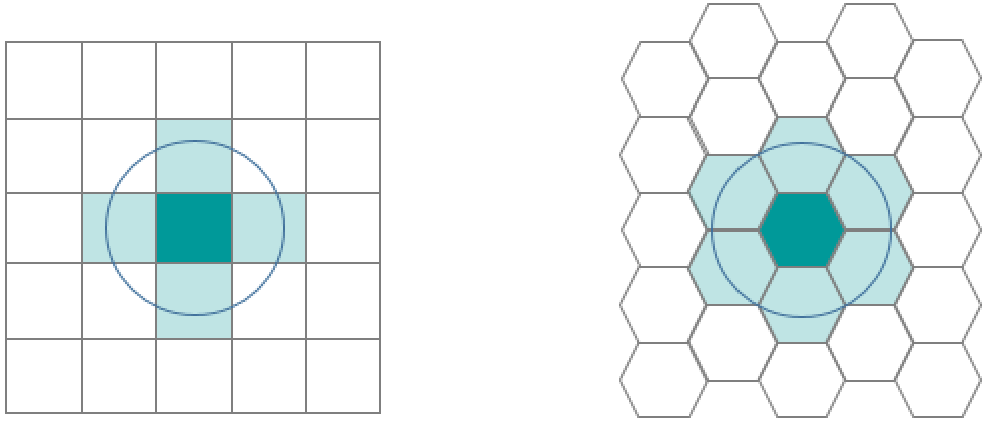
The Geographical Unit

- 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.

The Potential Model

The classic model

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

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

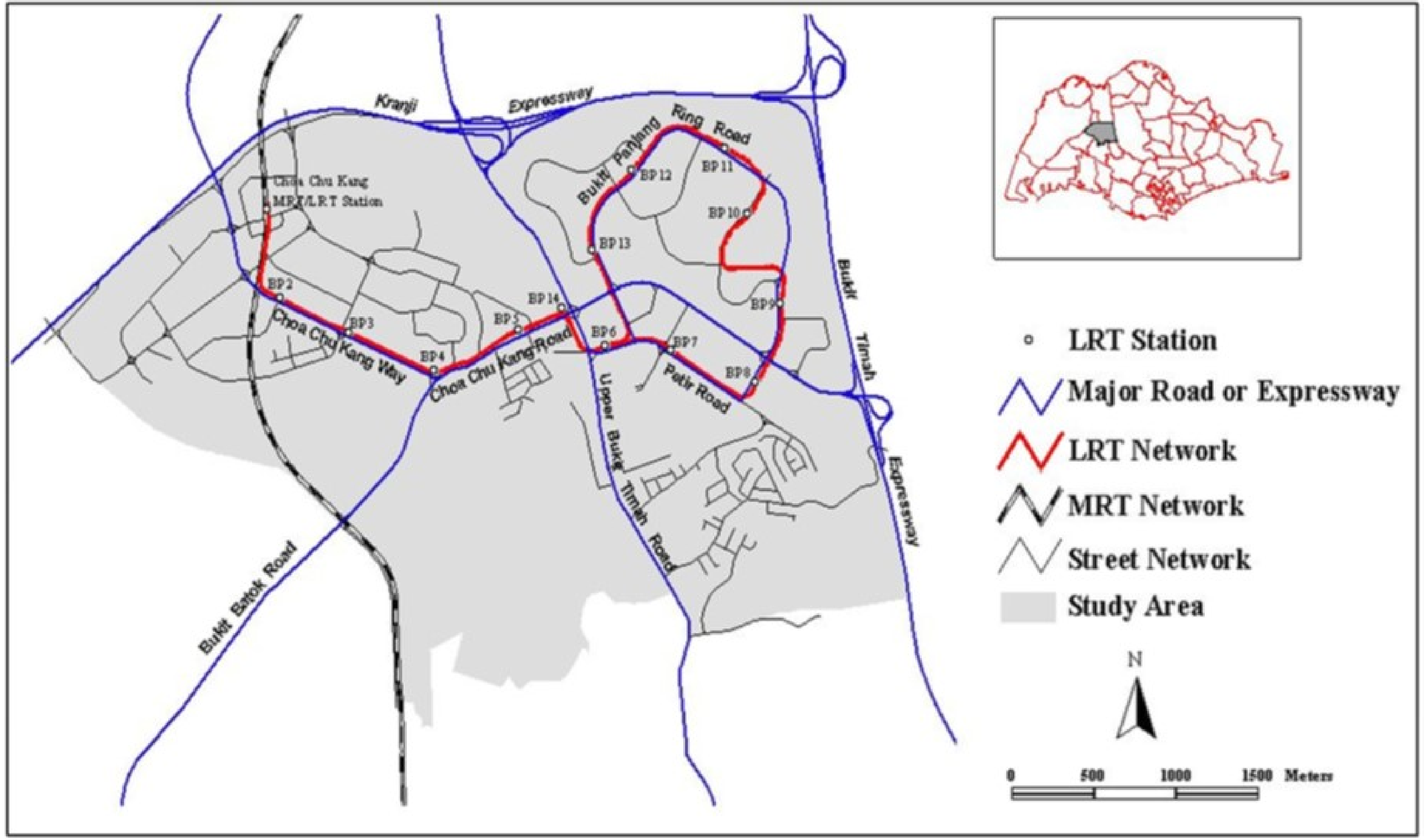
The Modified Potential Formula

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

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

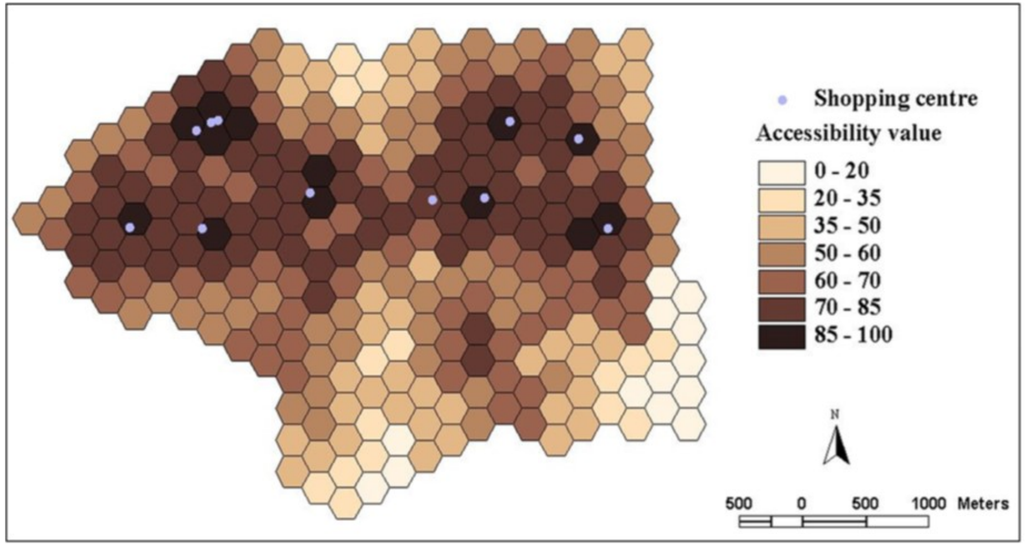
Real world application of potential model

- Accessibility to urban functions study

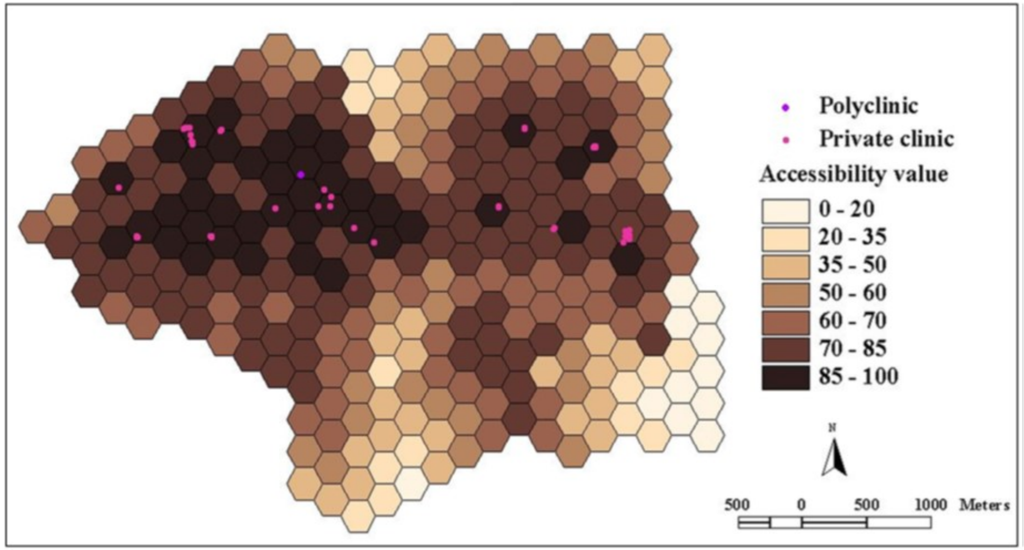


Real world application of potential model

Accessibility to shopping centres

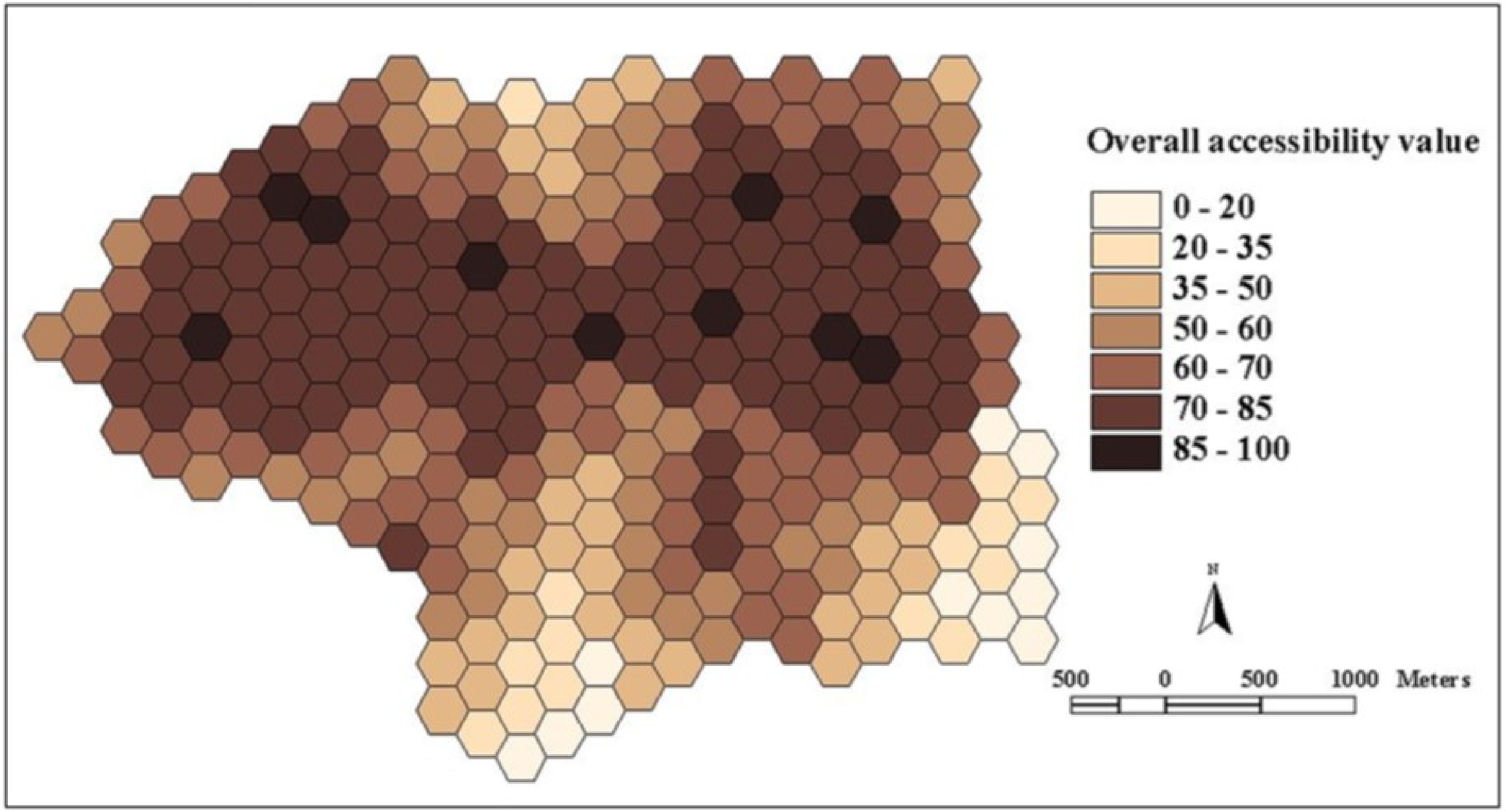


Accessibility to health services



Real world application of potential model

- Overall accessibility

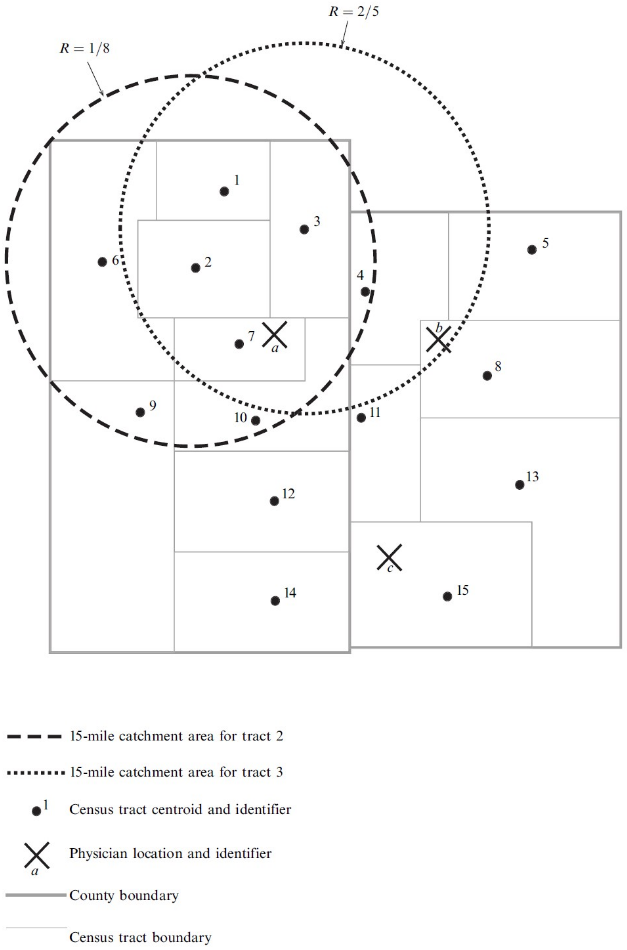


Two-step floating catchment area method (2SFCA)

- 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

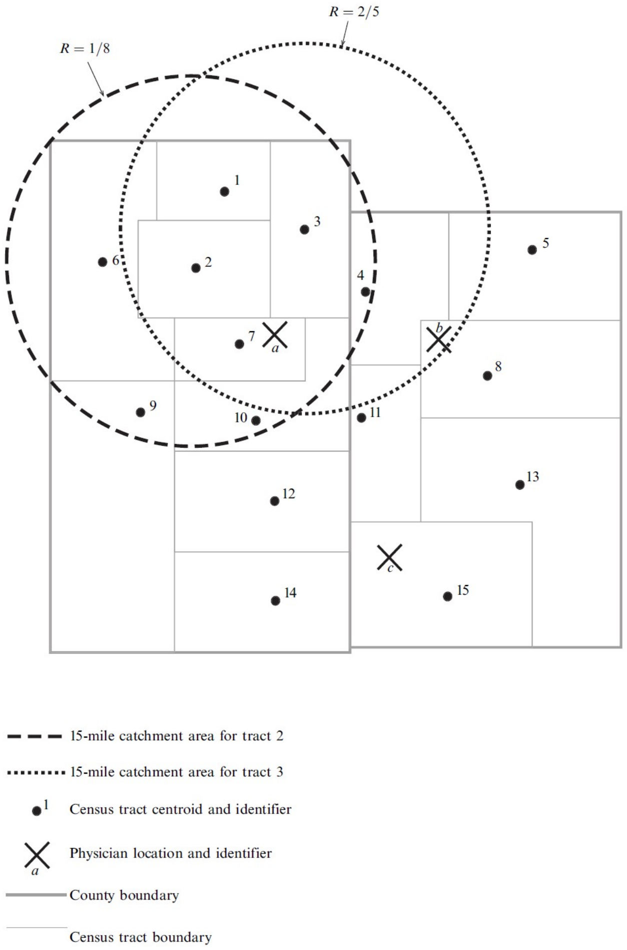


Two-step floating catchment area method (2SFCA)

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:

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

An earlier version of 2SFCA

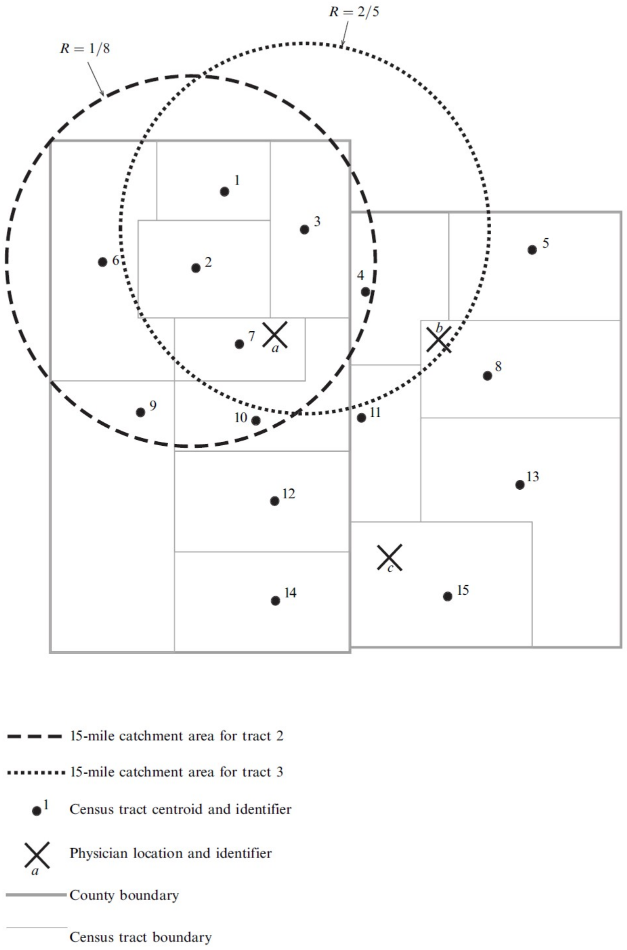


Two-step floating catchment area method (2SFCA)

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



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:

$$R_j = \frac{S_j}{\sum_{k \in \{d_{kj} \in D_r\}} P_k W_r} = \frac{S_j}{\sum_{k \in \{d_{kj} \in D_1\}} P_k W_1 + \sum_{k \in \{d_{kj} \in D_2\}} P_k W_2 + \sum_{k \in \{d_{kj} \in D_3\}} P_k W_3}$$

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

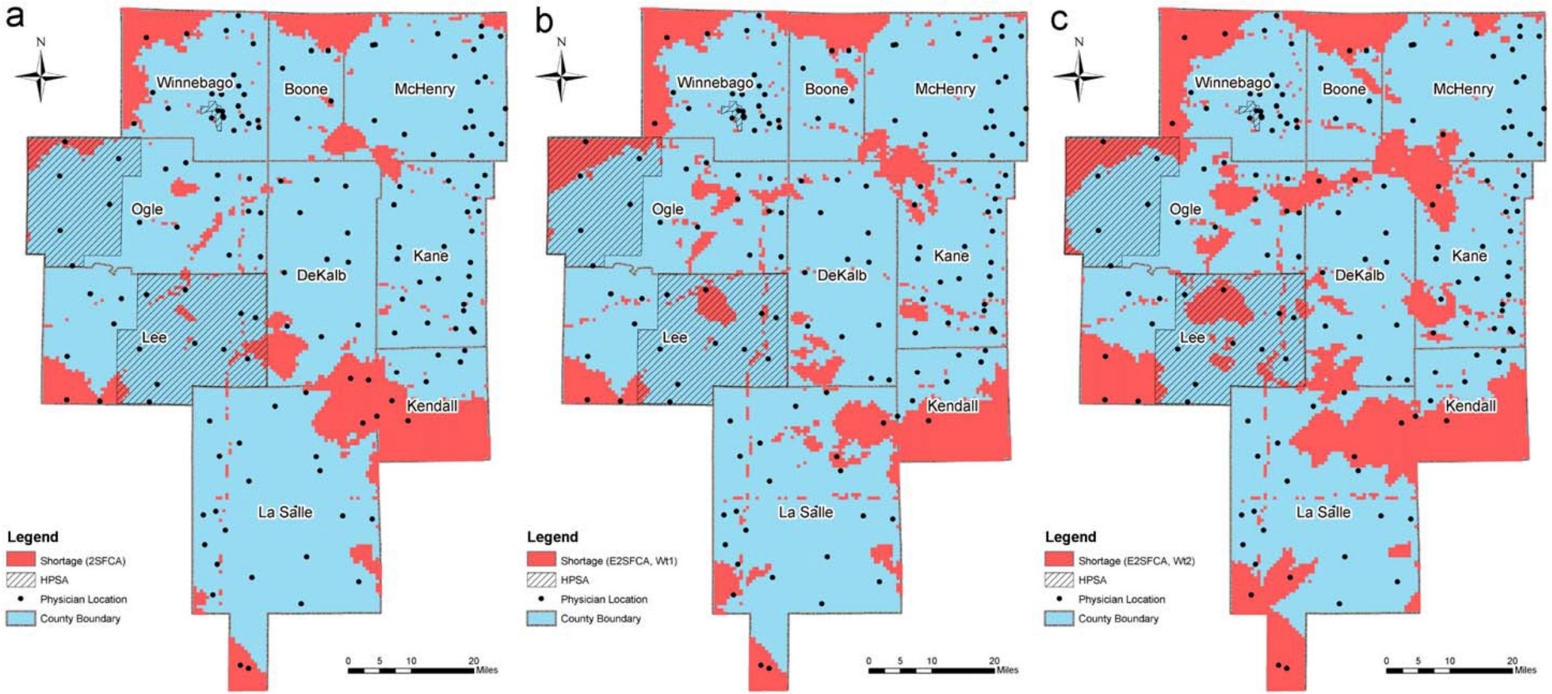


Fig. 6. Spatial distribution of shortage areas identified with 2SFCA (a), E2SFCA with weight1 (b), and weight 2 (c), along with published HPSA of 2000 by DHHS.

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.