

# A Review of Spatial Networks Insights and Methods in the Context of Planning: Applications, Challenges, and Opportunities

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# Outline

## **Why should planning cares about spatial networks?**

### **Four Areas of Applications**

- Revealing Spatial Structure
- Optimization of Urban Infrastructure
- Indicators of Economic Wealth, Social Capital, and Residential Mobility
- Public Health Control

### **Four Areas of Challenges and Opportunities**

- Data Openness and Privacy
- Direct Policy Implications
- Civic and Participatory Engagement
- Interface with GIS

## **A Vision of Spatial Networks in Collaborative Planning**

# Why should planning cares about spatial networks?

## **A vision of city based on “networks and flows”**

“Collaborative planning theorists treat networks as the mechanism to empower the stakeholders to build consensus (Innes and Booher 1999), while rationalists (Batty 2013) see networks as the mechanism to model and explain urban growth and morphology.”

## **A planning process that respects organic organizations and emergence from interconnected individuals and infrastructure**

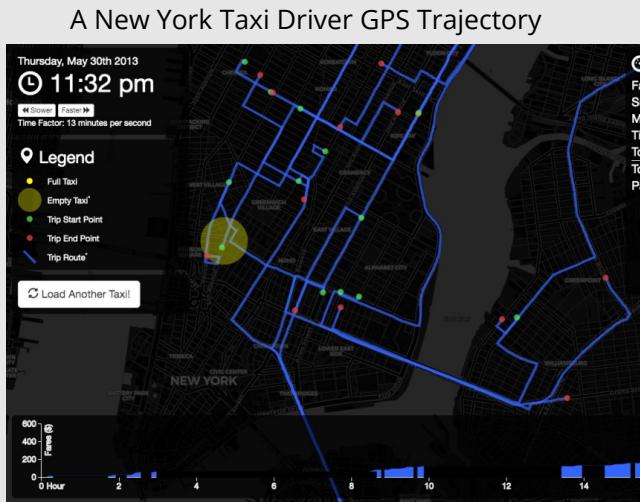
“Tools that support this vision of cities come from a wide range of disciplines (e.g., agent-based models, social network analysis), most of which rely on individuals to interact and effect changes on collective phenomenon.”

# What is a spatial network?

**“We define a spatial network as a graph structure in which nodes can be geolocated”**

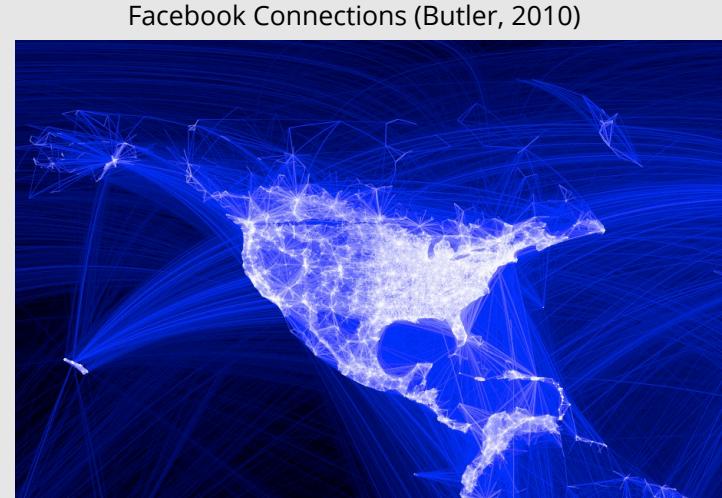
## Planar Networks:

Edges are Spatially-embedded  
(Roads, Trajectories, etc.)



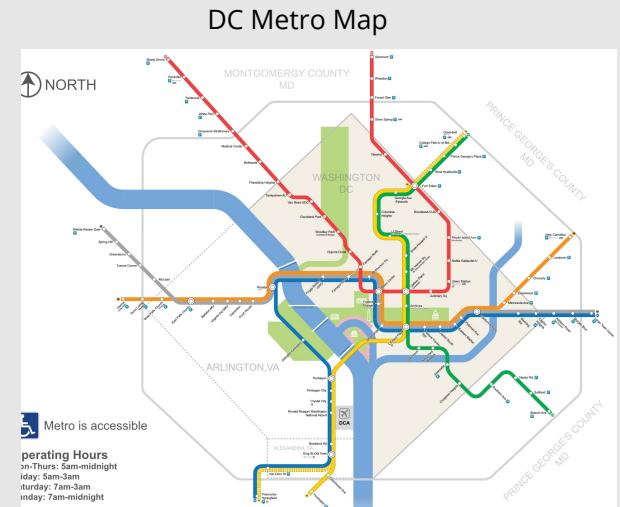
## Non-Planar Networks:

# Edges are NOT Spatially-embedded



## Mixed:

Not exactly embedded but follow geographic constraints



# Applications *Revealing Spatial Structure*

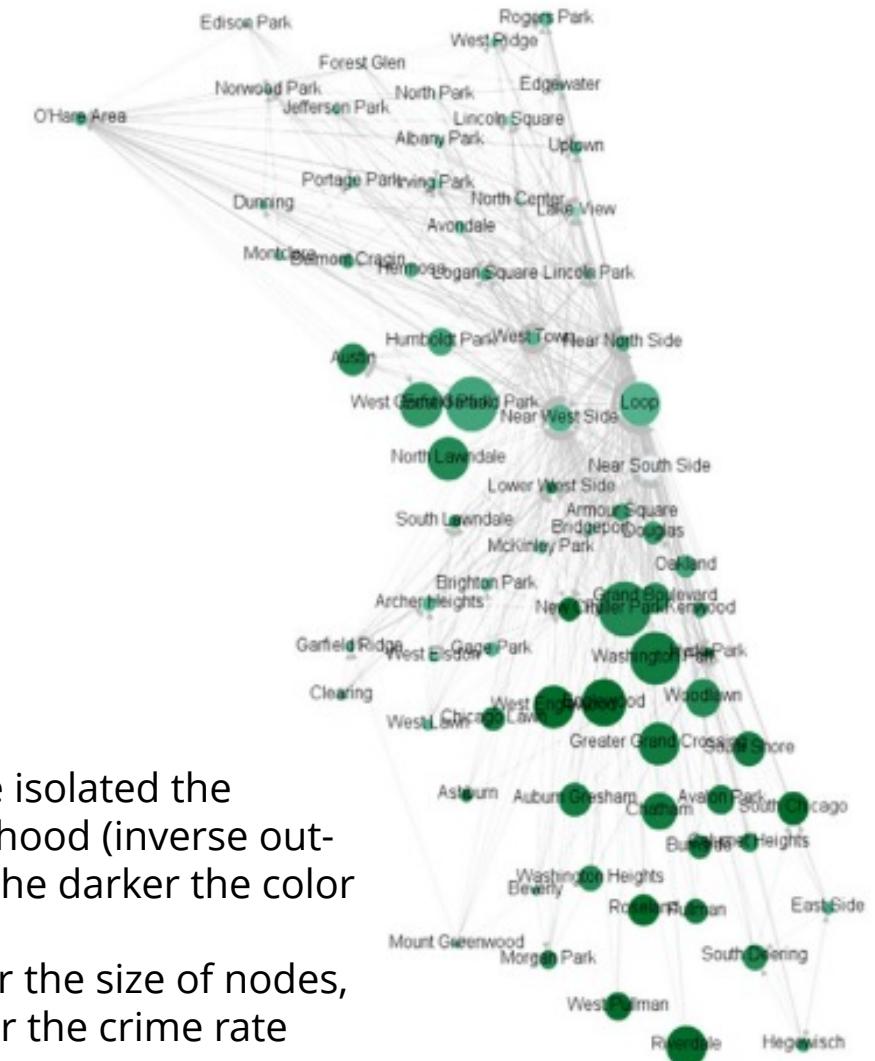
## Research Questions:

How social and economic relationships intersect with space

## Research Methods:

Apply GIS and network visualization to contrast spatial and social patterns or construct statistical indices to measure the effect of interests.

**High crime rate is associated with neighborhood isolation**



The more isolated the neighborhood (inverse out-degree), the darker the color

The larger the size of nodes, the higher the crime rate

Graif C, Lungeanu A, Yetter AM (2017) Neighborhood isolation in Chicago: violent crime effects on structural isolation and homophily in inter-neighborhood commuting networks. Soc Netw 51:40-59

# Applications

## *Revealing Spatial Structure*

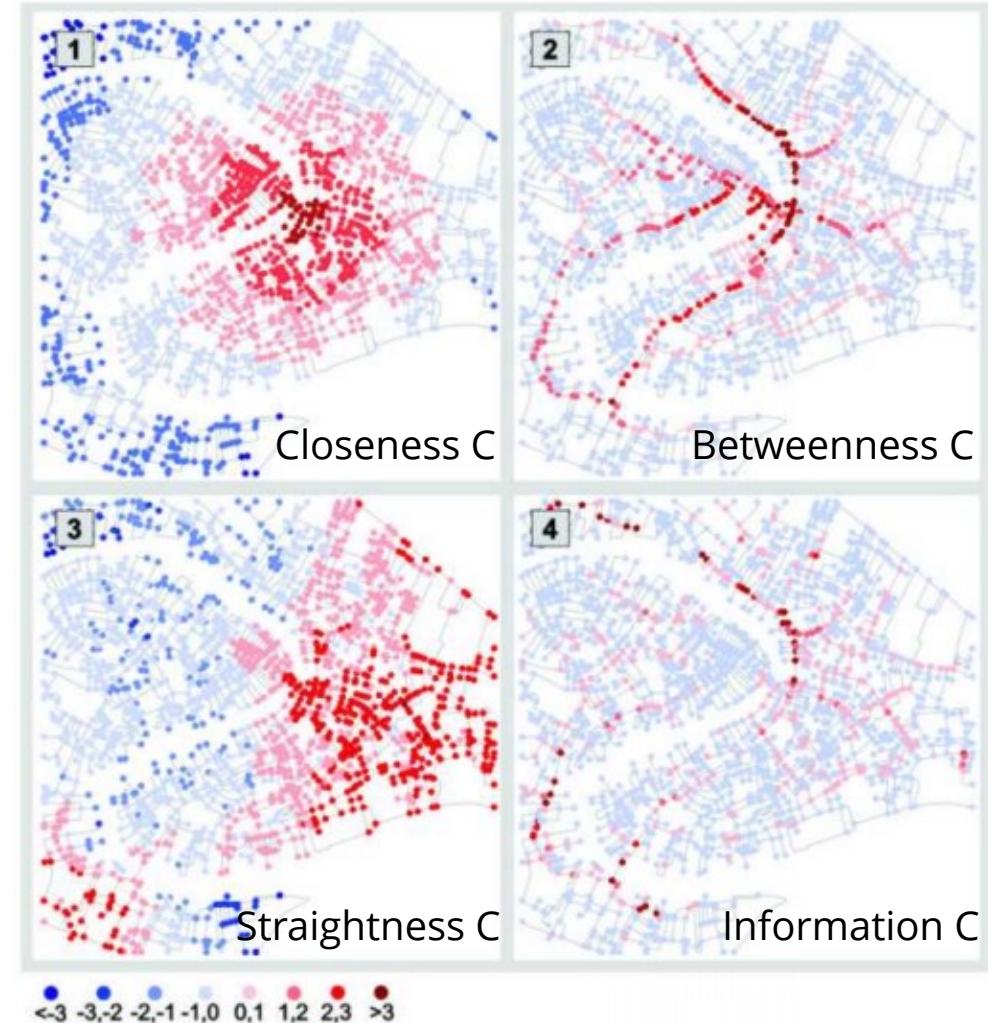
### Research Questions:

What is the hierarchy in the network?  
Which node is more influential?

### Research Methods:

Network metrics (e.g., centrality);  
High degree centrality: influence and vibrancy  
High closeness centrality: accessibility  
High betweenness centrality: low resilience  
Hubs and spokes;  
Single-linkage analysis;  
Rich-hub coefficients

Color-coded maps representing the spatial distributions of node centrality in Venice Roads



Crucitti P, Latora V, Porta S (2006) Centrality measures in spatial networks of urban streets. Phys Rev E 73(3):36125

# MILWAUKEE: SEGREGATED ISOLATION

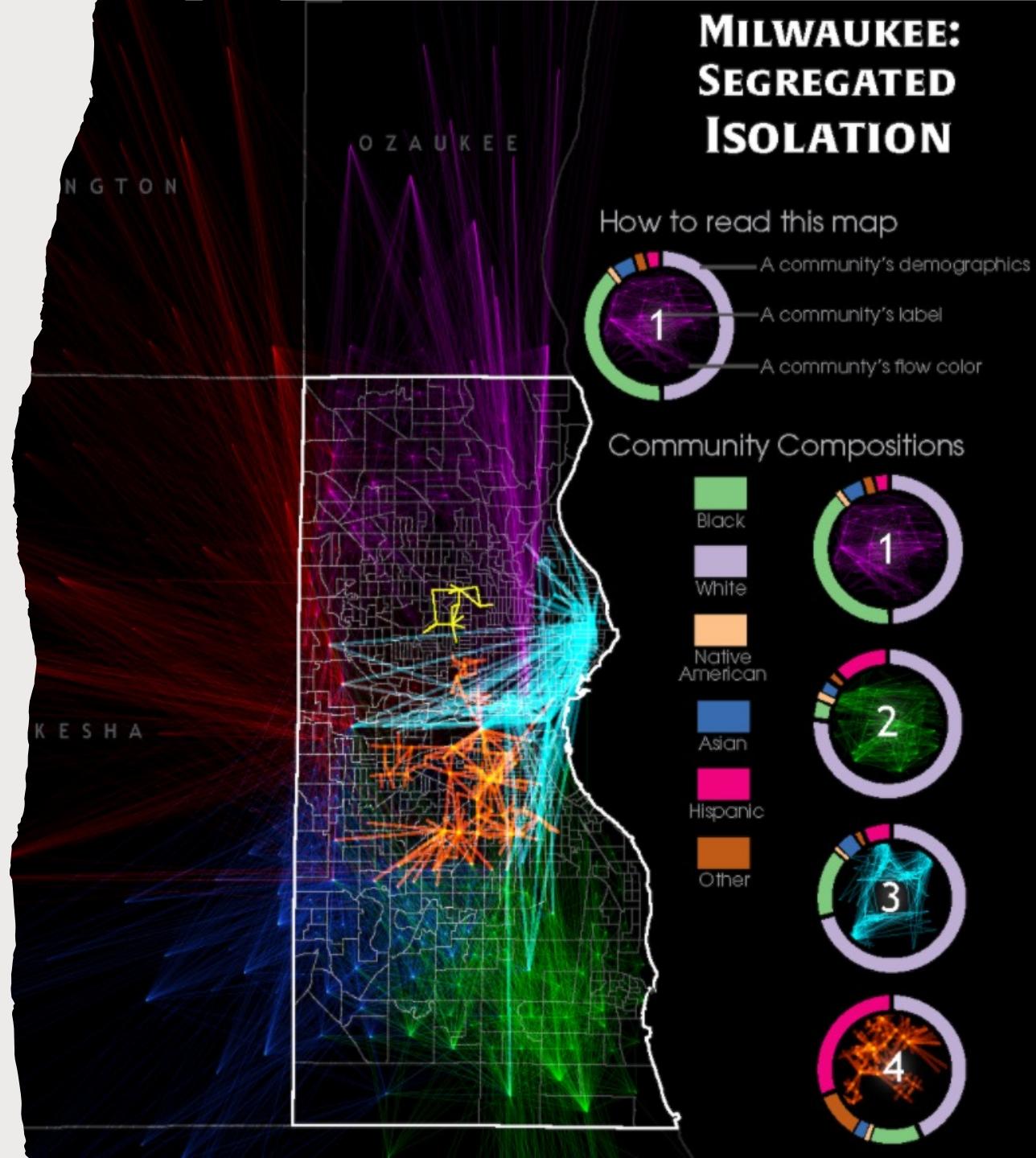
# Applications *Revealing Spatial Structure*

## Research Questions:

Where do spatial networks naturally cluster? What are the types of social/commuting/physical connectivity patterns?

## Research Methods:

Graph Partitioning Algorithm  
Hierarchical Clustering Algorithm  
Modularity Optimization Algorithm



# Applications Optimization of Urban Infrastructure

## Research Questions:

What is the most efficient network path to cover the problem area?

How to improve traffic and human flows with minimum network changes?

## Research Methods:

Travel demand models based on spatial network flows.

Network topology.

This interactive interface shows which road to extend in a slum in Cape Town to optimize accessibility based on a network topology method

### Cape Town Project

#### Cape Town, South Africa

This map shows a block in Khayelitsha, a township in Capetown, South Africa. These parcels were identified from March 2009 aerial photography, in conjunction with a data collection exercise by SDI South African Alliance and the Santa Fe Institute. In this map, black lines show new roads and paths, orange outlines parcels with no direct access to roads or paths. Parcels with street access are outlined in grey.

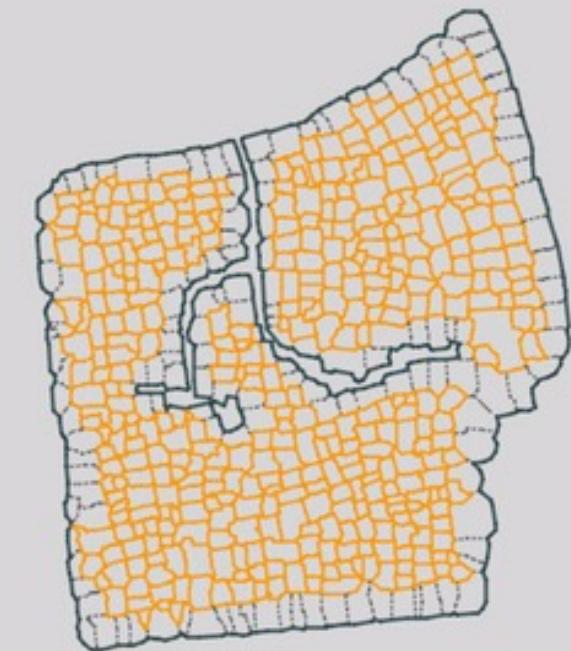
0m of paths

22,513m<sup>2</sup> of parcels

0.00% of area needed for paths

390 isolated parcels

#### Step Selector



Leaflet | Map data © OpenStreetMap contributors, CC-BY-SA, Imagery © Mapbox

# Applications

## *Indicators of Economic Wealth, Social Capital, Residential Mobility*

### **Research Question:**

How are individuals or places' network patterns correlate with their economic wealth, social capital, and ability to relocate?

### **Research Methods:**

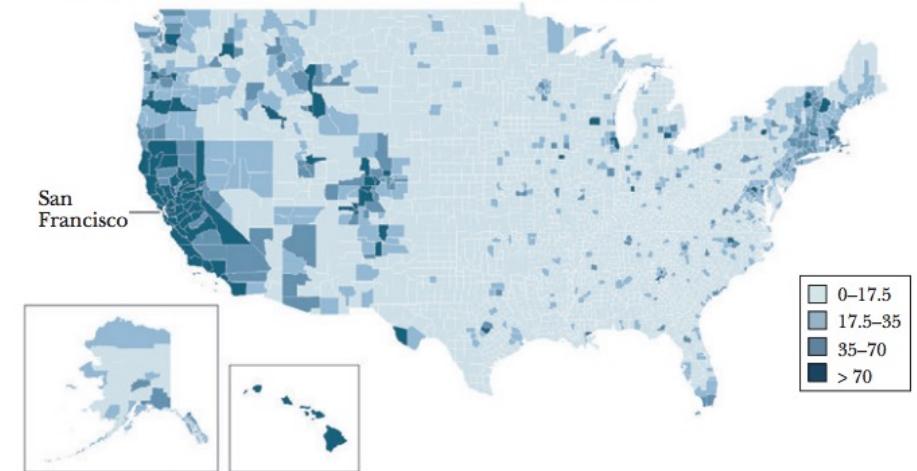
Correlation

Causal Models

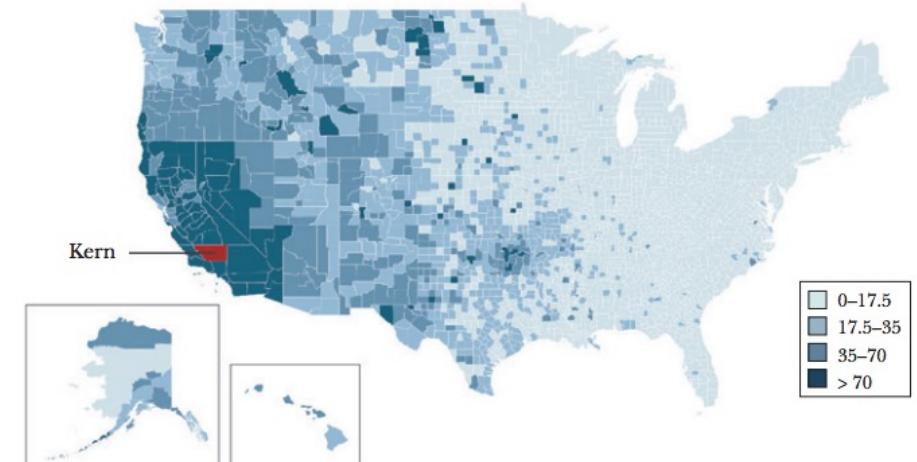
Statistical Analyses

**San Francisco has more connections to farther and wealthier places than Bakersfield (Kern County)**

A: Relative Probability of Friendship Link to San Francisco County, CA



B: Relative Probability of Friendship Link to Kern County, CA



# Applications Public Health Control (COVID-19)

## Research Question:

How can spatial networks inform public health crisis?

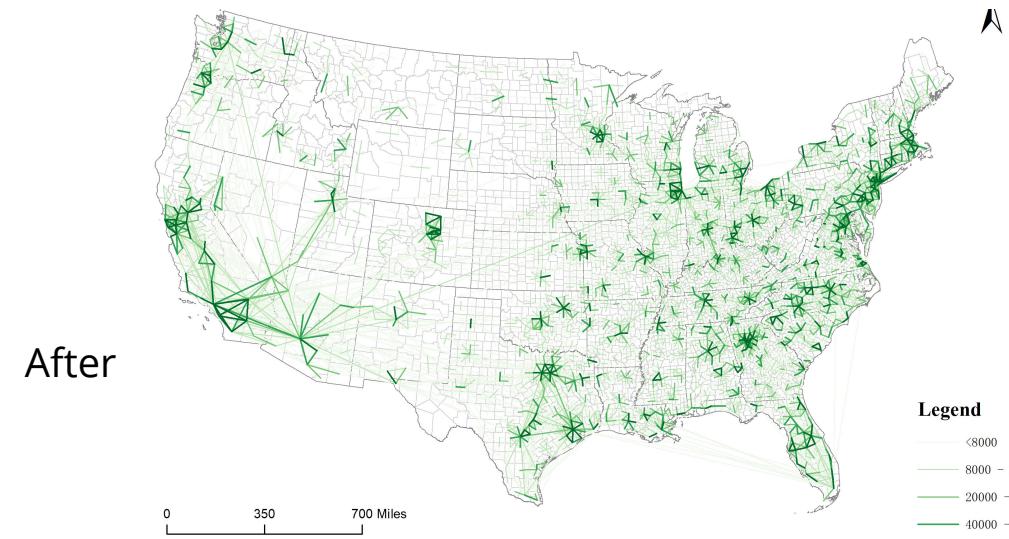
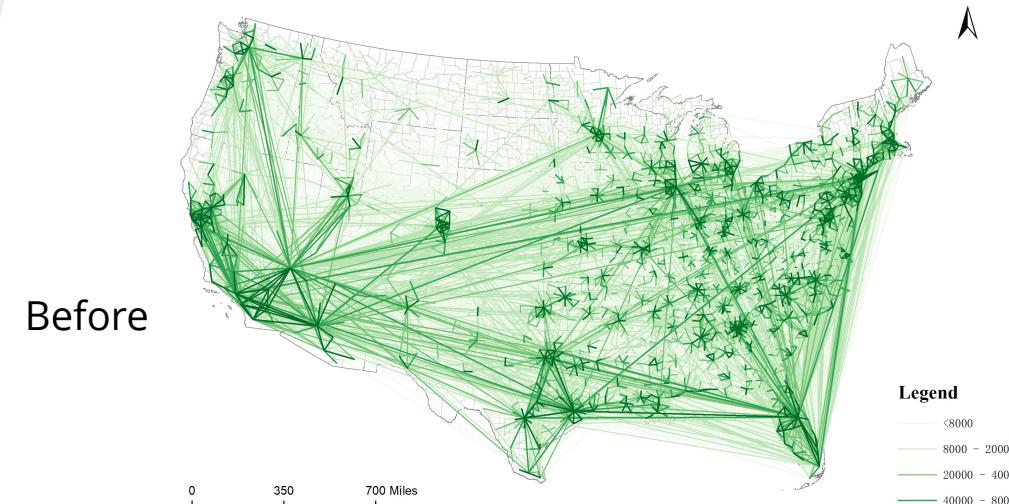
## Research Methods:

Track disease transmission through spatial networks

Augment epidemiology models with spatial networks

Re-interpret POI flow characteristics as transmission risks

## Comparing mobility pattern before and after U.S. stay-at-home order for COVID-19



Kang Y, Gao S, Liang Y, Li M, Rao J, Kruse J (2020) Multiscale dynamic human mobility flow 620 dataset in the us during the covid-19 epidemic. ArXiv Preprint  
<https://arxiv.org/abs/2008.12238>

# Challenges & Opportunities

## Data Openness and Privacy

### Private Data:

Cellphone calls; micro-mobility traces; social media, etc.

### Collaborative/Crowdsourced Data:

OpenStreetMap; surveys; collaboration with public institutions

### Public Data:

Tax records, commute data, street shapefiles, bus routes, and smart cards

The data source of the papers we reviewed for applications

	Private Big Data	Collaborative/ Crowdsourced Data	Public Data
Physical Networks	3	3	10
Mobility Networks	29	1	8
Social Networks	1	2	0
Sum	33	6	18

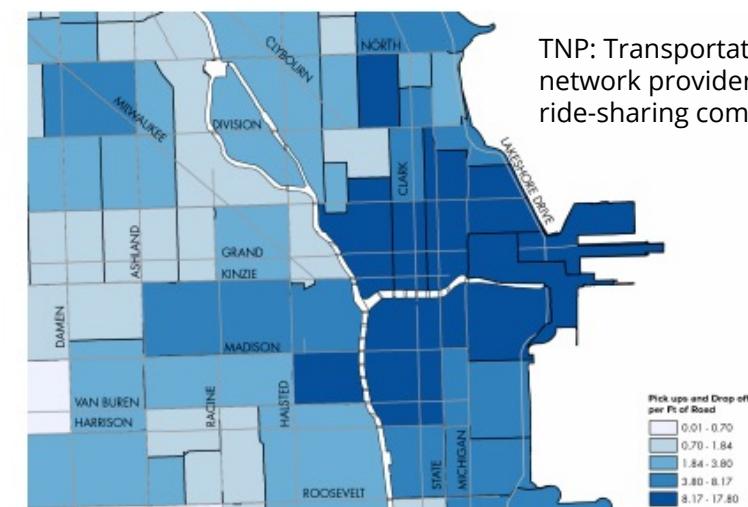
Number represents the count of papers

### Data openness through policy making

Starting in 2018, all ride-share companies are required by an ordinance to send routine reports to the City of Chicago, including the origins and destinations of trips.

The City of Chicago uses the TNP data requested under the ordinance to assess the impact of TNP services at congestions.

Map 2. Downtown Area that Experiences the Highest Density of TNP Congestion, March 2018–February 2019



Report: Transportation network providers and congestion in the city of Chicago. Retrieved from: [https://www.chicago.gov/content/dam/city/depts/bacp/Outreach%20and%20Education/MLL\\_10-18-19\\_PR-TNP\\_Congestion\\_Report.pdf](https://www.chicago.gov/content/dam/city/depts/bacp/Outreach%20and%20Education/MLL_10-18-19_PR-TNP_Congestion_Report.pdf)

# Challenges & Opportunities

## Data Openness and Privacy

### Geoprivacy

Spatial Networks (esp. trajectory) can include private/confidential information

The task of ensuring the privacy is often offloaded to the service vendors.

Public data only reports on tract, county, or state level, which is not enough for planners' place-based work.

### Geoprivacy Technique Innovation

Aggregate fine-resolution data to upper-level scales



Grouping and mixing geographic data (Gruteser and Grunwald, 2003)

Geomasking (Gao et al. 2019)

Deep learning to generate privacy-preserving synthetic trajectory (Rao et al. 2020)

# Challenges & Opportunities

## Direct Policy Implications

### Lack of Direct Policy Implications

Interesting insights, but not a step further to support policy decisions and normative discussions.

"If we have spatial segregation in people's activity space, should we respect such structure or optimize it to a healthier balance?

If we know a city is at the margin of the urban hierarchy, how can we help the city move up the ladder or should we intervene at all?"

Evaluate the impact of network changes (i.e., high-speed rail network) on city-to-city travel time and air traffic distribution (Cao et al, 2013; Liu et al, 2019)

Use geo-industry and labor flow network to direct local economic policy development (Park et al, 2019)

Contextualize spatial networks insight in the socio-political history of a locale (Shelton, 2019)

# Challenges & Opportunities

## Participation and Collaboration

### Data/Perspective Representation

Big spatial networks data may not represent every population.

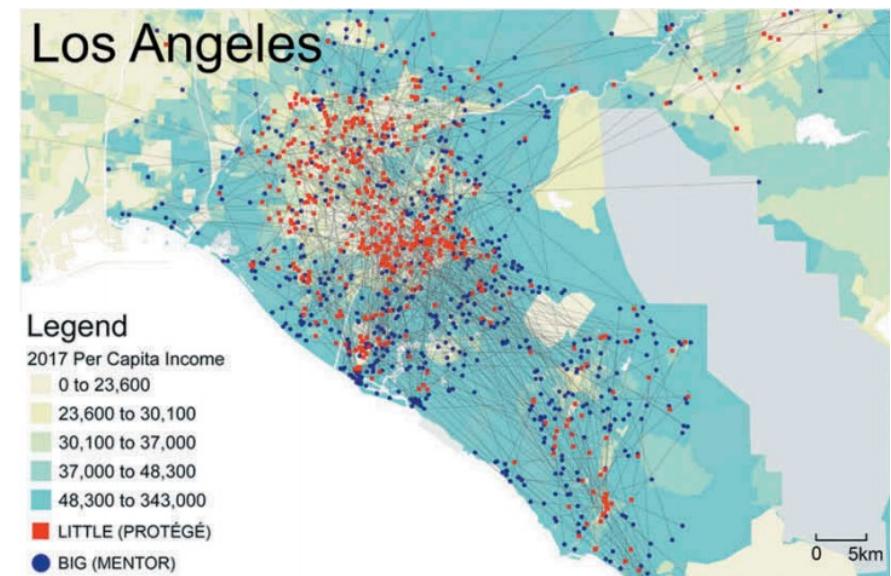
### Duality of Network Nodes and Edges

A network node may serve the region but not the immediate neighborhood (e.g., airports; ports)

If the edges (e.g., highway) are not accessible, they can be harmful too.

### Alternative Spatial Network data to support activism and NGOs

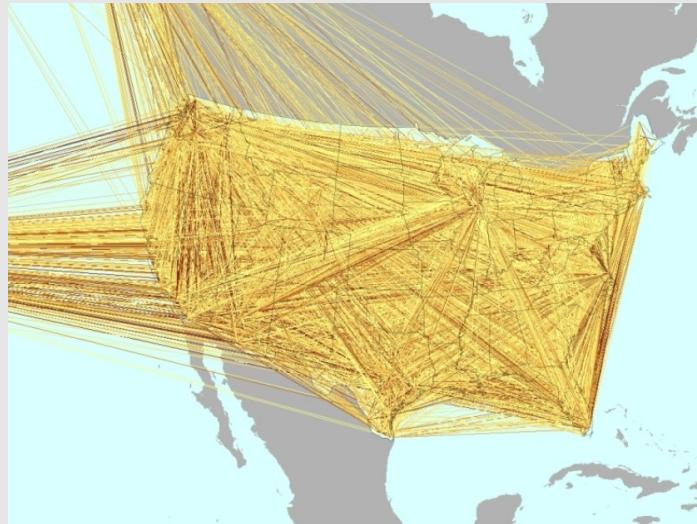
Researchers mapped out the mentorship pairs with the NGO Big Brothers and Big Sisters to evaluate if the program bridges the ties across spatial and social groups



Andris C, Liu X, Mitchell J, O'Dwyer J, Van Cleve J (2019) Threads across the urban fabric: youth mentorship relationships as neighborhood bridges. *J Urban Aff* 1-16

# Challenges Interface with GIS

## Node and Edge Clutter



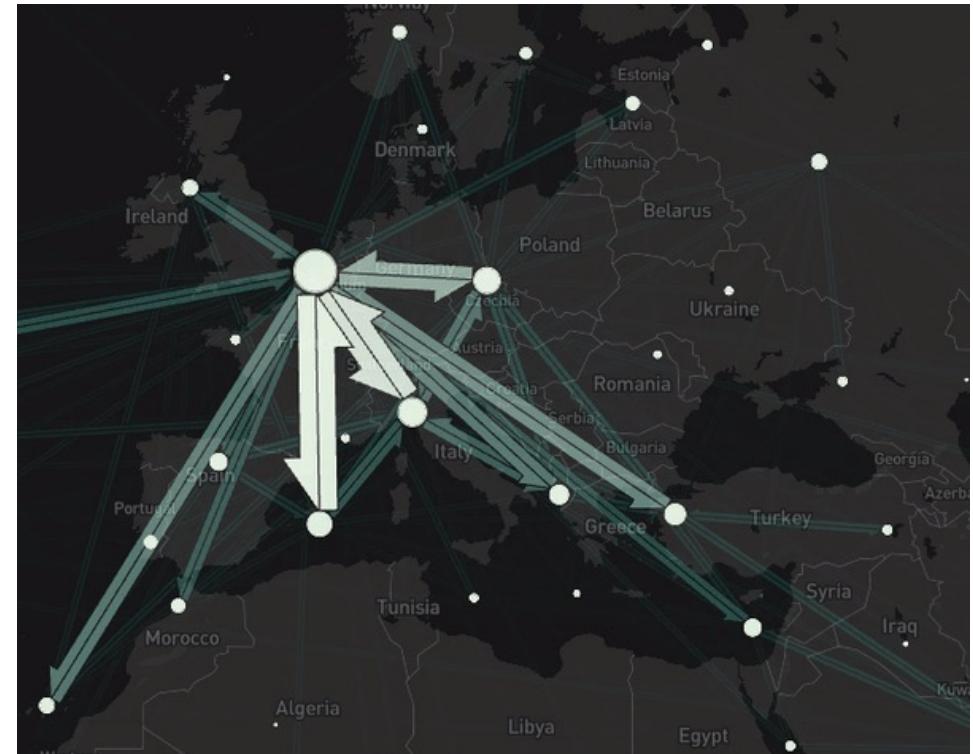
**Lack of GIS Infrastructure to support Network data and viz**

See a review at Andris et al. 2018

Andris C, Liu X, Ferreira J Jr (2018) Challenges for social flows. Comput Environ Urban Syst 70:197–207

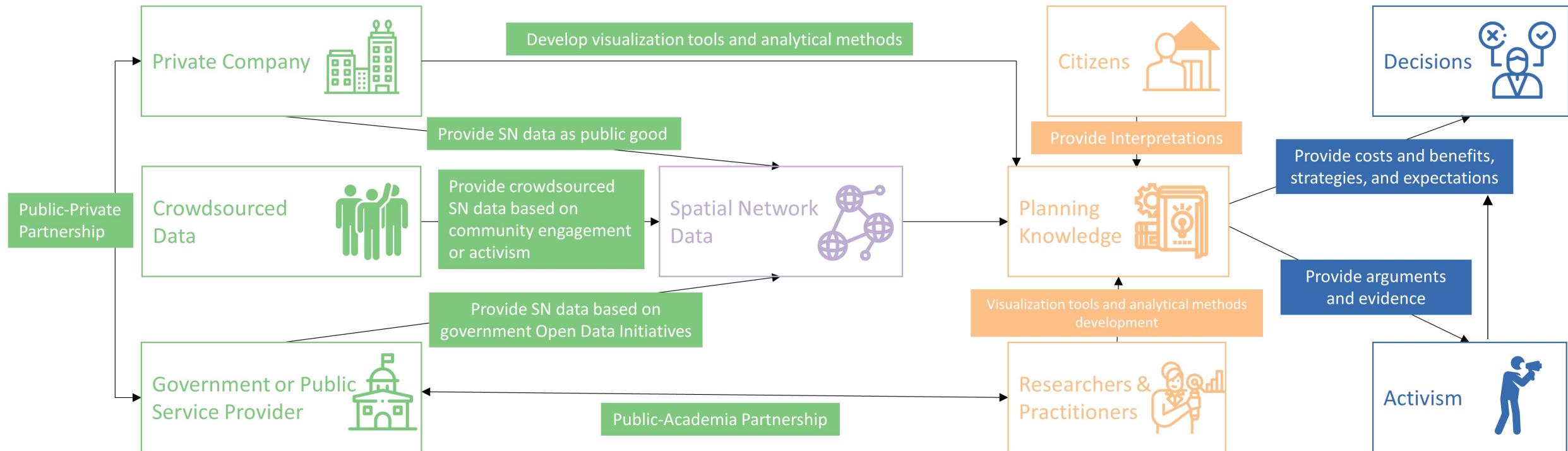
# & Opportunities

Edge Bundling  
Alluvial Diagram  
Web-based interactive tool



<https://flowmap.blue/>

# Envisioning a Collaborative Planning Model with Spatial Networks



# Additional Reference

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Gao S, Rao J, Liu X, Kang Y, Huang Q, App J (2019) Exploring the effectiveness of geomasking techniques for protecting the geoprivacy of Twitter users. *J Spat Inform Sci* 19:105–129. <https://doi.org/10.5311/JOSIS.2019.19.510>

Rao J, Gao S, Kang Y, Huang Q (2020) LSTM-TrajGAN: a deep learning approach to trajectory privacy protection. ArXiv Preprint <https://arxiv.org/pdf/2006.10521.pdf>

Cao J, Liu XC, Wang Y, Li Q (2013) Accessibility impacts of China's high-speed rail network. *J Trans Geogr* 28:12–21

Park J, Wood IB, Jing E, Nematzadeh A, Ghosh S, Conover MD, Ahn YY (2019) Global labor flow network reveals the hierarchical organization and dynamics of geo-industrial clusters. *Nat Commun* 10(1):1–10.

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