SDL202210

Spatiotemporal Innovation Workshop

ASSESSING THE SPATIAL INEQUALITY OF HEALTHCARE ACCESSIBILITY

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Future Data Lab

Open for Innovation KNIME

Key Points

2SFCA and I2SFCA models

Uncertainty in Accessibility Issue

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Data Source

Textbook： Quantitative Methods and Socioeconomic Applications in GIS

https://github.com/UrbanGISer/Quantitative-Methods-and-Socioeconomic-Applications-in-GIS

Workflow

Local Version: G2SFCA.knwf ;
Cloud Version: G2SFCAWeb.knwf ;

Data

G2SFCA.zip

- trt2k.zip
- trtcent.zip
- zipcent.zip

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KNIME Package Requirements

Python Packages

#Basic
pandas
matplotlib
shapely
mapclassify
#GIF
imageio
cv2

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Contents

01

Disparity Issue in Health Geography

Health Economics

Health Economics

Scarcity

Supply and demand

Need and demand

Opportunity cost

Discounting

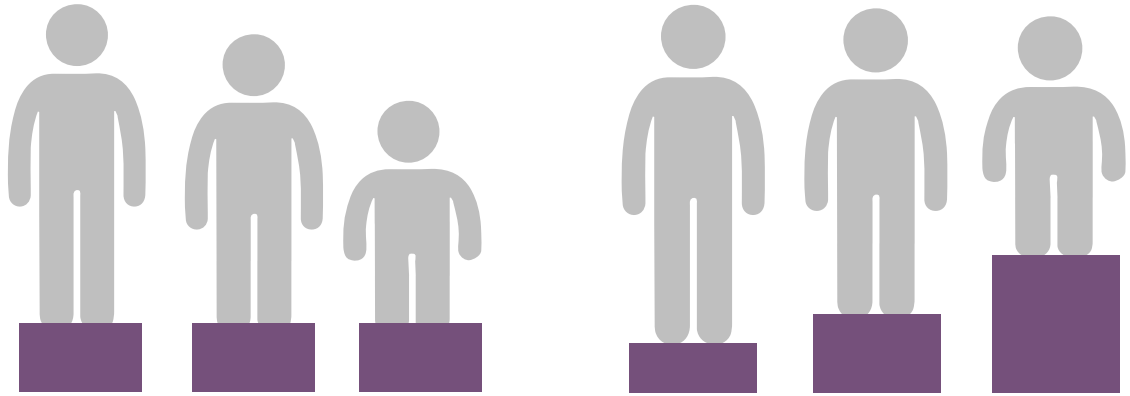
Time horizons

Margins

Efficiency and equity

Needs are things that satisfy the basic requirement. Wants are requests directed to specific types of items. Demands are requests for specific products that the buyer is willing to and able to pay for.

Economic analysis usually judges the way in which resources are used according to two main criteria: efficiency and equity.
Efficiency refers to obtaining the greatest output for a given set of resources. Equity refers to a fair distribution of that output amongst the population.



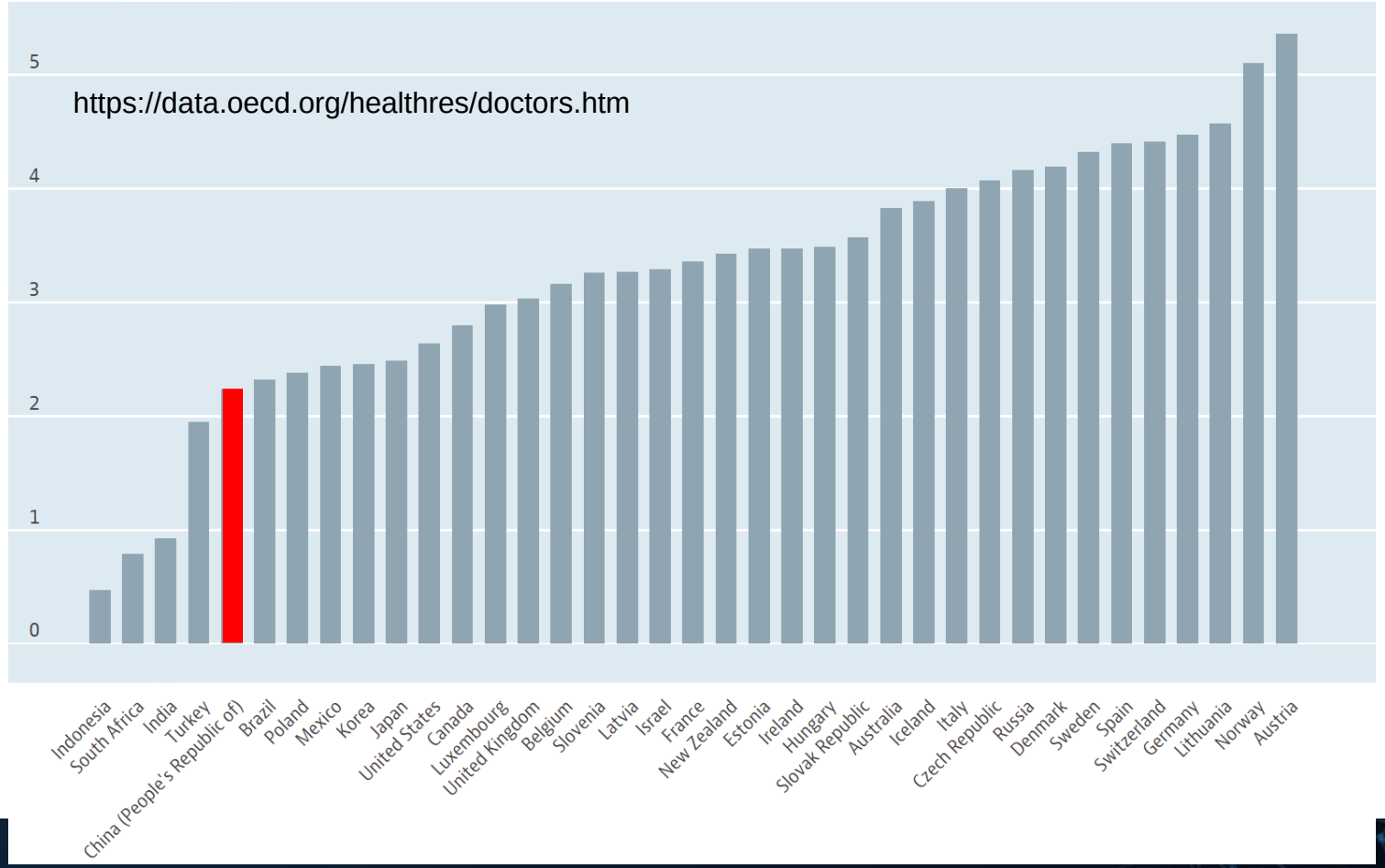
https://www.healthknowledge.org.uk/public-health-textbook/medical-sociology-policy-economics/4d-health-economics/principles-he

Equity and Efficiency in Healthcare

Trade-off between equity and efficiency： the central issue of healthcare spatial distribution

Equity — WHO initiated a strategy for universal coverage of healthcare.
Hierarchical Diagnosis and Treatment (HTD) reform in China.

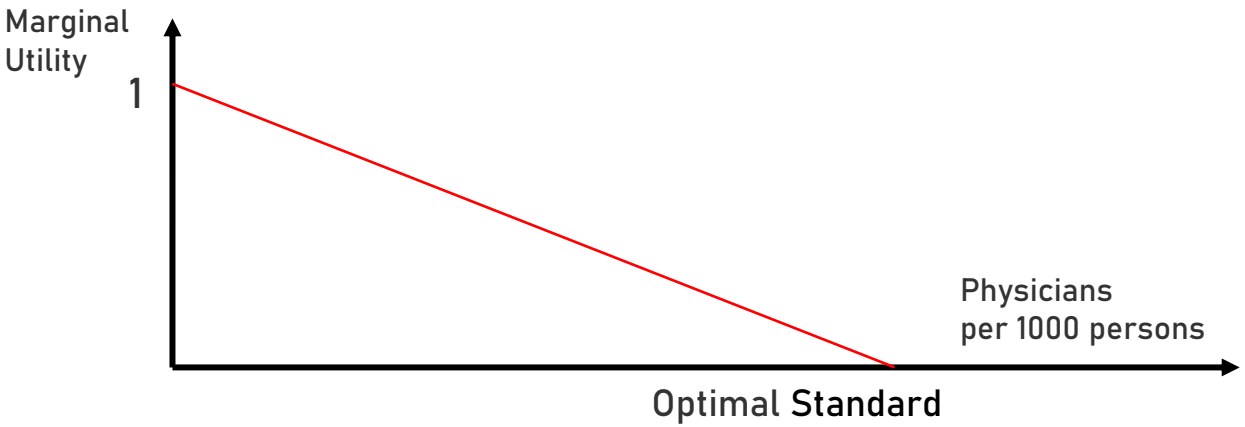
Efficiency — Healthcare allocation under limited resource constraints
Optimize spatial distribution of medical resources to obtain a supply-demand equilibrium with lower cost and higher input-output efficiency.

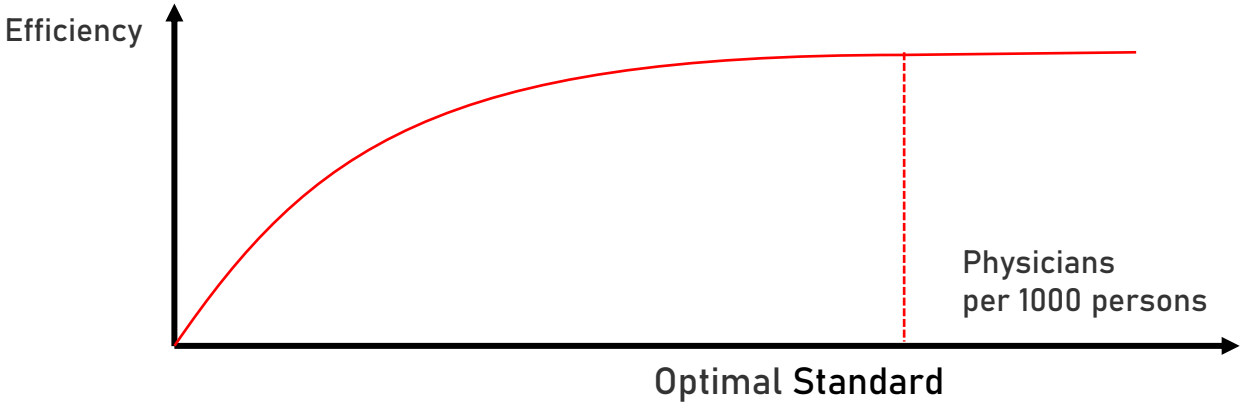


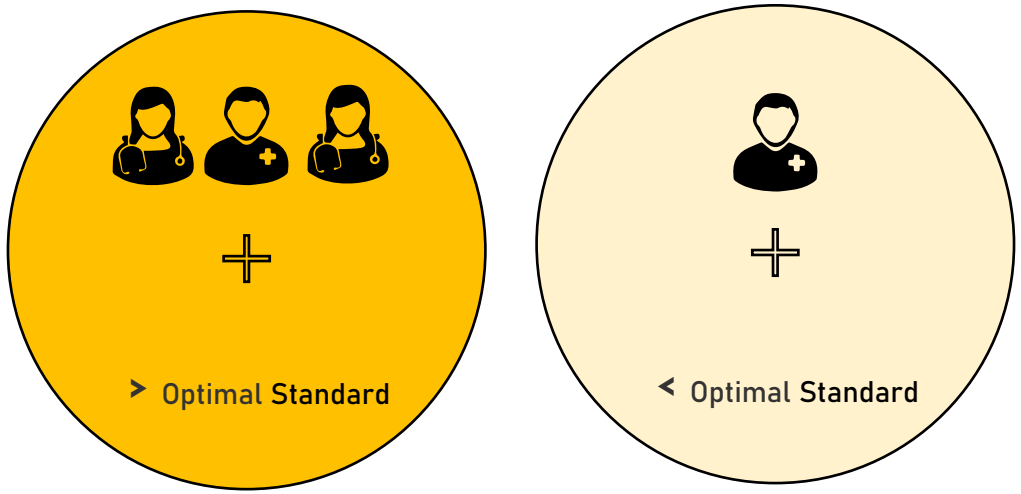
WHO ： 1 Physician per 1000 persons

Equity and Efficiency in Healthcare

law of diminishing marginal utility



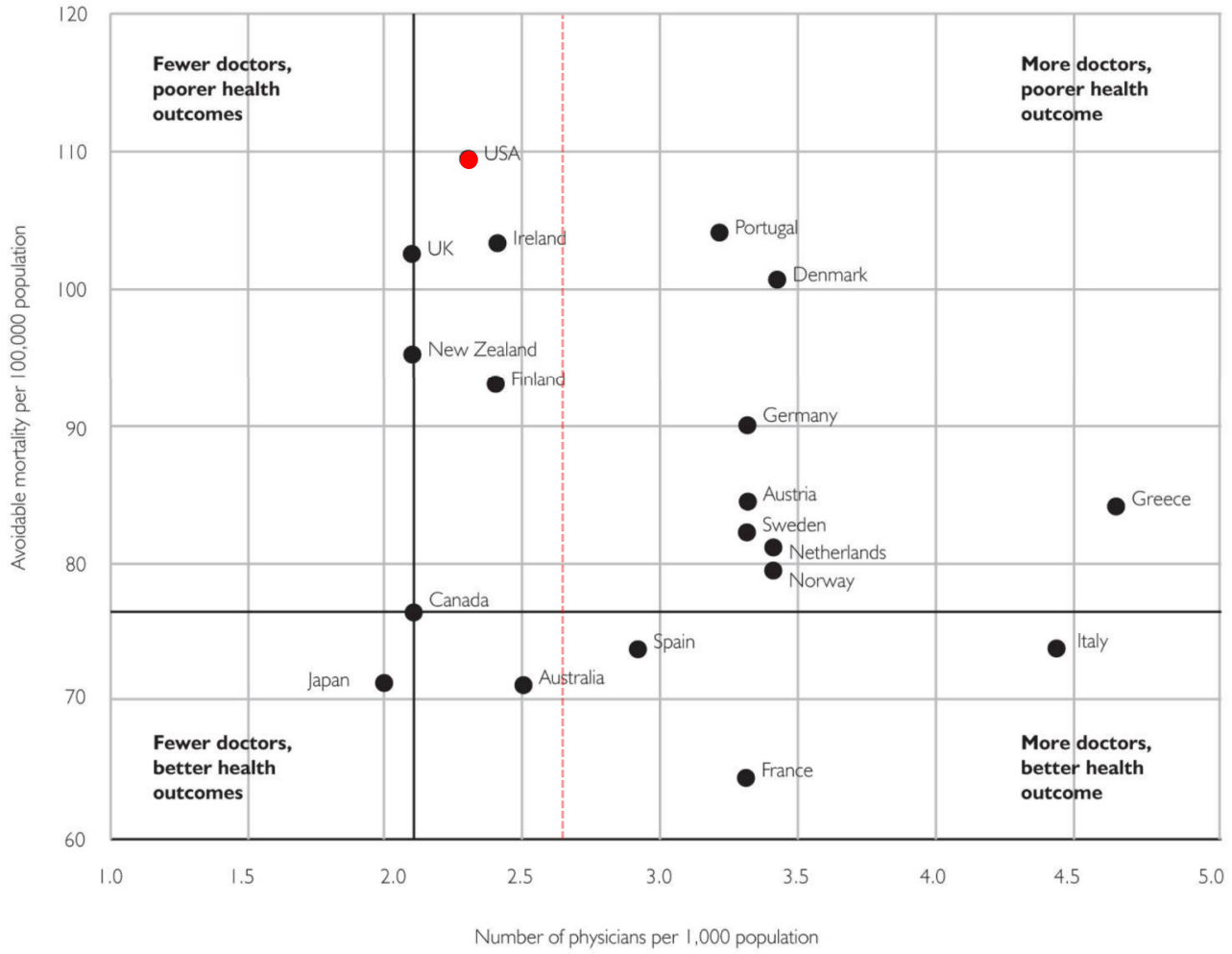




Weighted Marginal Utility=

Population x Marginal Utility

ISSUES ON ACCESSIBILITY



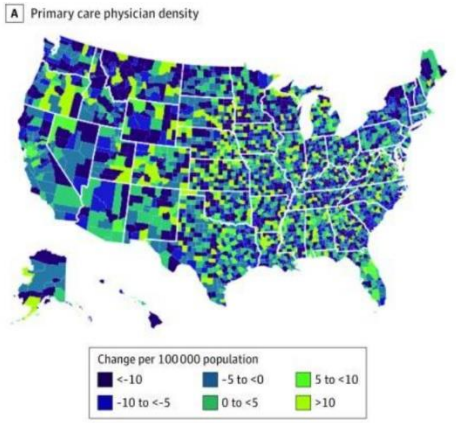
Source: Physician-to-population ratios from 2005 OECD Health Data for 2002/03. Avoidable mortality as reported by Nolte and McKee (2008).

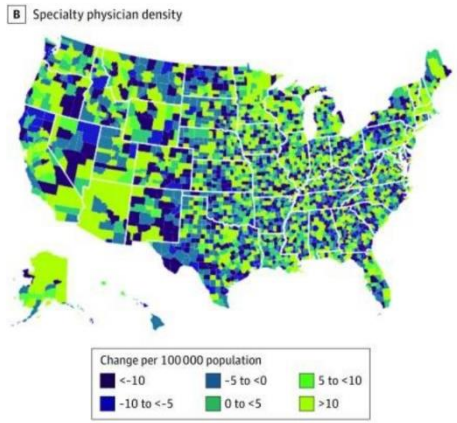
More Doctors or Better Care?

Healthc Policy. 2009 Aug; 5(1): 26–31.

Equity and Efficiency in Health Geography

Spatial Heterogeneity : Primary Care Physician Versus Population Mortality





An increase of 10 primary care physicians per 100 000 population was associated with a reduction in cardiovascular mortality by 30.4 deaths per million (95% CI, –52.4 to–8.4; a 0.9% reduction)

Association of Primary Care Physician Supply With Population Mortality in the United States, 2005-2015 doi: 10.1001/jamainternmed.2018.7624

Characteristics of the Study Sample of 3142 US Counties, 2005-2015

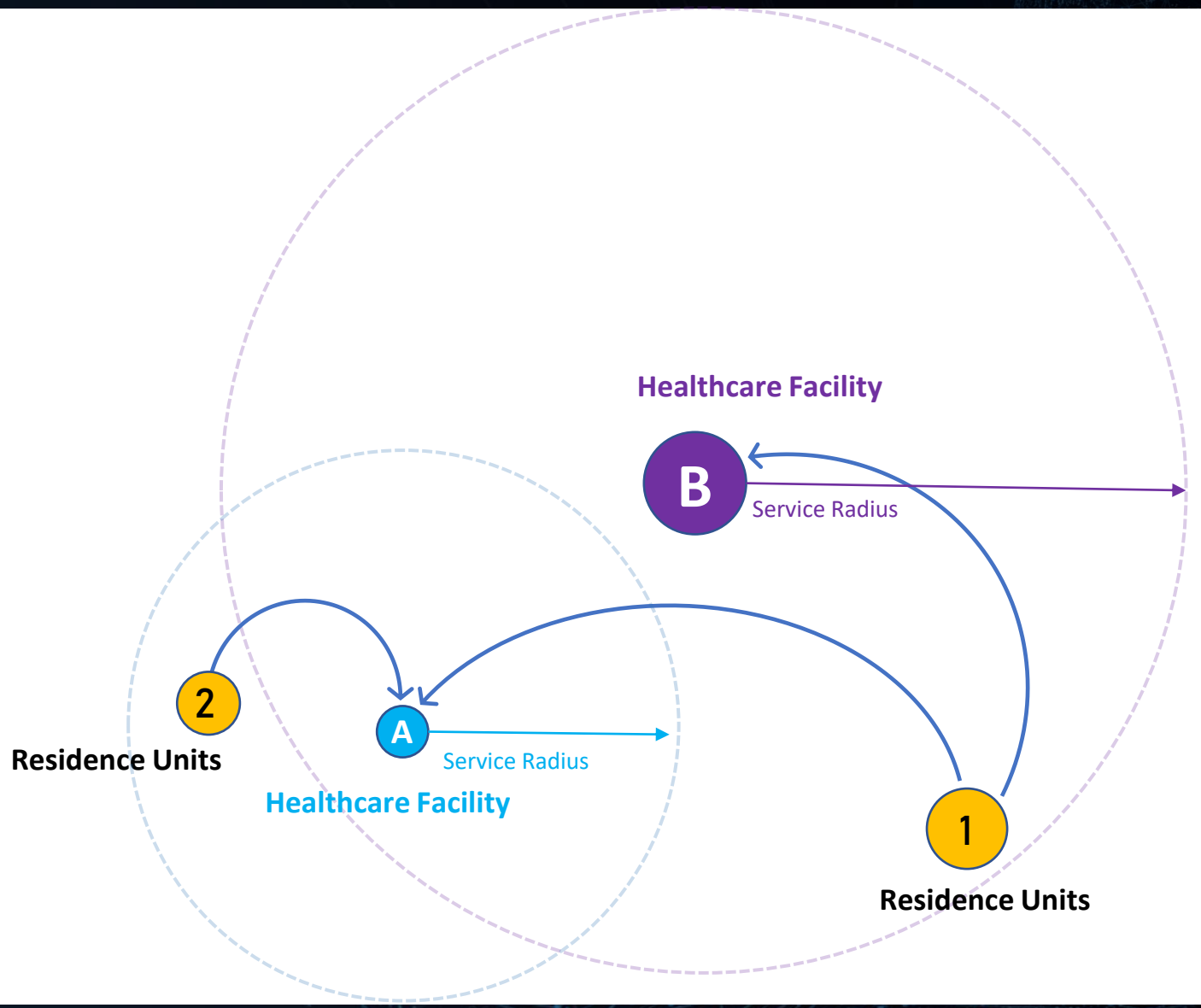
Characteristic	Mean (95% CI)			
	2005	2010	2015	Within-County Change, 2005 to 2015[a]
Independent Predictor Variables				
Physicians per 100 000 population[b]				
Total	114.6 (0.0 to 425.7)	111.6 (0.0 to 434.9)	112.8 (0.0 to 461.3)	−1.9 (−64.0 to 67.1)
Primary care	46.6 (0.0 to 114.6)	44.0 (0.0 to 113.7)	41.4 (0.0 to 108.6)	−5.2 (−44.6 to 28.8)
Specialist	68.0 (0.0 to 326.7)	67.6 (0.0 to 327.5)	71.3 (0.0 to 356.2)	3.4 (−40.1 to 58.9)
Nonmetro area, %	67.3	73.0	73.0	5.7
Population in poverty, %[c,d]	15.3 (5.6 to 31.4)	16.8 (7.0 to 31.8)	16.3 (6.9 to 32.0)	1.0 (−4.2 to 5.6)
Median household income, 2015 $US	54 038.4 (34 370.7 to 90 744.6)	53 068.2 (34 523.4 to 87 779.4)	48 600.6 (30 622.5 to 80 641.5)	−5448 (−15 011.1 to 6711.5)
Population with less than high school education, %	17.8 (6.4 to 37.7)	15.4 (5.5 to 32.3)	13 (3.2 to 29.2)	−4.8 (−16.7 to 4.3)
Population ⩾65 y, %	14.8 (7.6 to 24.1)	15.8 (8.5 to 25.2)	18.0 (10.0 to 27.9)	3.1 (−1.4 to 7.9)
Population female, %	50.3 (45.1 to 53.0)	49.8 (43.3 to 53.6)	50.0 (43.9 to 52.8)	−0.3 (−3.1 to 1.5)
Population black, %	9.0 (0.0 to 53)	9.1 (0.2 to 53.1)	9.3 (0.3 to 53.2)	0.3 (−2.7 to 3.1)
Population Hispanic, %	7.1 (0.5 to 46.9)	8.1 (0.8 to 50.4)	9.2 (0.9 to 53.6)	2.1 (−0.1 to 7.5)
Unemployment rate, %	5.6 (2.8 to 12.3)	9.4 (3.7 to 17.5)	5.7 (2.5 to 12.4)	0.1 (−2.3 to 3.1)
Uninsured among persons aged <65 y, %	25.0 (13.0 to 40.4)	18.5 (9.3 to 30.7)	12 (4.7 to 23.2)	−13.0 (−25.4 to −4.0)
Hospital beds per 100 000 population	358.6 (0.0 to 1733.0)	324.3 (0.0 to 1462.3)	294.7 (0.0 to 1336.0)	−63.2 (−592.9 to 185.9)
Medicare enrollment, %	16.3 (7.0 to 26.4)	18.3 (8.7 to 28.2)	20.6 (9.8 to 32.0)	4.3 (−1.4 to 10.6)
Geographic variation in terms of per capita medical costs, 2015, $US	8946.3 (5734.3 to 13 002.4)	9395.5 (7311.4 to 12 394.6)	9843.4 (7790.6 to 12 676.8)	898.4 (−2914.8 to 4608.3)
Adult tobacco smoking, %	17.9 (12.7 to 25.6)	21.3 (11.0 to 33.0)	21.3 (11.0 to 33.0)	3.4 (−5.9 to 12.2)
Adult obesity, %	27.5 (19.0 to 34.0)	30.7 (21.0 to 39.0)	32.1 (21.0 to 42.7)	4.5 (−3.0 to 13.0)
High pollution days, %	4.7 (0.0 to 24.3)	1.3 (0.0 to 9.3)	6.2 (0.0 to 34.6)	1.5 (−16.5 to 26.3)
Median home value 2015, $US	158 526.7 (60 822.4 to 462 389.7)	143 960.4 (63 335.6 to 371 204.1)	129 446.3 (55 081.0 to 293 371.5)	−29 080.4 (−192 909.3 to 45 054.4)
Dependent Outcome Variables				
Life expectancy at birth, age-standardized years	76.8 (72.5 to 80.5)	77.7 (73.2 to 81.5)	77.8 (72.9 to 82.0)	1.0 (0.1 to 1.9)
Age-adjusted deaths per 100 000 population				
Cancer	214.1 (162.2 to 271.7)	204.2 (149.8 to 264.1)	206.9 (148.2 to 273.6)	−7.2 (−21.9 to 8.0)
Cardiovascular disease	317.2 (215.7 to 439.7)	278.4 (185.4 to 397.2)	277.6 (179.6 to 406.6)	−39.6 (−66.6 to −12.9)
Infectious diseases	38.8 (22.2 to 63.2)	34.6 (18.3 to 58.8)	34.8 (17.0 to 61.4)	−4.0 (−9.9 to 2.7)
Respiratory tract diseases	62.3 (38.1 to 93.1)	62.1 (35.5 to 95.0)	64.2 (34.3 to 102.2)	1.8 (−7.5 to 13.7)
Substance use or injury	30.4 (16.3 to 53.8)	33.3 (17.4 to 59.8)	35.5 (17.9 to 64.7)	5.1 (−1.3 to 15.1)
Interpersonal violence	5.3 (1.6 to 15.2)	4.9 (1.5 to 14.6)	5.0 (1.6 to 14.7)	−0.3 (−1.9 to 0.7)

Equity and Efficiency in Health Geography

Accessibility Issue

Uneven Spatial Distribution

- Population
- Healthcare Capacity
- Spatial barrier(time, distance)



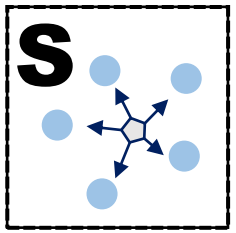
ISSUES ON ACCESSIBILITY

可达性问题

ISSUES ON ACCESSIBILITY

RASP

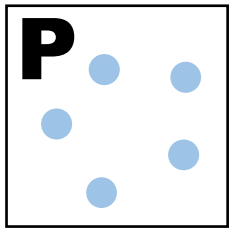
Spatial



空间可达性

the importance of spatial separation between supply and demand as a barrier or a facilitator

Joseph and Phillips, 1984

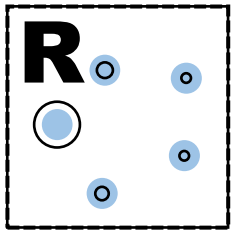


隐性可达性

Potential

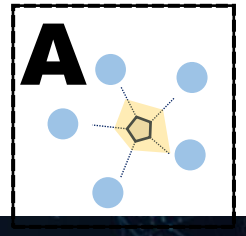
the probable utilization of a service

Khan, 1992



Revealed 显性可达性

actual use of a service



Aspatial 非空间可达性

Non geographic barriers or facilitators

Demographics :age, sex, and ethnicity
Socioeconomic : poverty , income; education
Environment : basic amenities; transportation

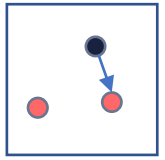
Potential Spatial Accessibility

隐性空间可达性

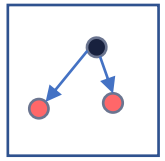
Accessibility Model

可达性传统模型

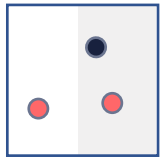
Traditional Model of ACCESSIBILITY



- supply-oriented accessibility 单供给模型
  minimum travel time



- Cumulative opportunities 累计机会法
  gravity-based potential model



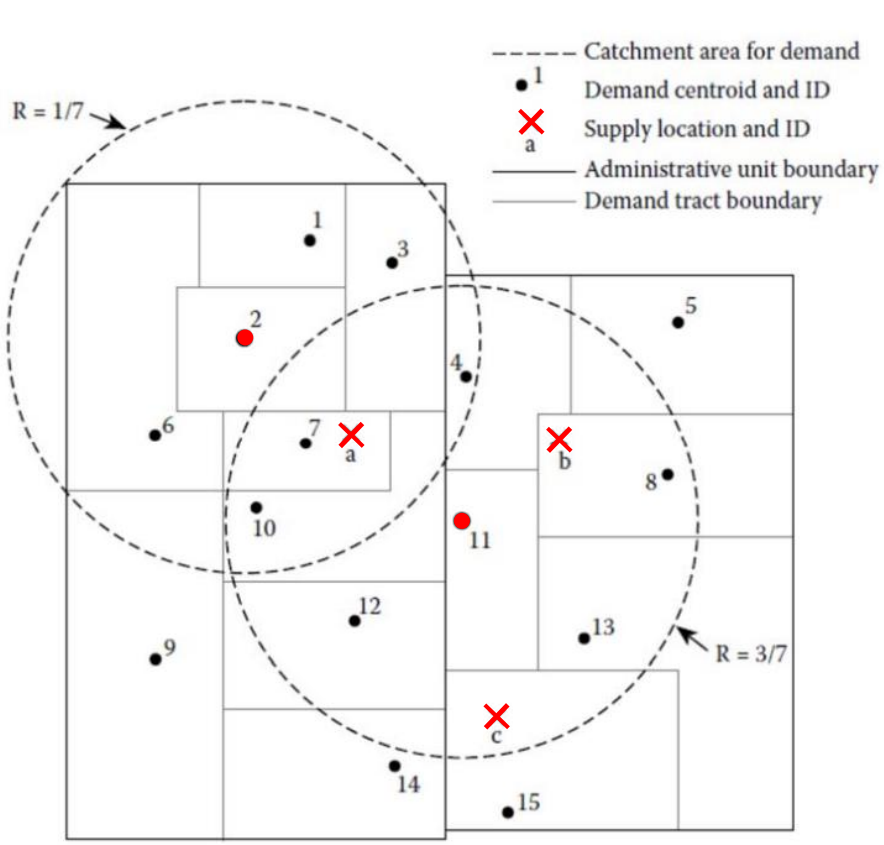
- simple supply-demand ratio method 供需比例法
  jobs-housing balance approach
  Rational service area

regional availability measure
regional accessibility measure based on a gravity model

SHORTCOMINGS Spatial variations within an area unit
Impermeable boundaries

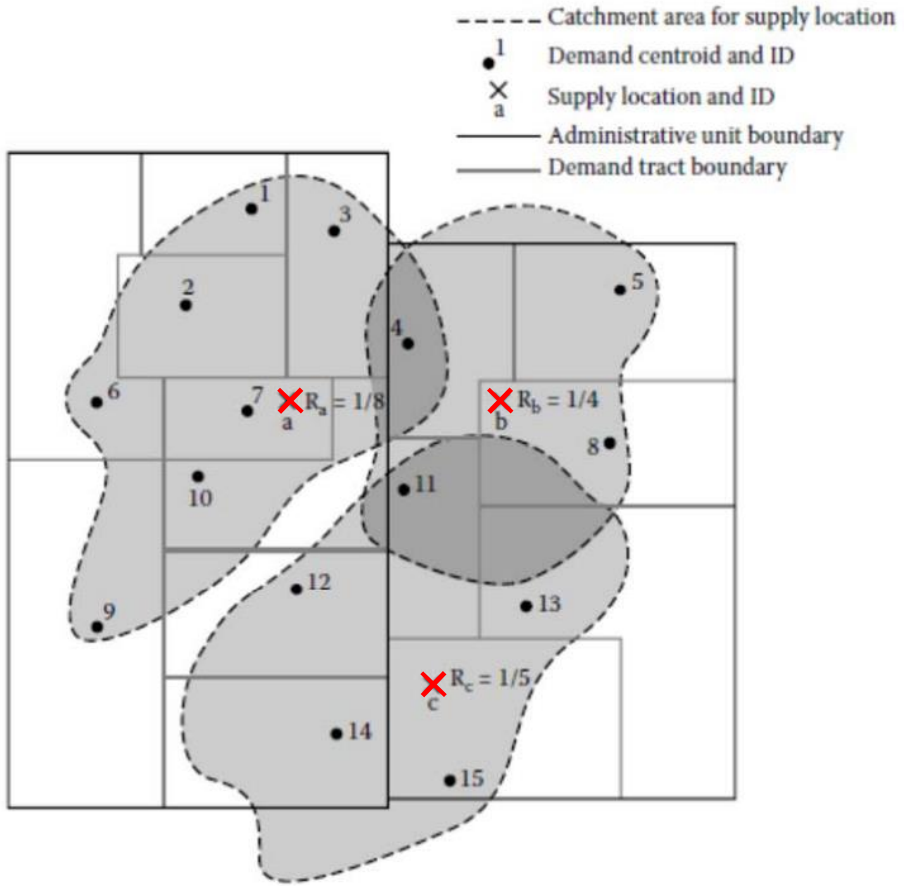
Accessibility Model

移动搜索法
FCA



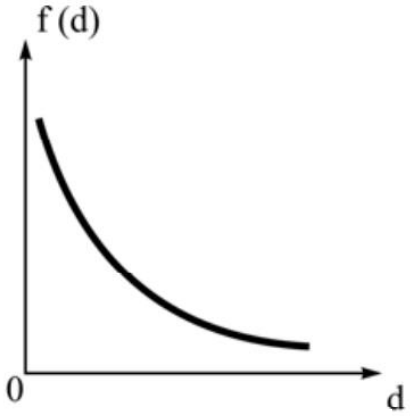
两步移动搜索法
2SFCA

Distance decay parameter

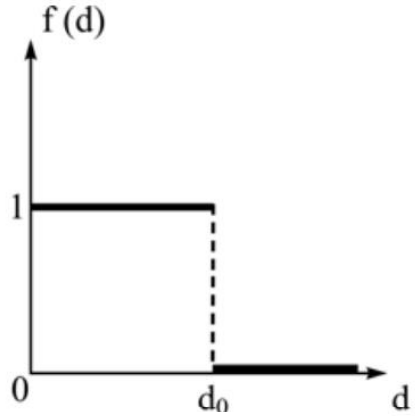


Distance Decay Parameter

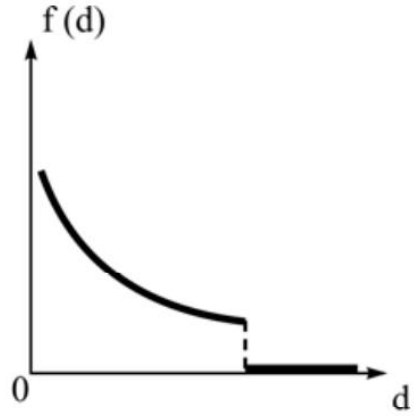
Generalized 2SFCA Toolkit: Power, Exponential, and Gaussian



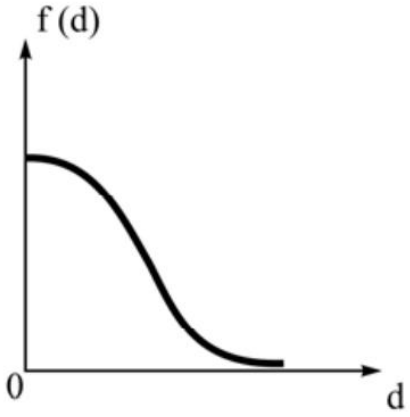
Gravity function



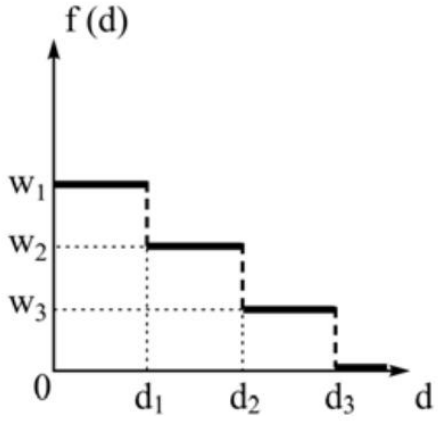
2SFCA



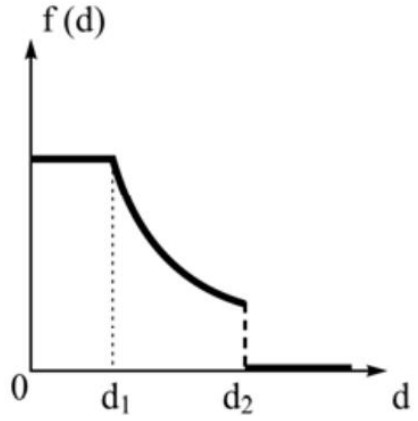
Kernel



Gaussian function



E2SFCA



Three-zone hybrid approach

02

Case Study for G2SFCA and GI2SFCA

Case Study

Title Measuring spatial accessibility to primary care physicians in Chicago region

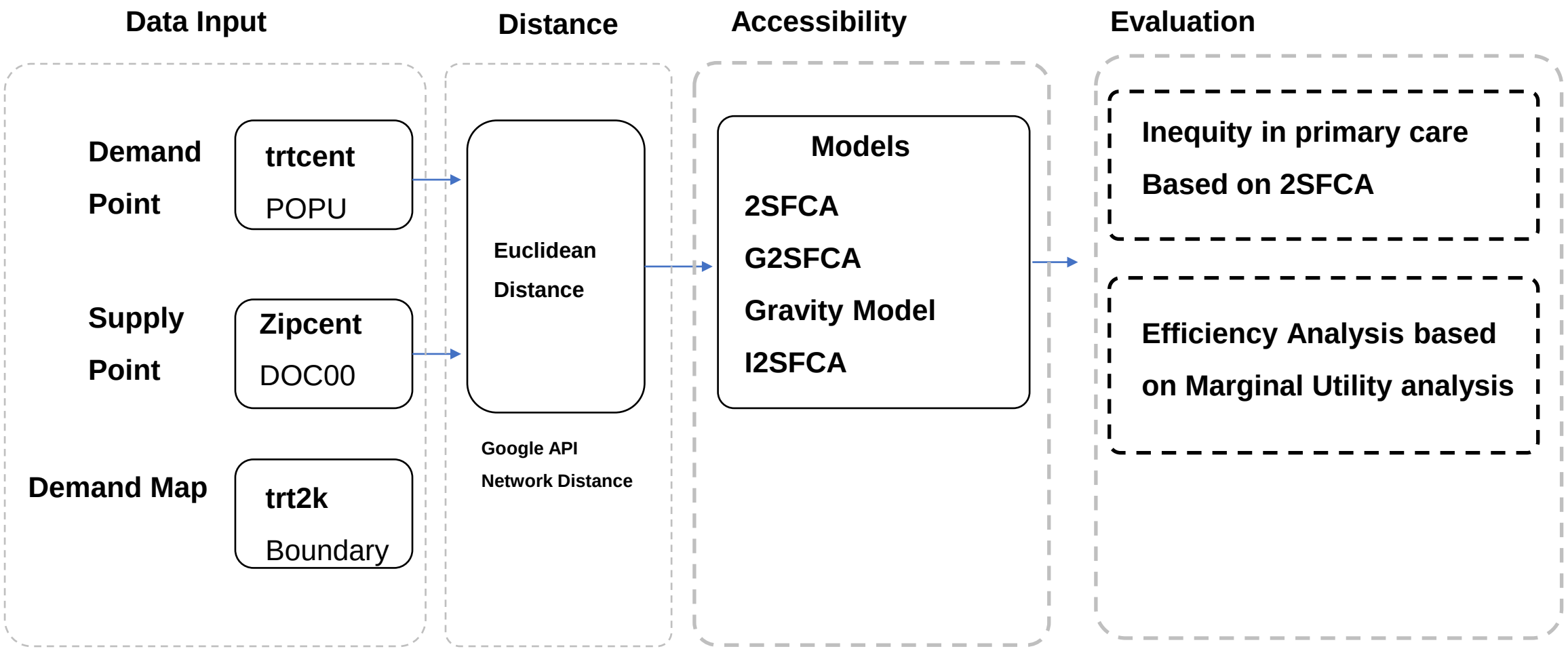
Objectives Spatial inequality in Healthcare

Methodology 2SFCA & Gravity-Based Accessibility Model

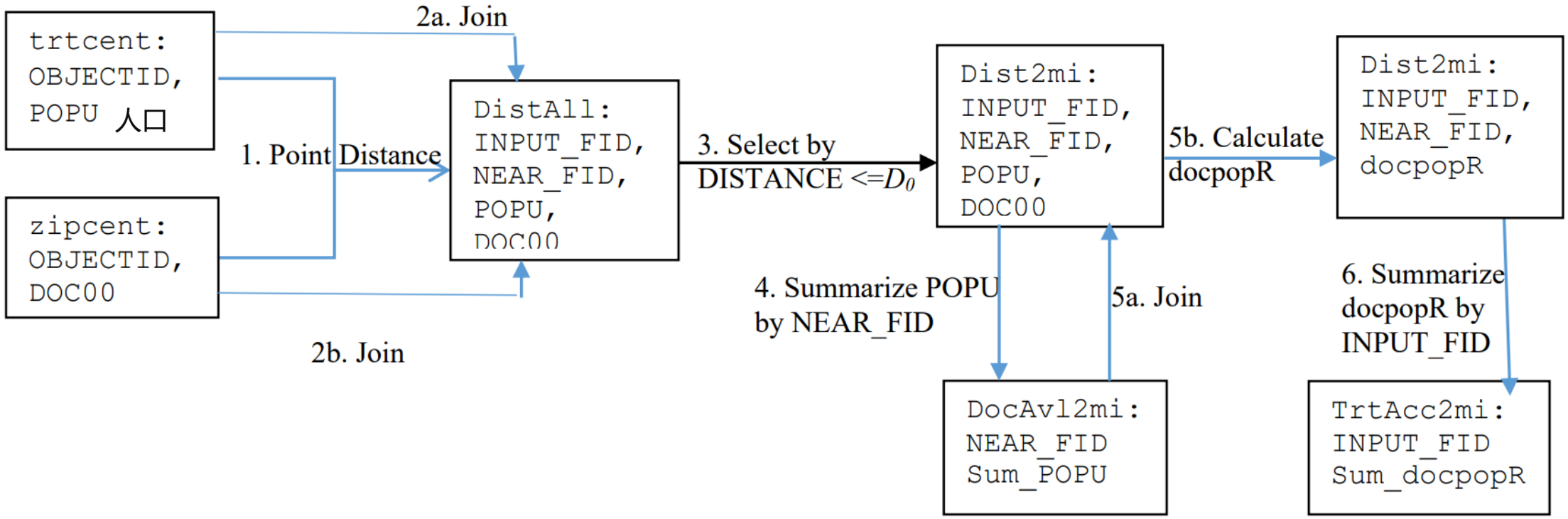
Data

Shapefile	Type	File Detail	Key Fields	Key Variable	Data Source
trtcent	Point	census tract centroids	**POPU**	Population in each census tract	2000 US census
Zipcent	Point	zip code area centroids	**DOC00**	number of primary care physicians in each zip code area	2000 Physician Master File of the American Medical Association (AMA)
trt2k	Polygon	Base map for plotting			Tiger line shapefile in US census data 2000

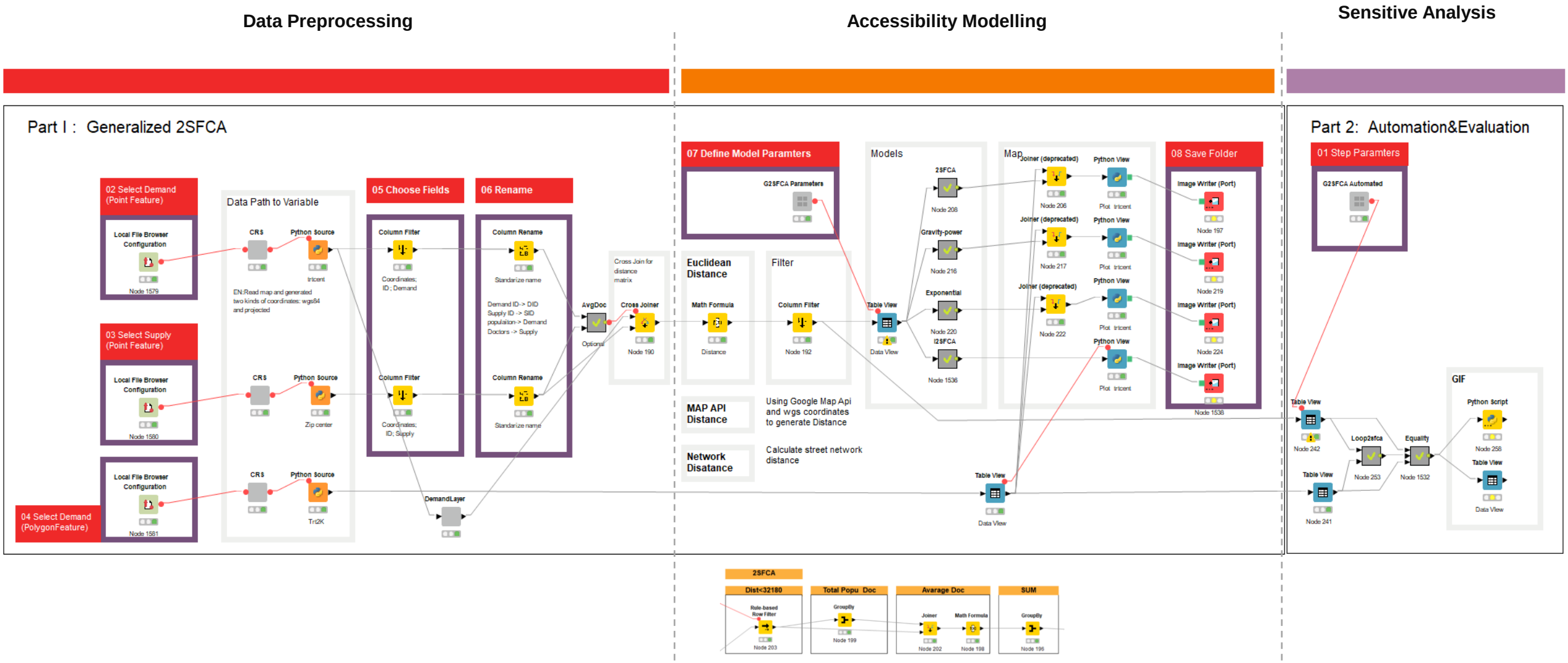
Flowchart for Case Study



Flowchart for 2SFCA

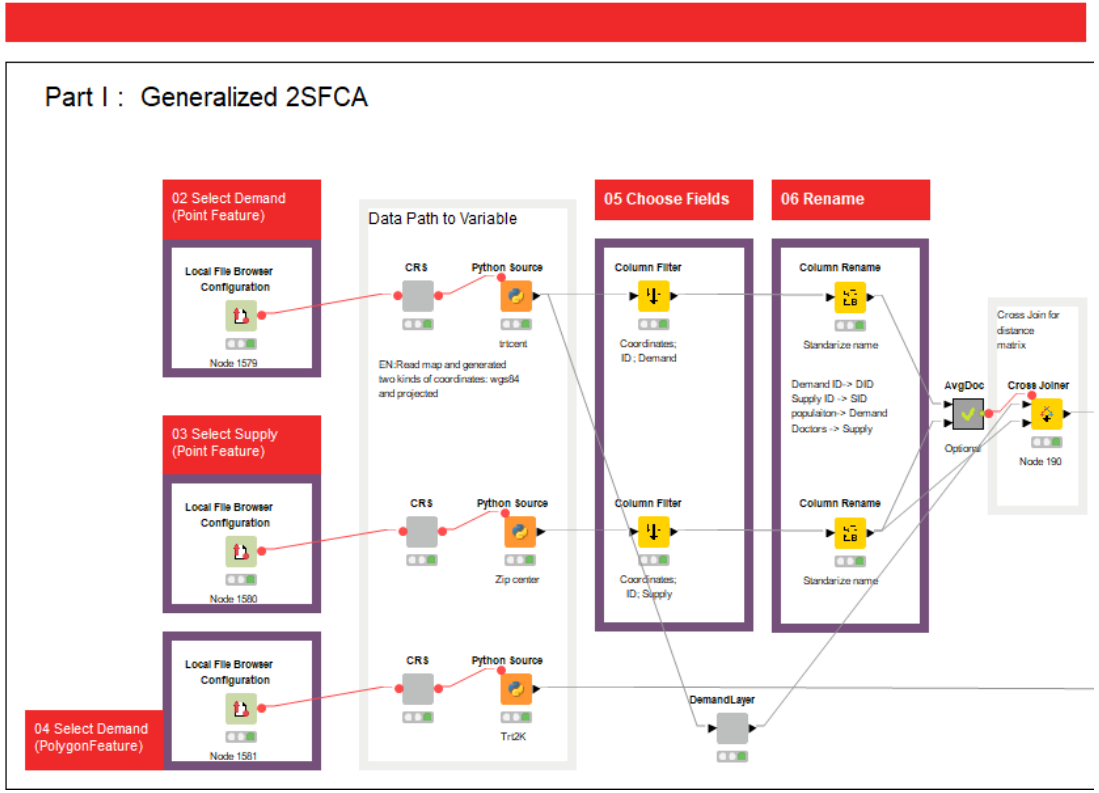


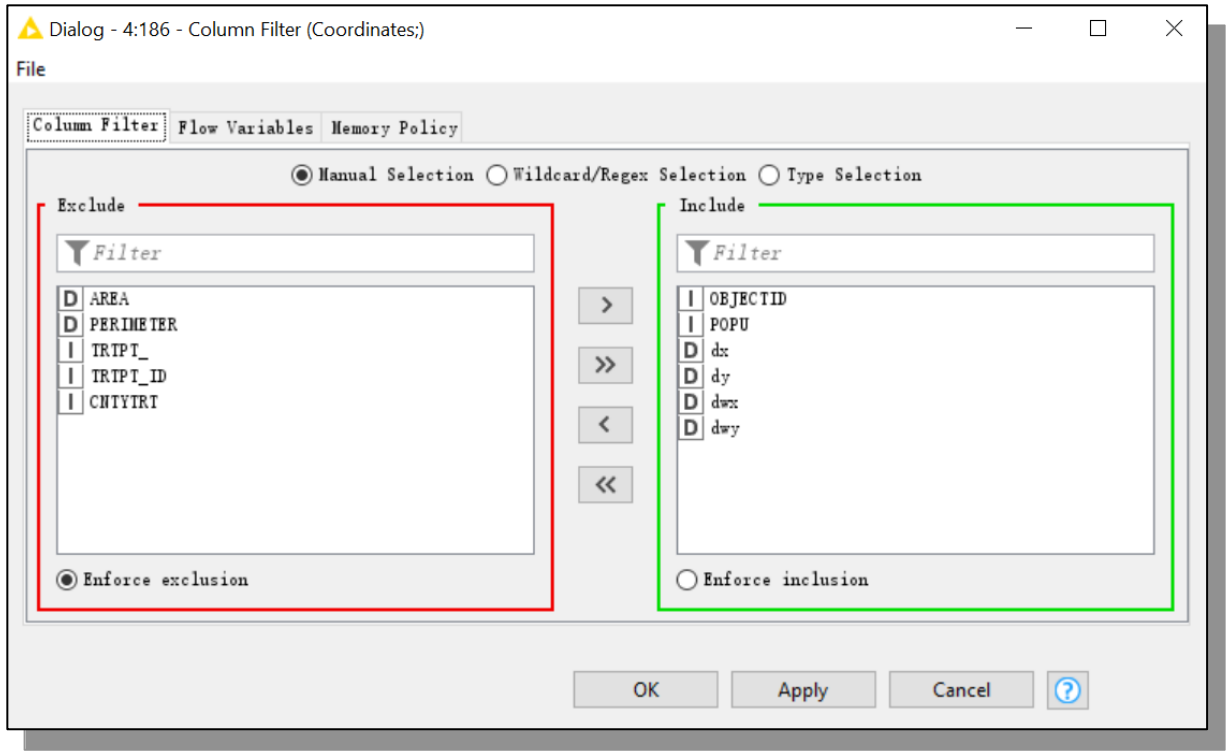
The Workflow Implementation



Step by Step Workflow Execution I

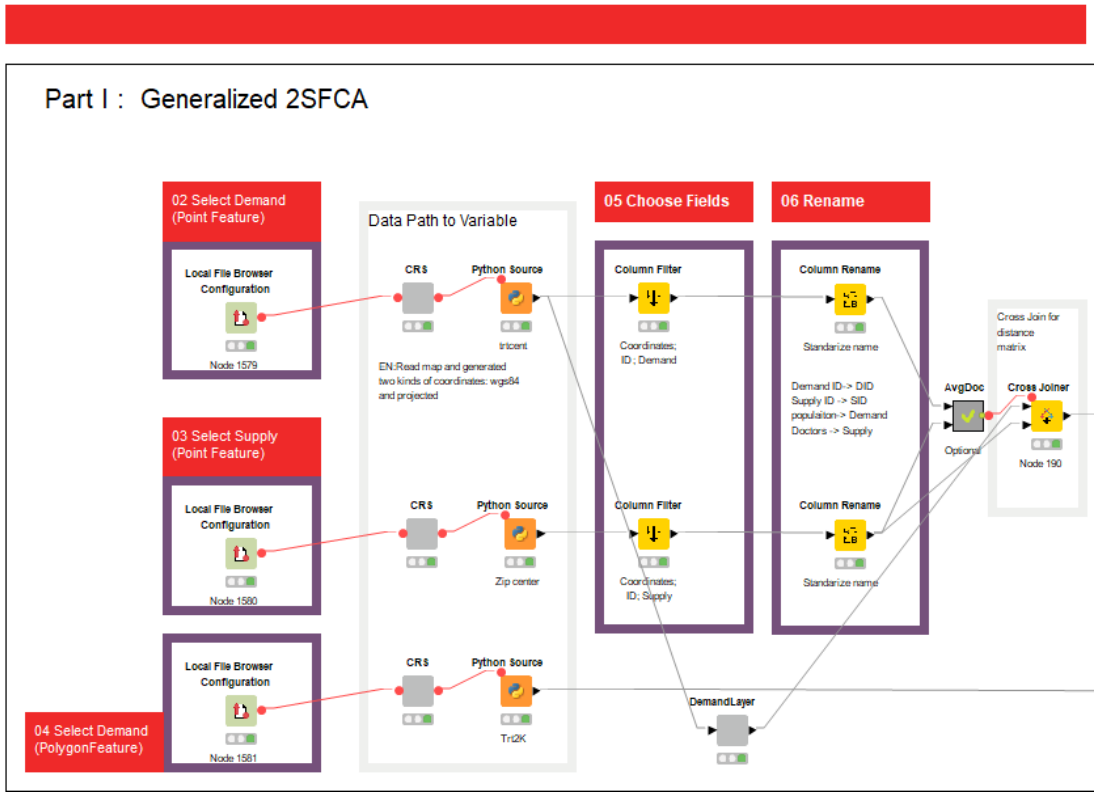
Data Preprocessing |

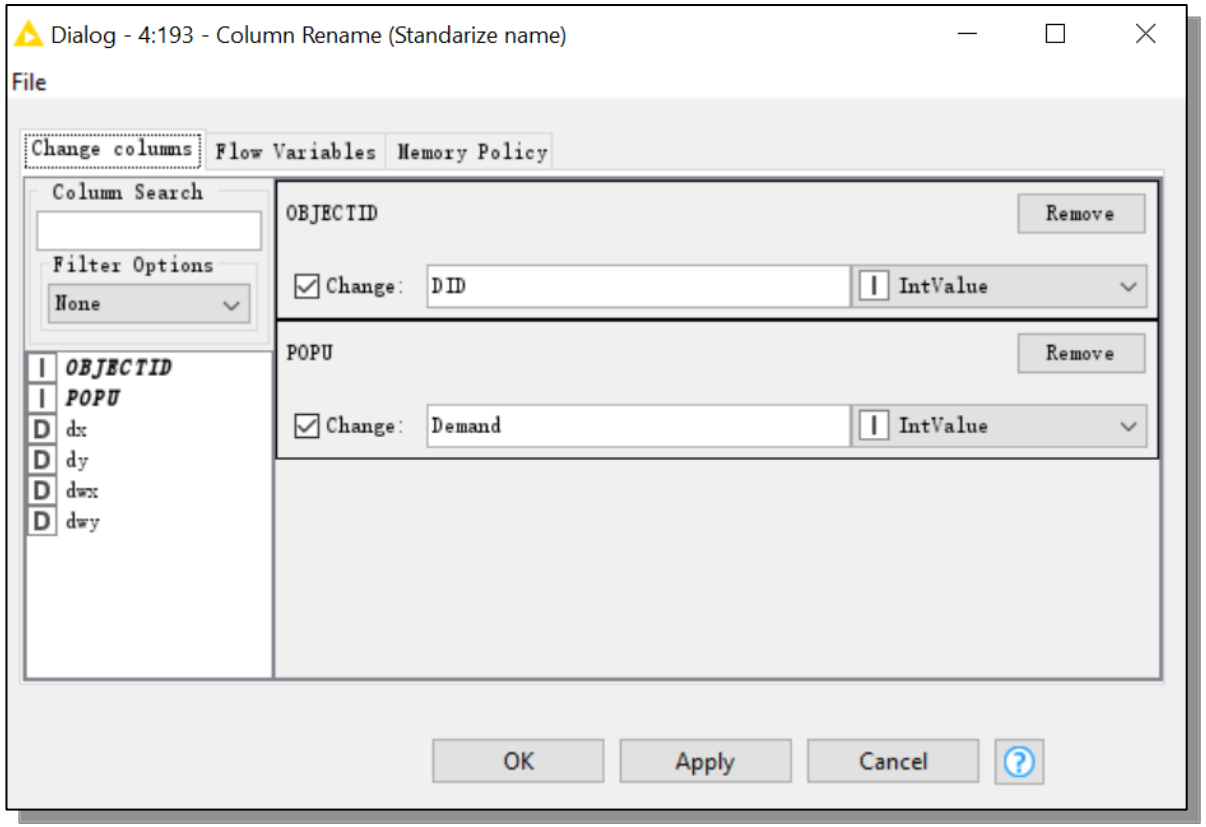




Step by Step Workflow Execution I

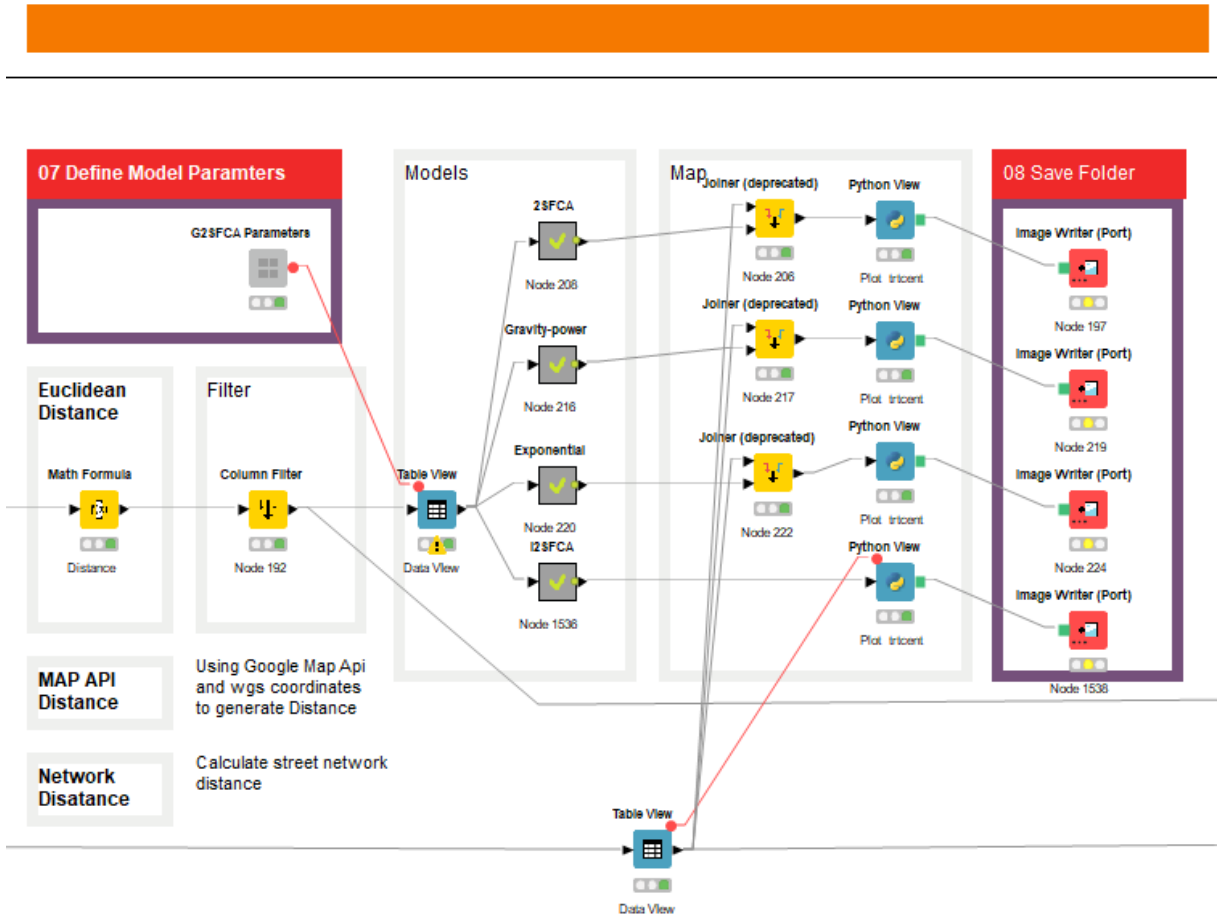
Data Preprocessing |

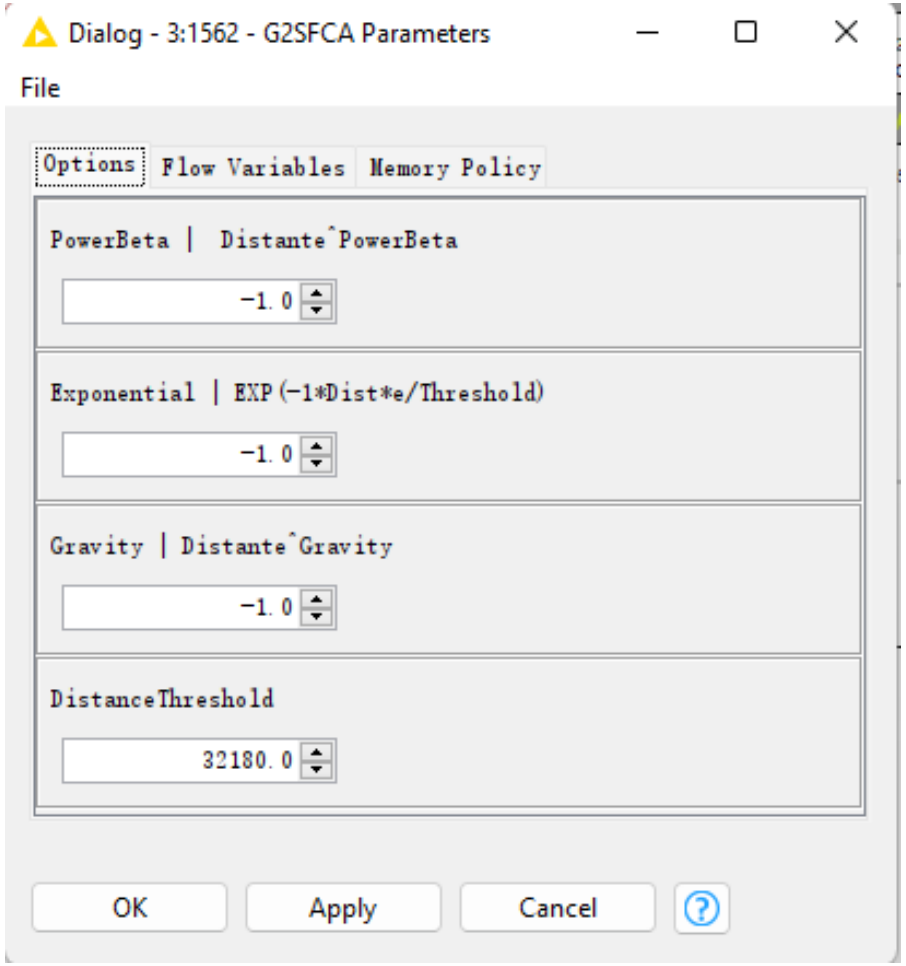




Step by Step Workflow Execution II

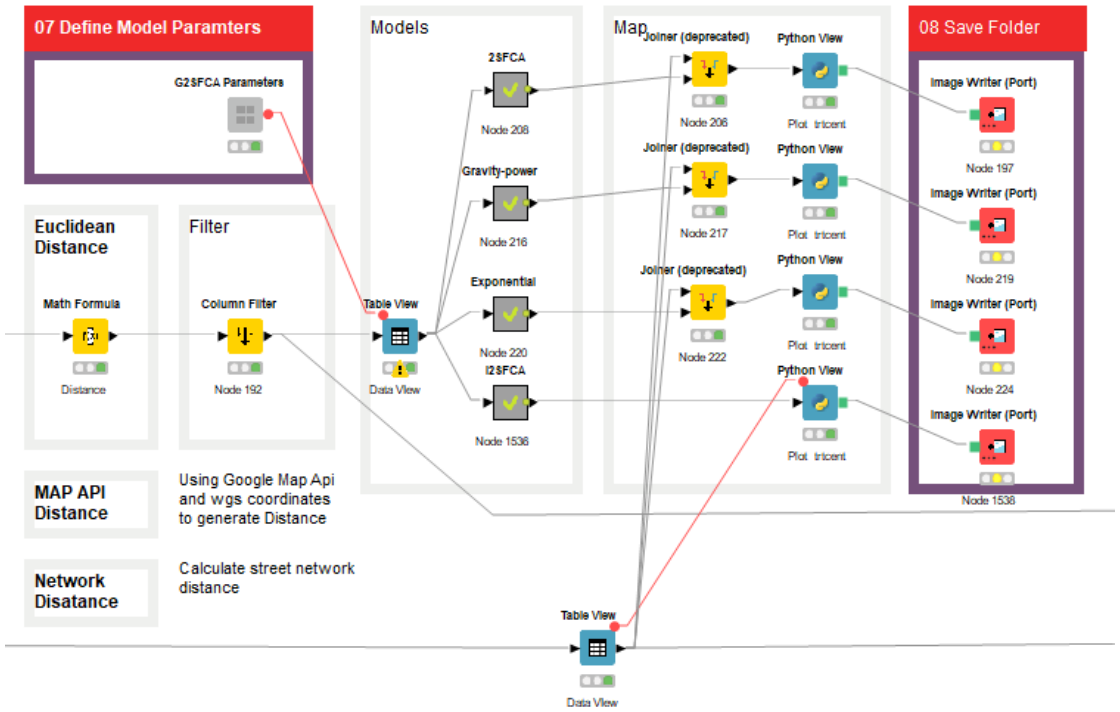
Accessibility Modelling

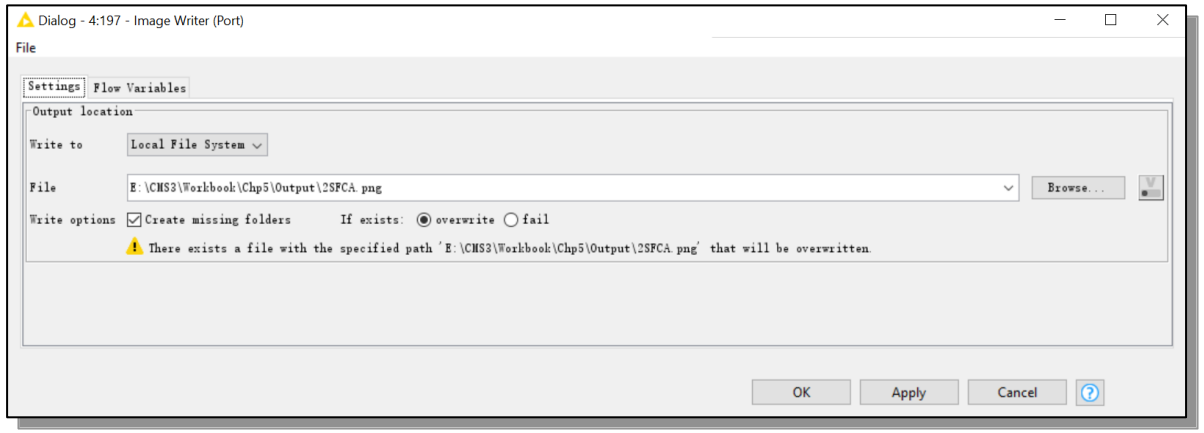




Step by Step Workflow Execution II

Accessibility Modelling

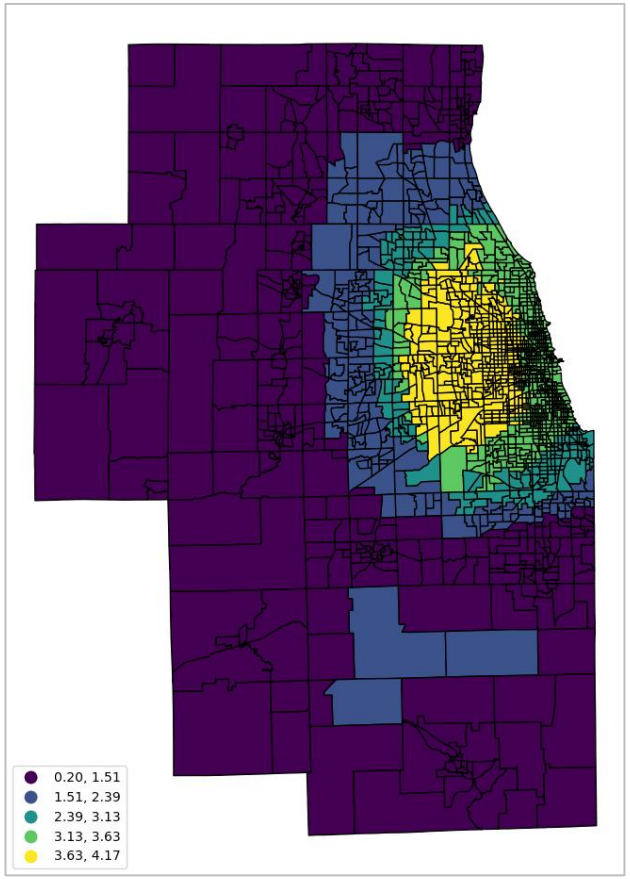




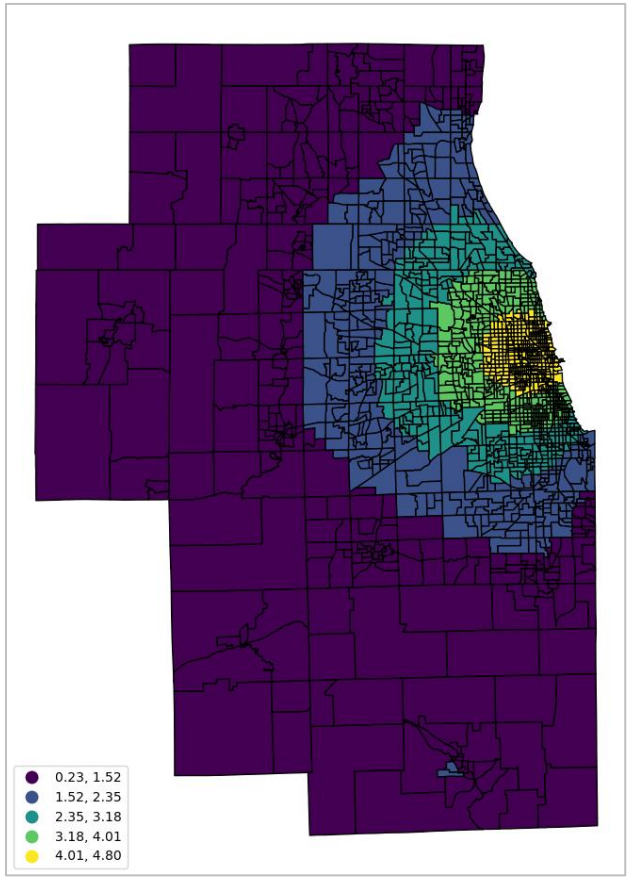
Step by Step Workflow Execution II

Accessibility Modelling

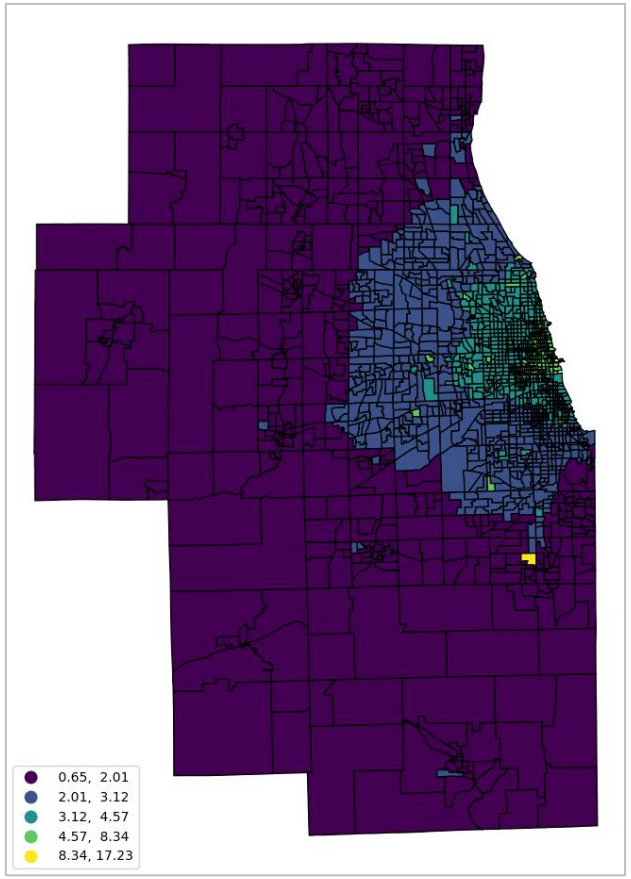
2SFCA



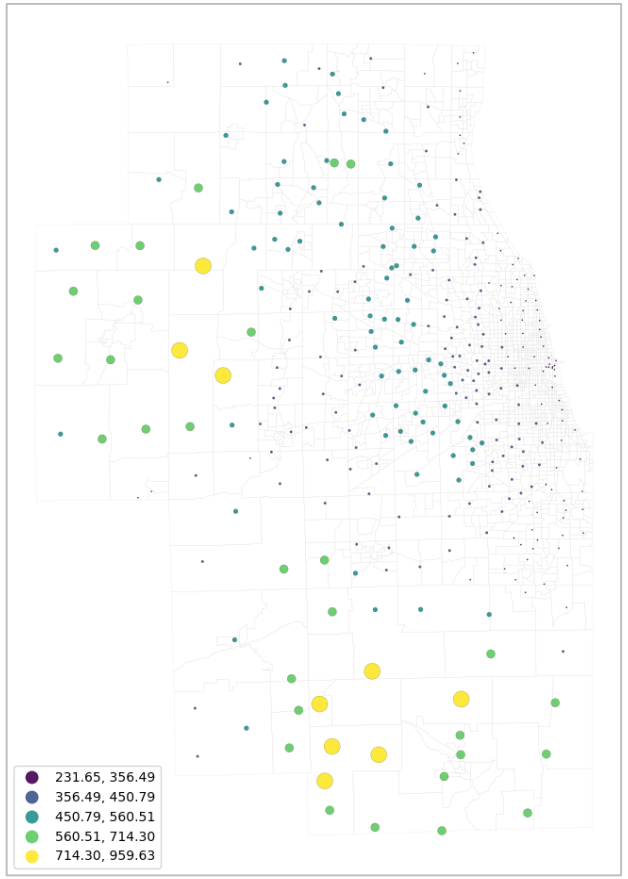
Exponential



Gravity—Power

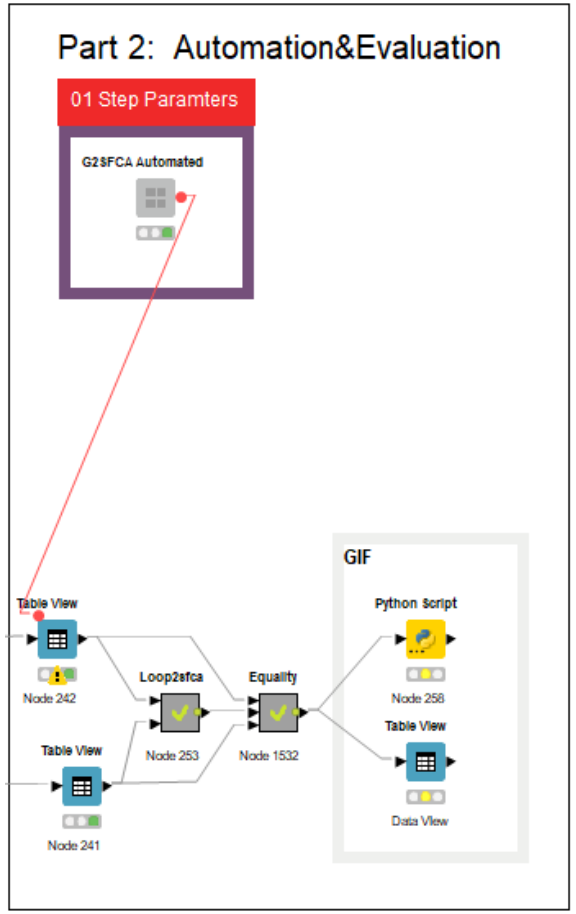


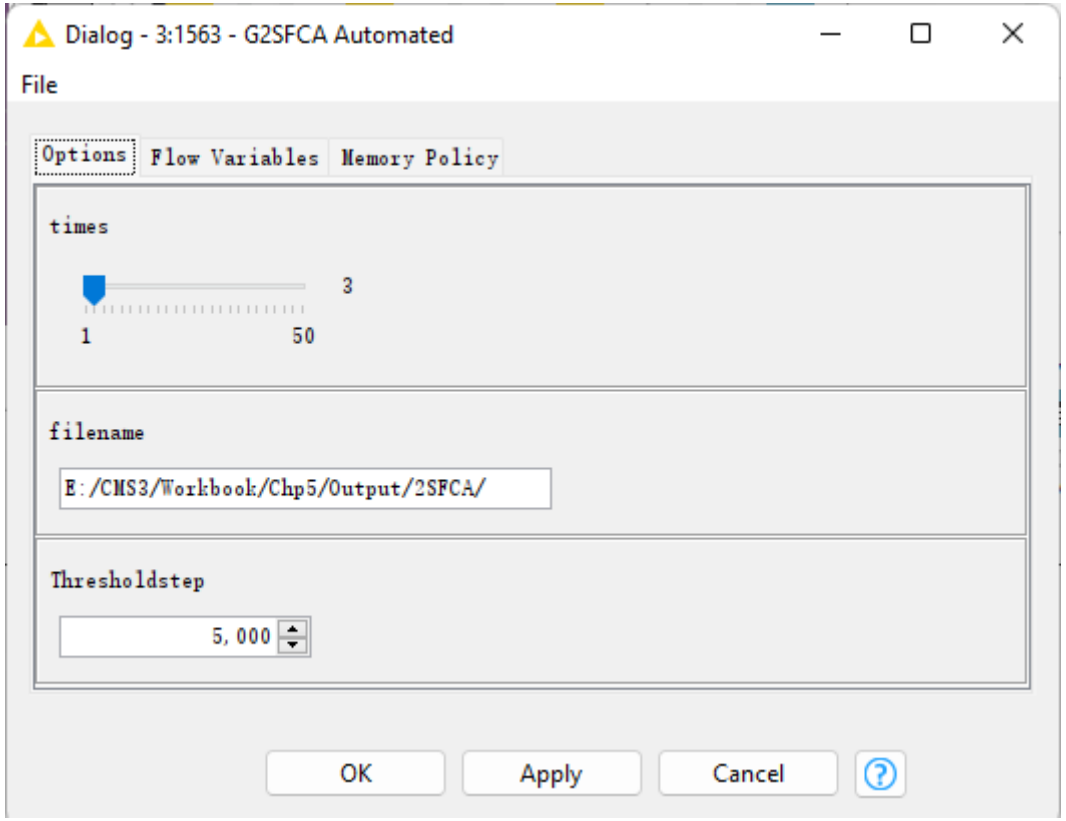
I2SFCA



Step by Step Workflow Execution III

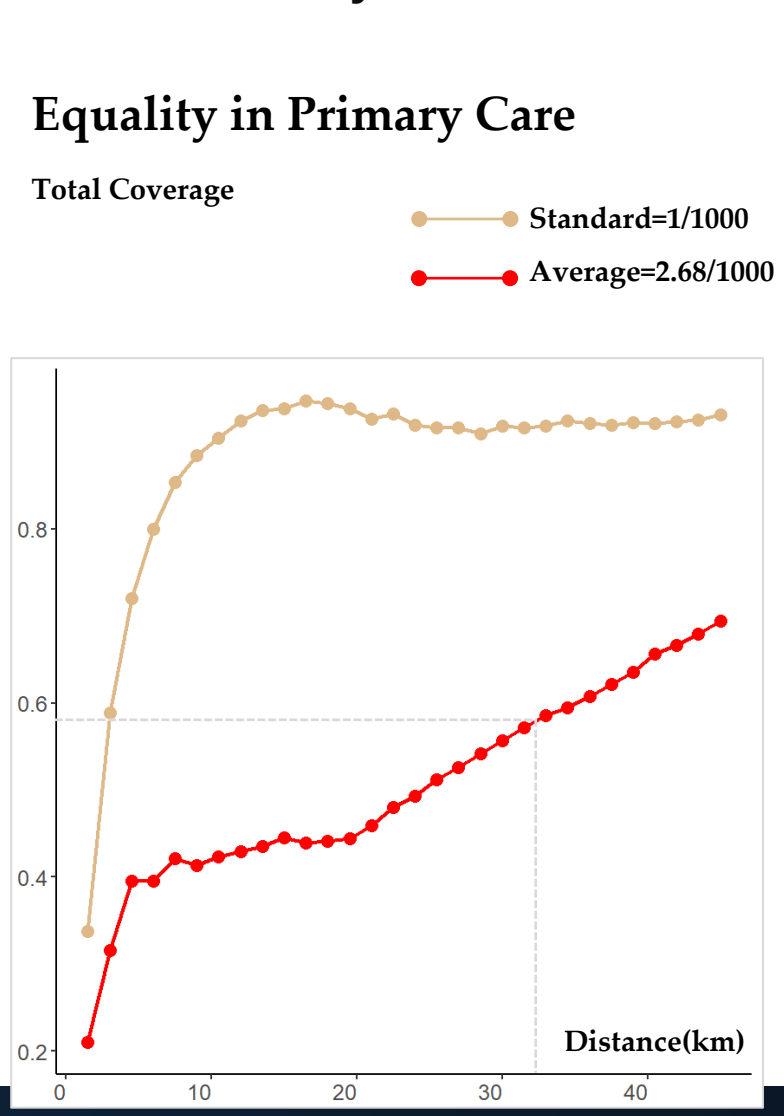
Evaluation

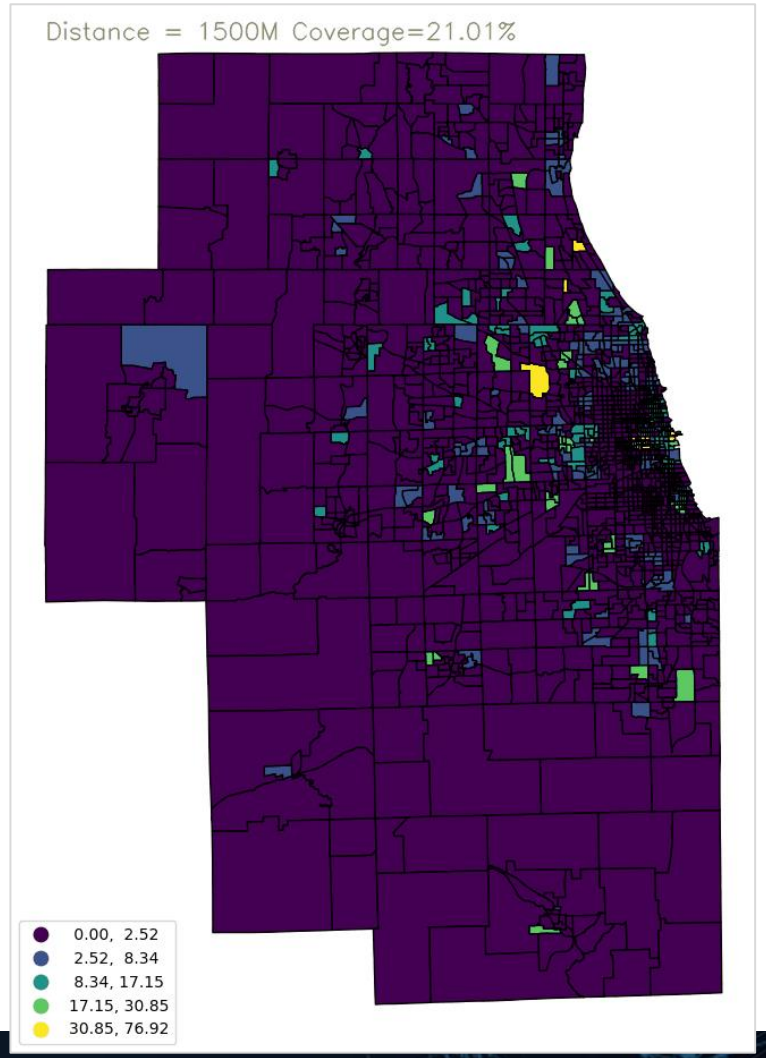




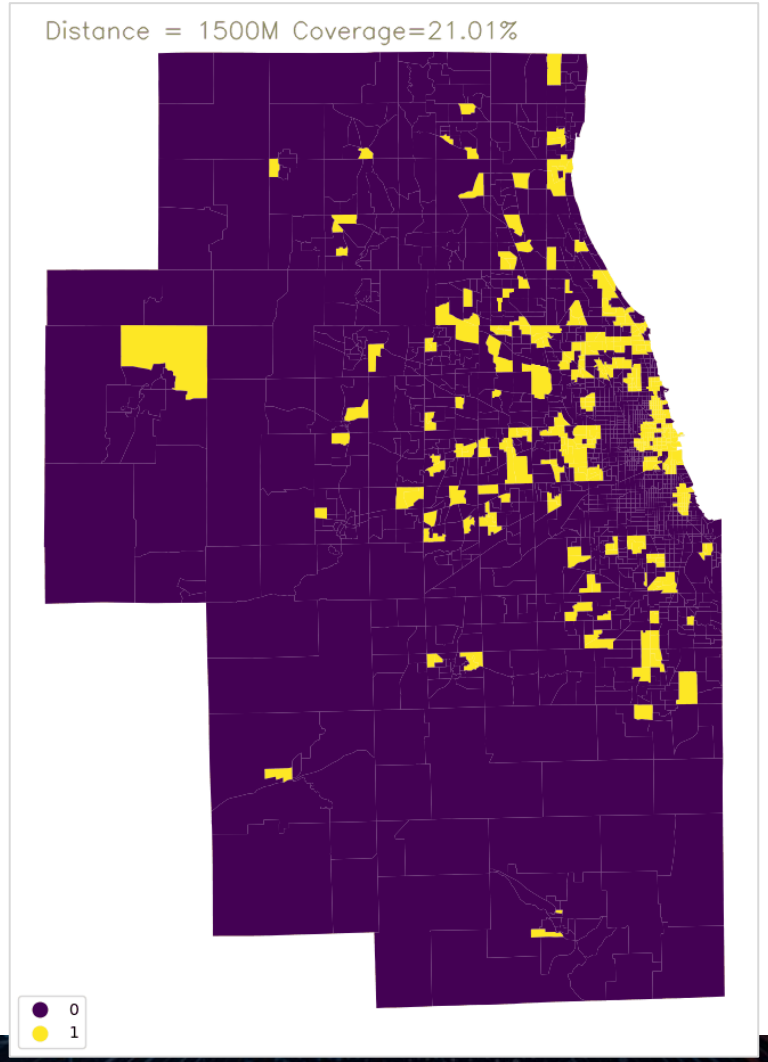
Step by Step Workflow Execution III

Sensitive Analysis





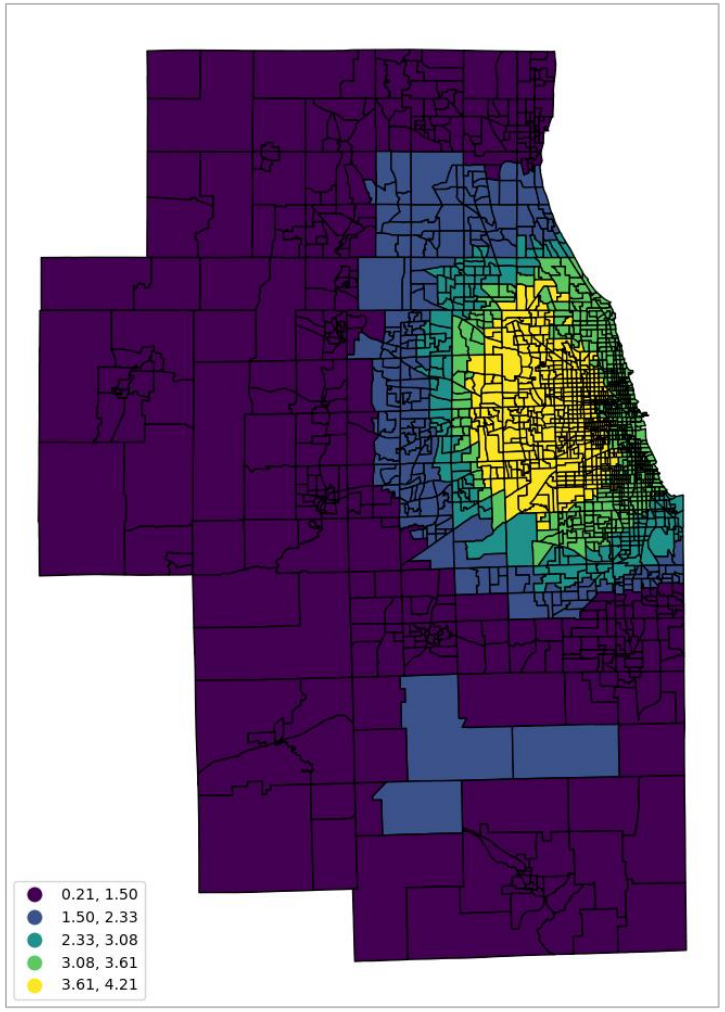
Average=2.68/1000



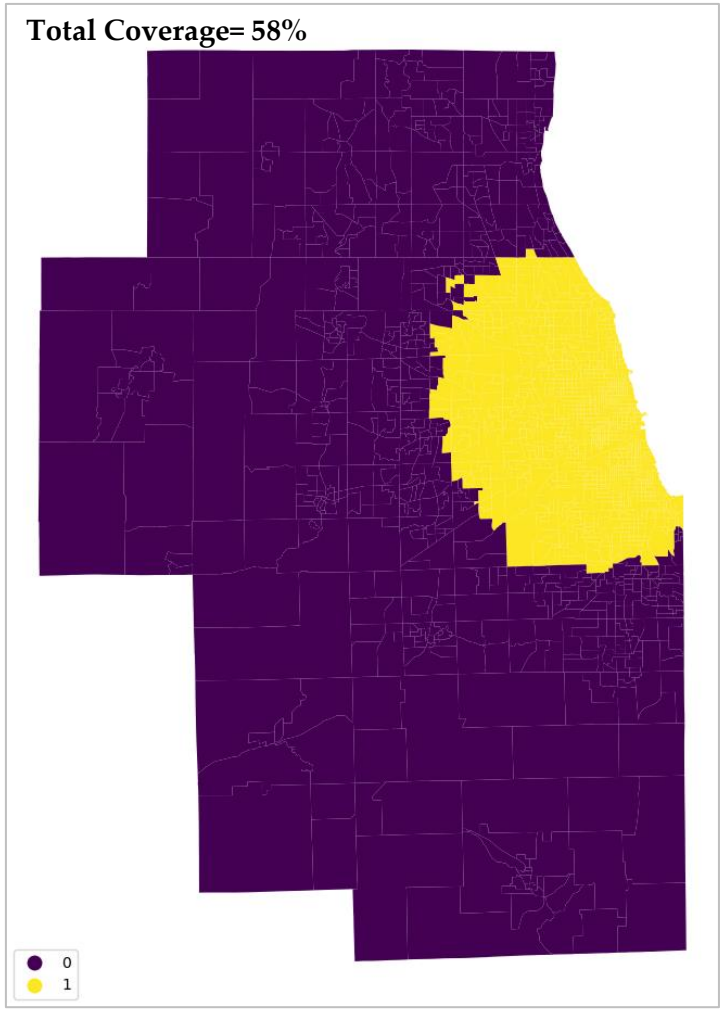
Step by Step Workflow Execution III

Evaluation

Distance=20Mile



Total Coverage= 58%



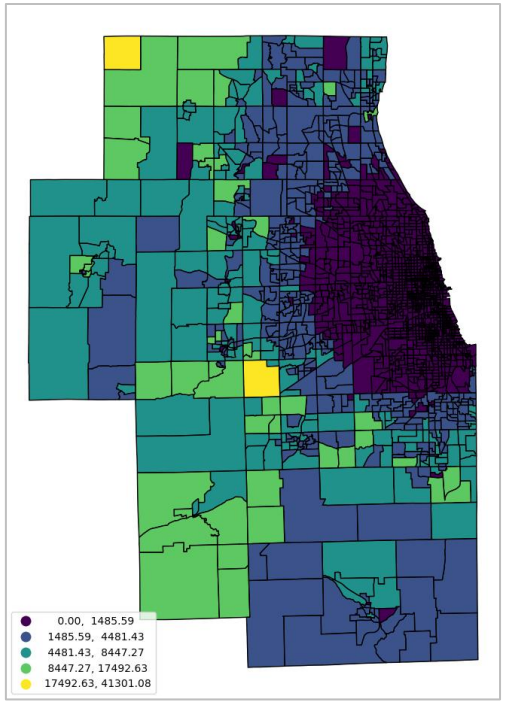
Step by Step Workflow Execution III

Evaluation

Weighted Marginal Utility（WMU）

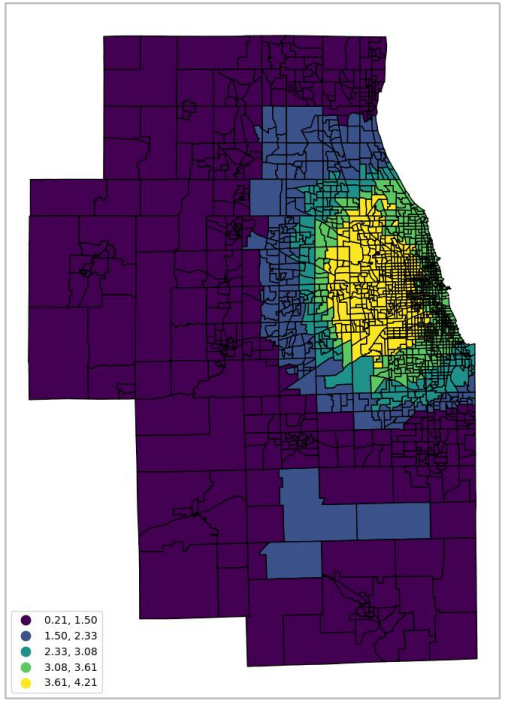
2.68 Physicians per 1000 person

WMU



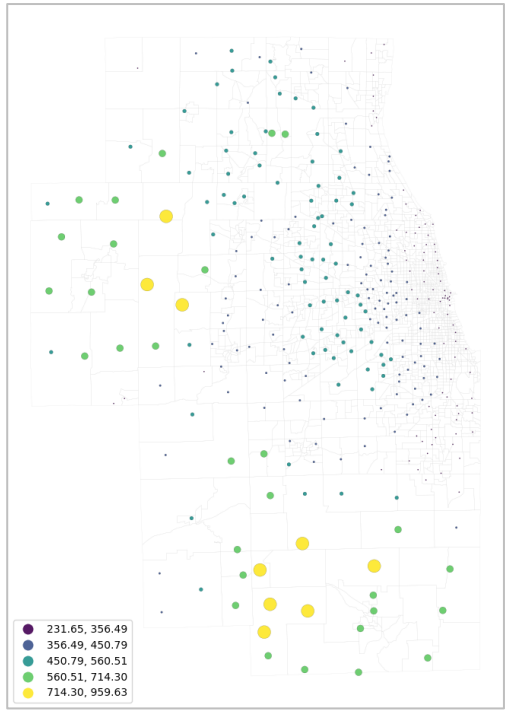
2SFCA Distance =31500

2SFCA

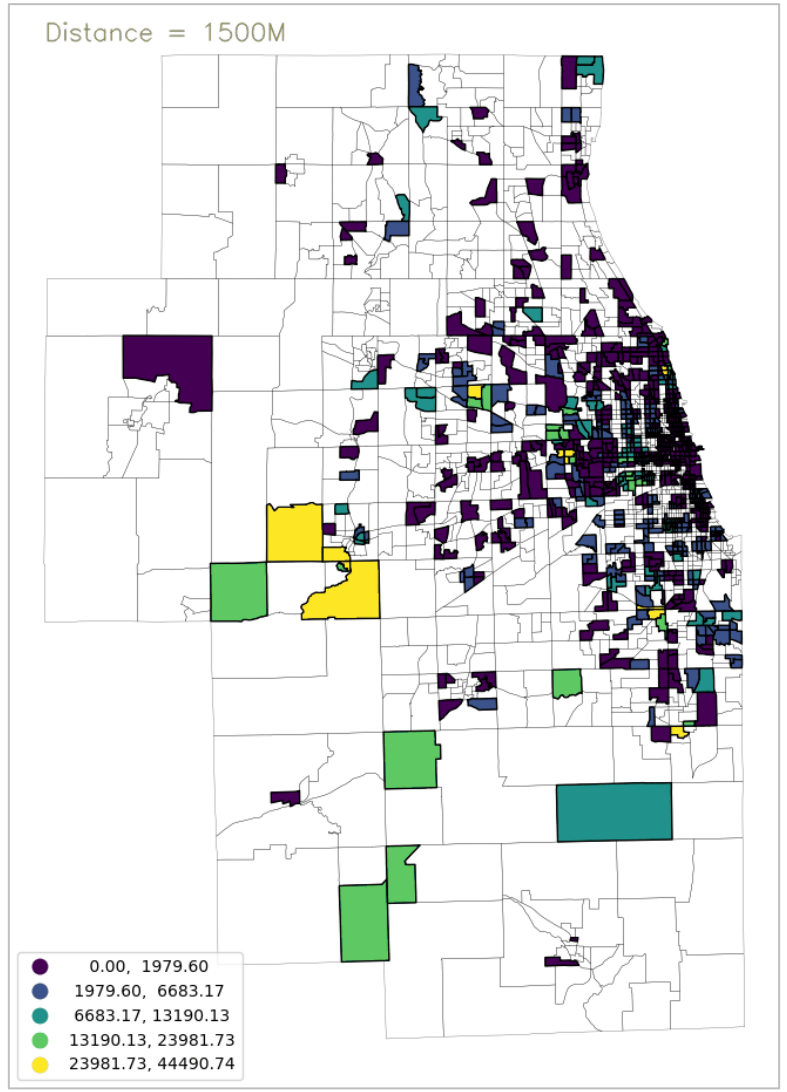


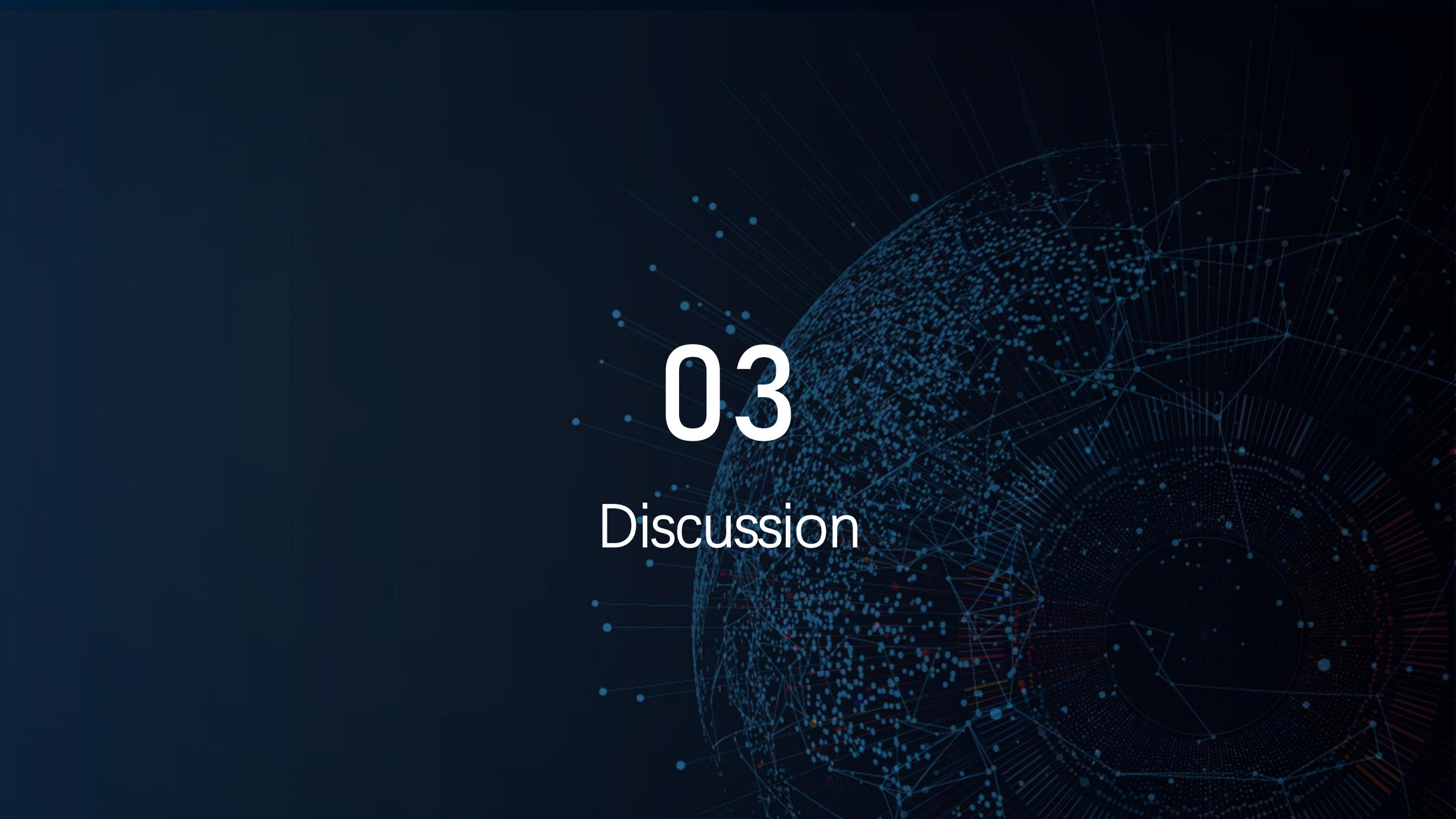
Distance =31500

I2SFCA



Distance =31500





03

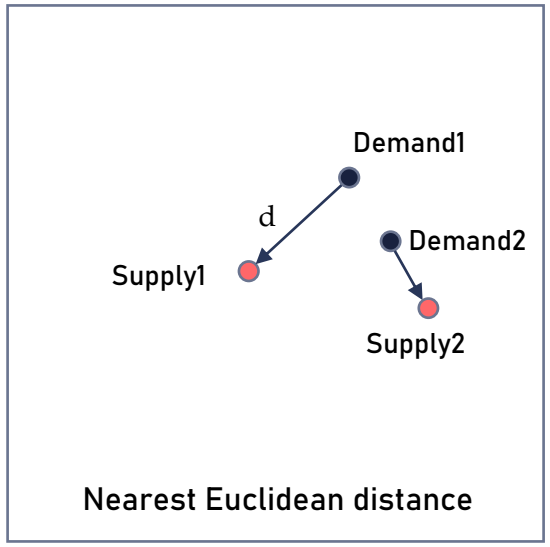
Discussion

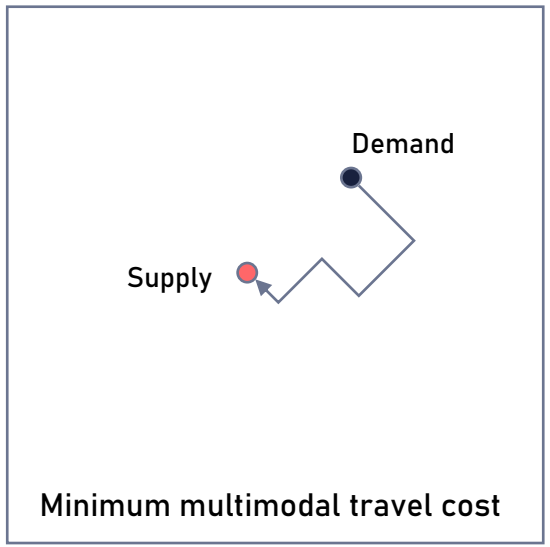
Accessibility Models

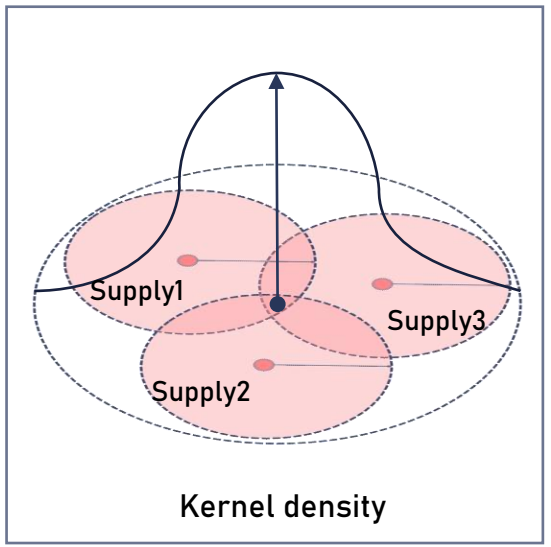
Model

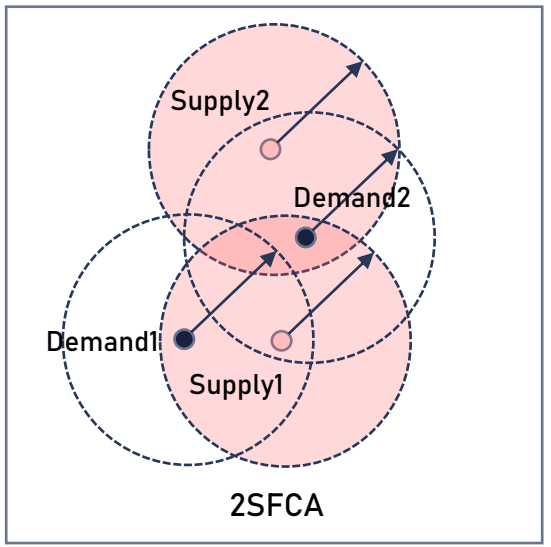
Different model

Different spatial cost – street network





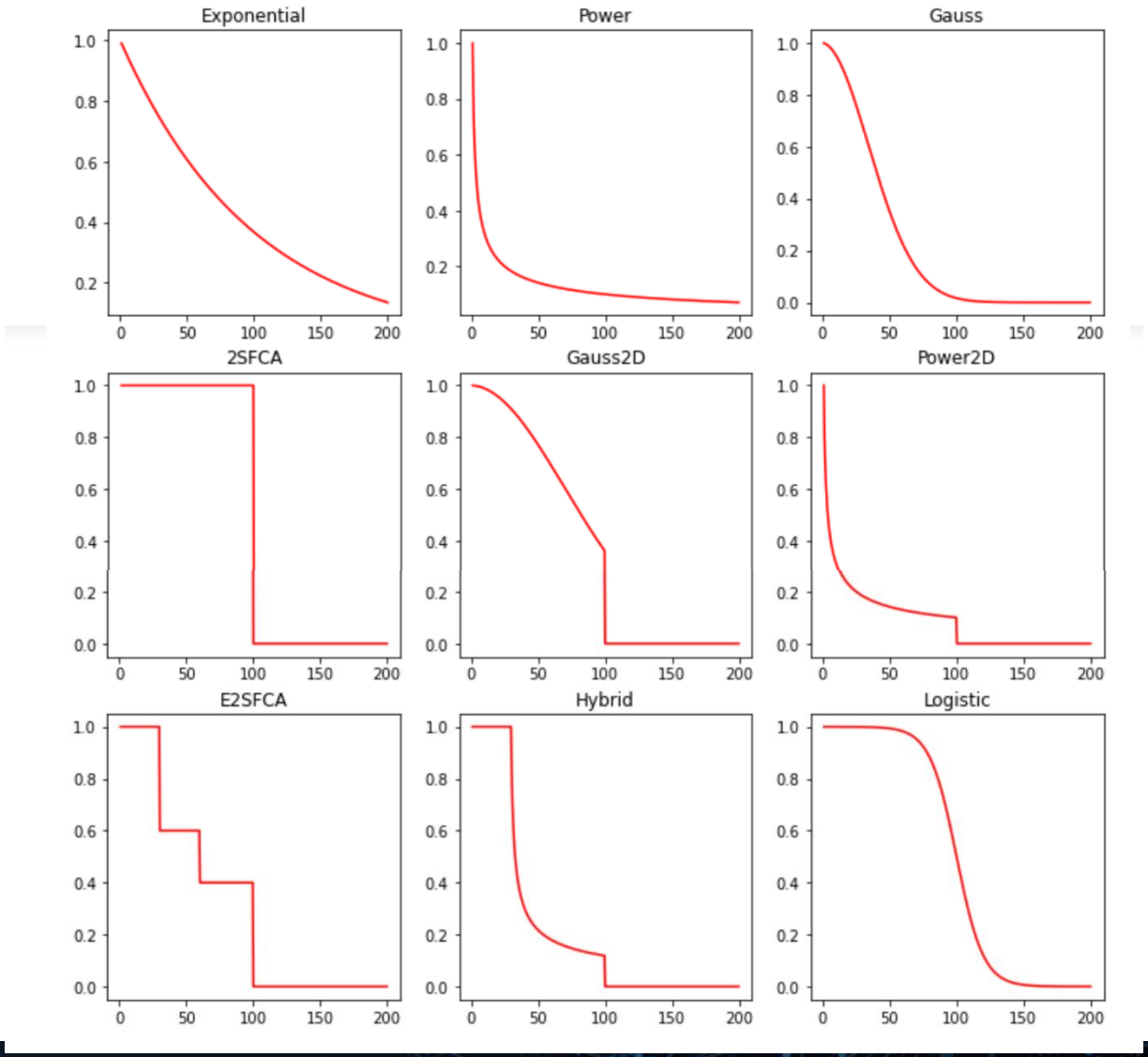




Distance Decay Models

Model

Distance Decay Parameters



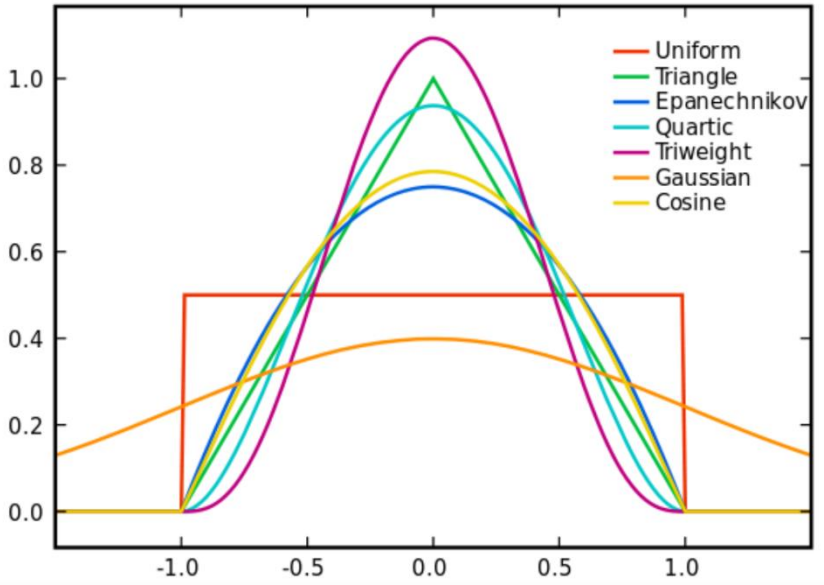
Parameters

Model

Kernel Parameters

Kernels	Function
Laplacian	$K(x,y) = \exp\left(-\frac{\|x-y\|}{\sigma}\right)$
Rational Quadratic	$K(x,y) = 1 - \frac{\|x-y\|^2}{\|x-y\|^2 + c}$
Multiquadratic	$k(x,y) = \sqrt{\|x-y\|^2 + c}$
Wave	$K(x,y_j) = \frac{\theta}{\|x-y\|}\sin\frac{\|x-y\|}{\theta}$
Power	$K(x,y) = -\|x-y\|^d$
Log	$K(x,y) = -\log\|x-y\|^d + 1)$
Bessel	$K(x,y) = \frac{J_{v+1}(\sigma\|x-y\|)}{\|x-y\|^{-n(v+1)}}$
Cauchy	$K(x,y) = \frac{1}{1+\frac{\|x-y\|^d}{d}}$
Wavelet	$K(x,y) = \prod_{m=1}^{N} h\left(\frac{x_i-c}{a}\right)h\left(\frac{y_i-c}{a}\right)$

- Examples of popular kernel functions:
  - Gaussian kernel: $K(x_i,x_j) = e^{-\frac{\|\mathbf{x}_i-\mathbf{x}_j\|^2}{2\sigma^2}}$
  - Laplacian kernel: $K(x_i,x_j) = \frac{\theta}{\|\mathbf{x}_i-\mathbf{x}_j\|}\sin\frac{\|\mathbf{x}_i-\mathbf{x}_j\|}{\theta}$
  - Polynomial kernel: $K(x_i,x_j) = \left(ax_i^T x_j + b\right)^d$

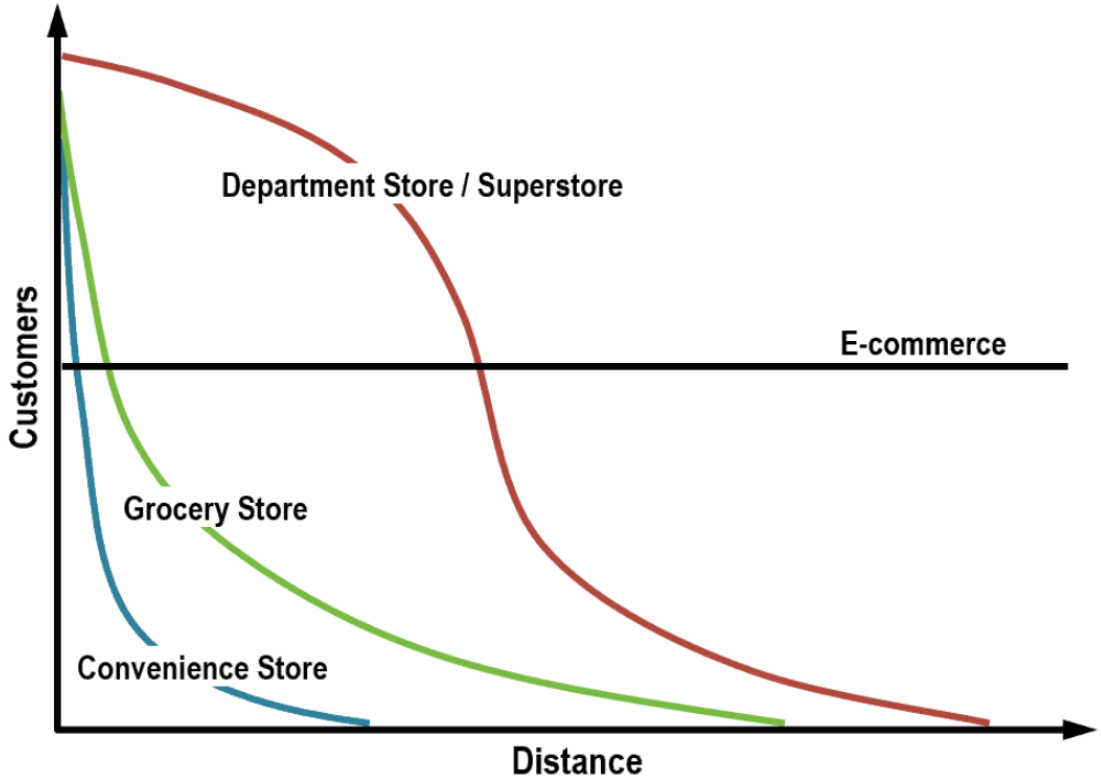


Exploration and Validation

Model

Public Facilities

Conventional Distance Decay Curves for Retail Activities



https://transportgeography.org/contents/methods/market-area-analysis/retail-distance-decay-curve-conventional/

SDL202210

Spatiotemporal Innovation Workshop

NSF Spatiotemporal Innovation Center

Center for Geographic Analysis Harvard University

Future Data Lab

Open for Innovation KNIME