CORVINUS UNIVERSITY of BUDAPEST

How Do We Know What We Know?

From Network to Social Network

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TU Delft Department of Urbanism
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Affiliations/Collaborations

CEU Department of Network and Data Science
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Erasmus University Rotterdam



COMPLEXITY SCIENCE HUB VIENNA

unicef INNOVATION

NetSci network science society

TU Delft Department of Urbanism
BK Bouwkunde

WOMEN IN DATA SCIENCE STANFORD UNIVERSITY

WOMEN in BIG DATA

WINS

Women in Network Science

COMPLEX SYSTEMS SOCIETY

yrCSS Young researchers of the Complex Systems Society

ecpr

Radboud Universiteit

RELATE European Studies in a Relational Universe

MethodsNET Methods Excellence Network

VDSG VIENNA DATA SCIENCE GROUP

cost EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

ANET LAB

NETTI

Outline

1. Network Overview

i. Spatial Network
ii. Temporal Network
iii. Spatio-Temporal Network
iv. Social Network

2. Network Emergence

i. Data Transformation
ii. Network Visualization

3. Research Overview

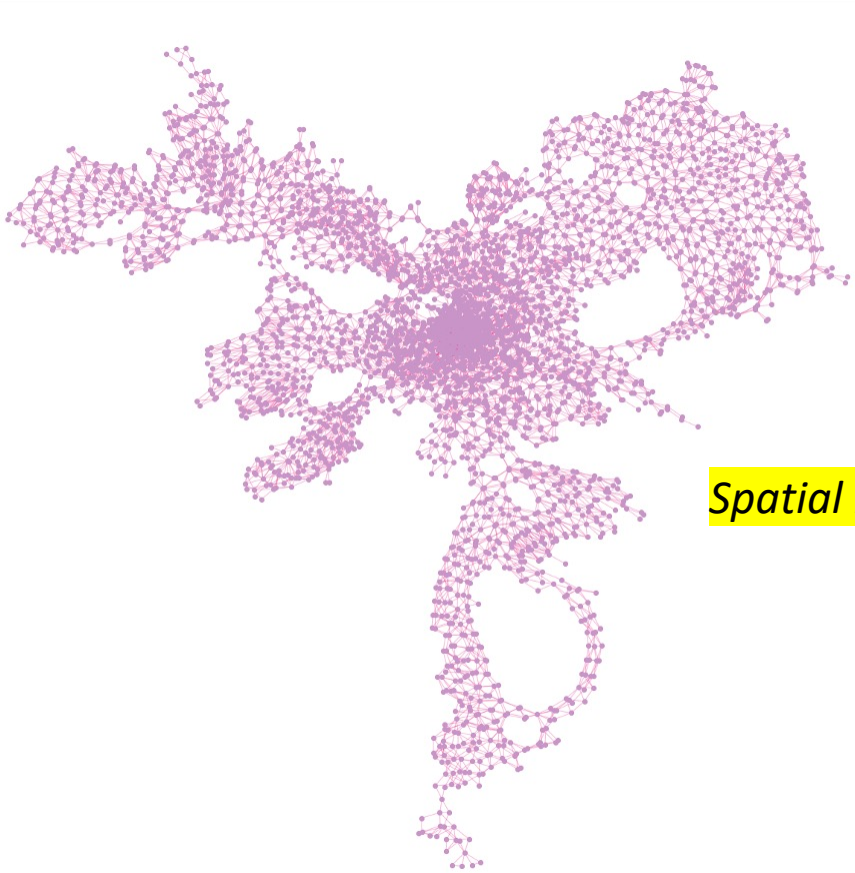
i. Urban Complex System
ii. Cities as Complex System

Neighborhood Network

How does stratification exist in space?

Spatial Network

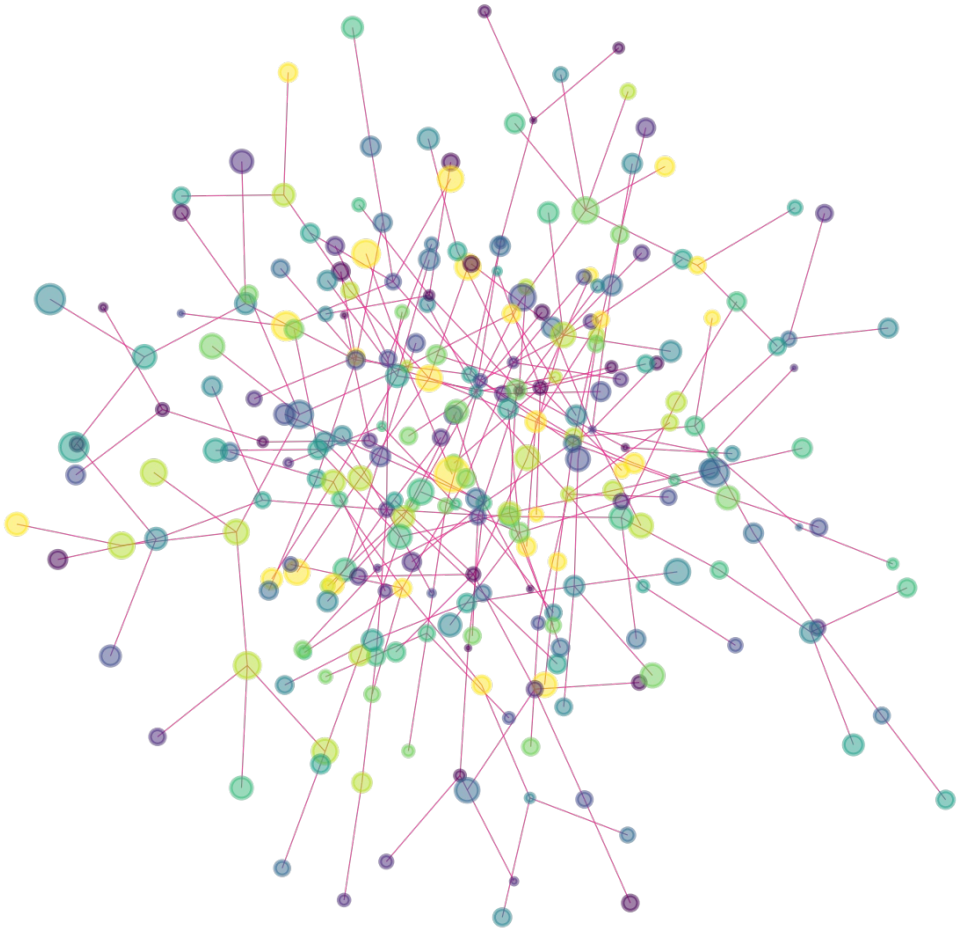
New York



Spatial isolation

Close-knitted neighborhood

Jakarta



Demographic distribution

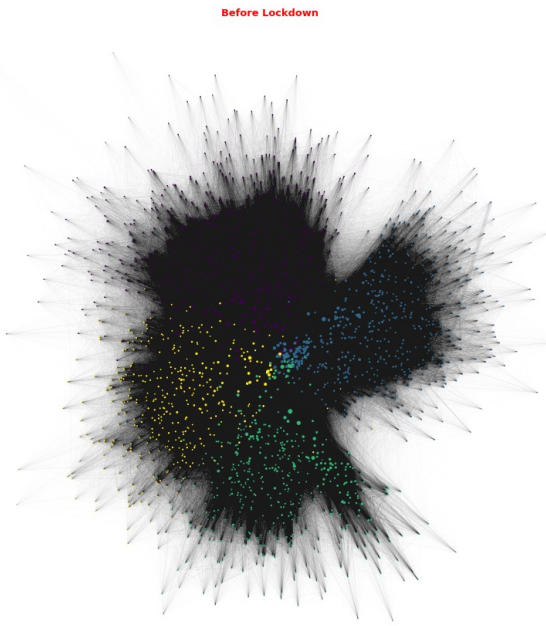
Socioeconomic stratification

COVID Mobility Network

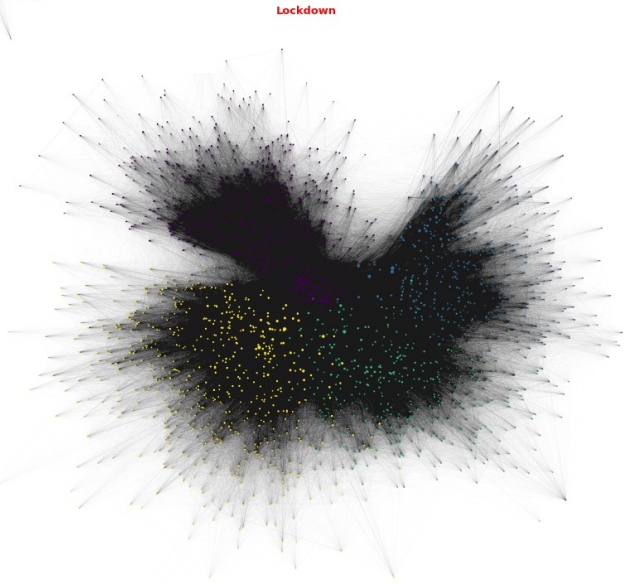
How does COVID outbreak change topological structure of mobility network?

Temporal Network

New York

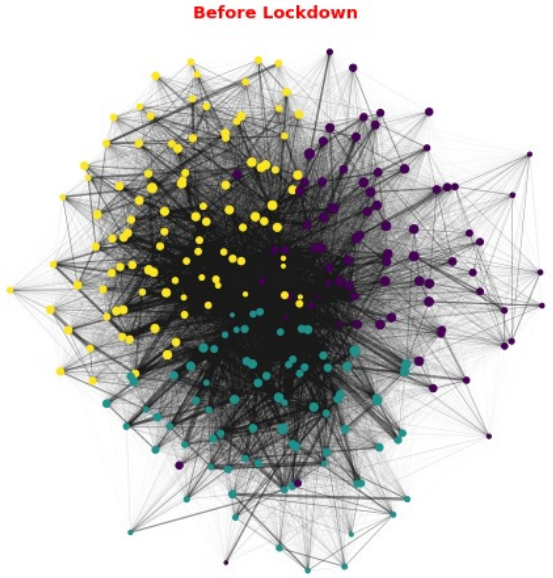


N = 2118
E[w] = 537599
<k> = 508
D = 0.240
Q = 0.268
C = 4

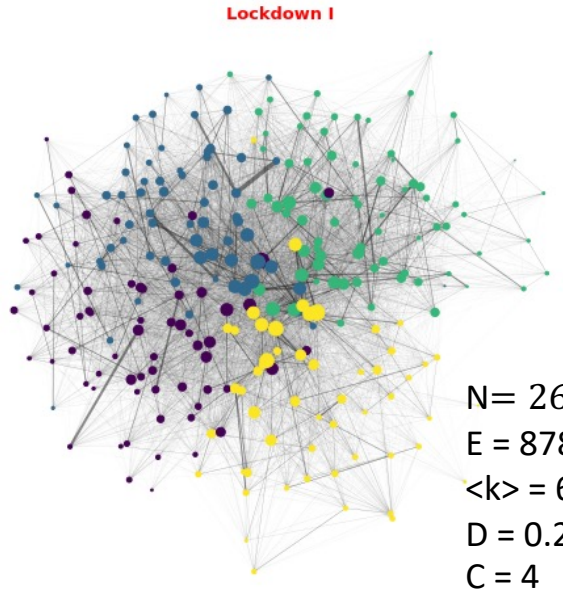


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Q = 0.356
C = 4

Jakarta



N = 261
E = 20979
<k> = 160.75
D = 0.62
C = 3

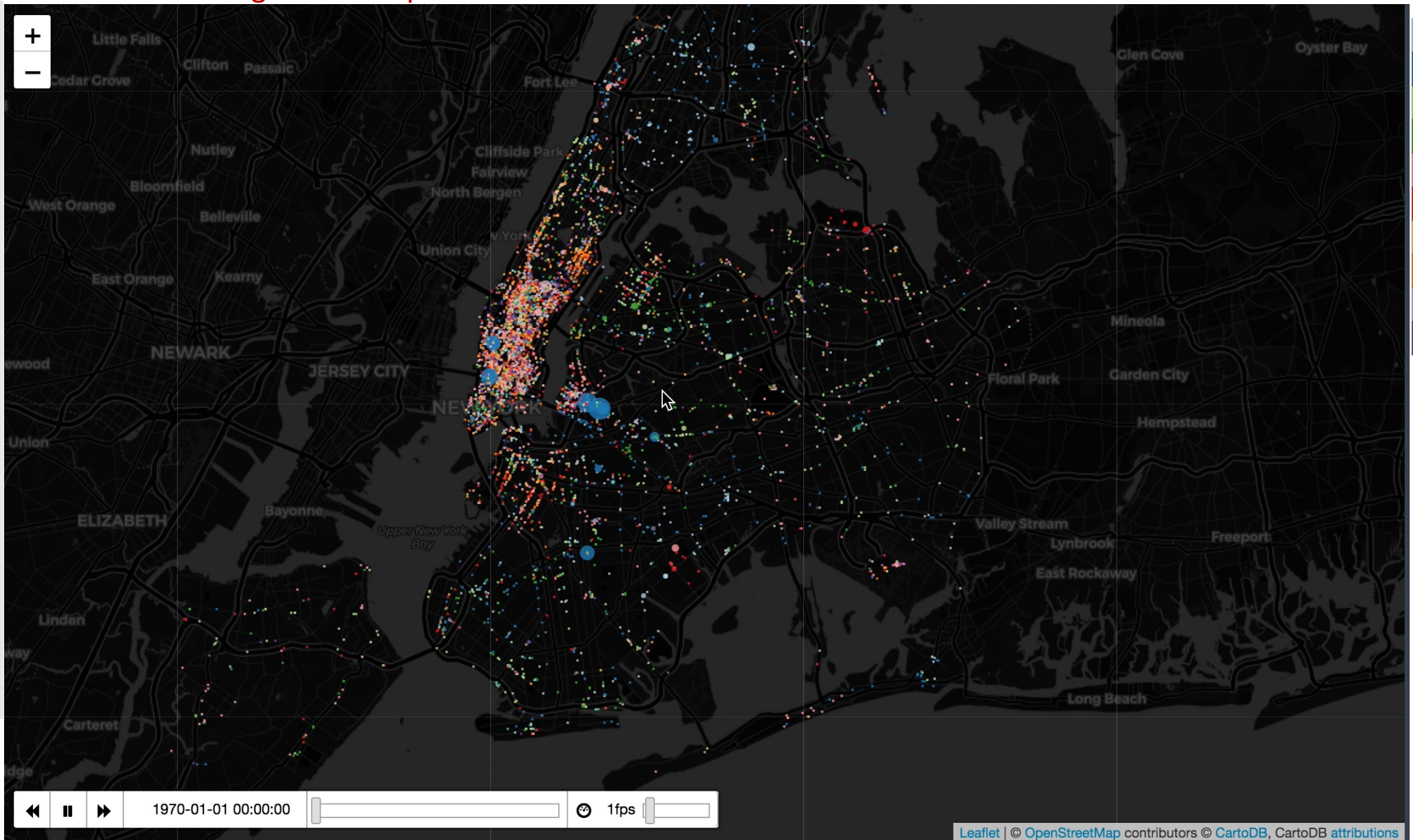


N= 261
E = 8783
<k> = 67.30
D = 0.26
C = 4

Preferential Visit Network

How do socioeconomic attributes and geographic constraints affect the spatiotemporal process of individuals moving in urban spaces?

Spatio-Temporal Network



Shortest Path and Small World Phenomena

Are socially distant people connected by short paths?

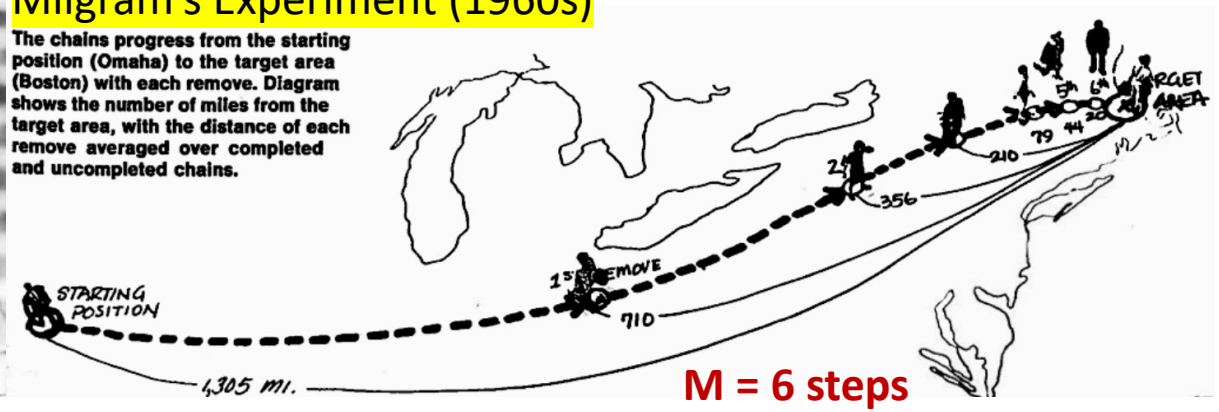
Six Degrees of Separation

Social Network



Stanley Milgram

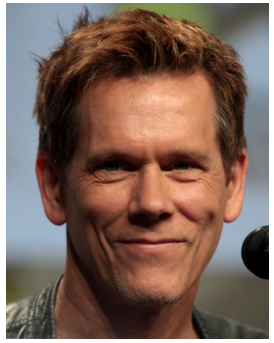
Milgram's Experiment (1960s)



M = 6 steps

Information: target's name, address, and occupation
Procedure: no direct mail to the target and forward it to a single acquaintance that he or she knew on a first-name basis
Objective: reach the target asap

Bacon's Law (1994)



Procedure: two actors are connected if they have appeared in a movie together

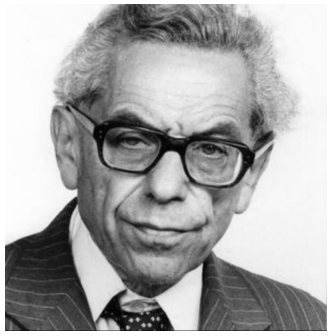
M = 6 steps

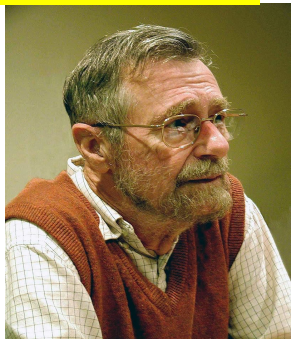
Kevin Bacon

(Fass, Brian Turtle and Mike Ginelli)

http://oracleofbacon.org/

Collaborative Distance (2000s)



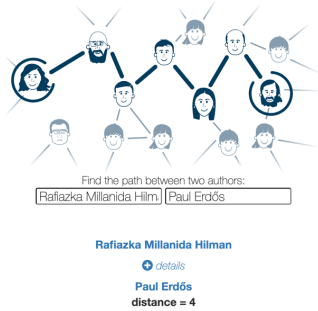


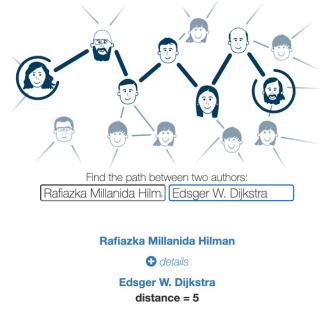
Paul Erdős **Edsger Dijkstra**

https://www.csauthors.net/distance

Procedure: two authors are connected if they have co-authored a paper

M = 6 steps



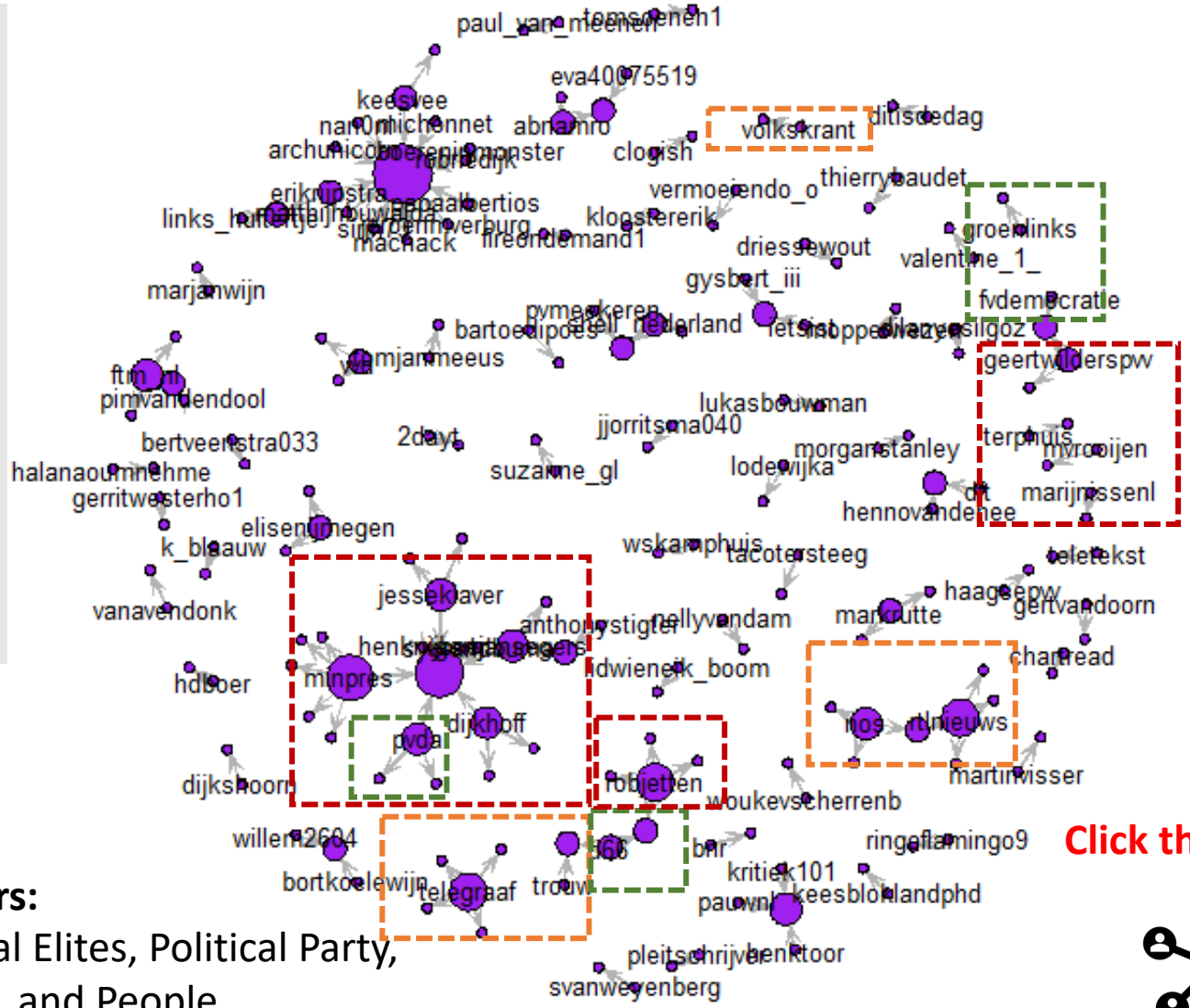


Discourse Network

How does debate on dividend tax abolishment portray ideological proximity/distance?

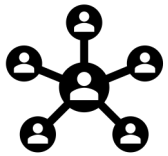
Social Network

RT Network on *Dividendbelasting*

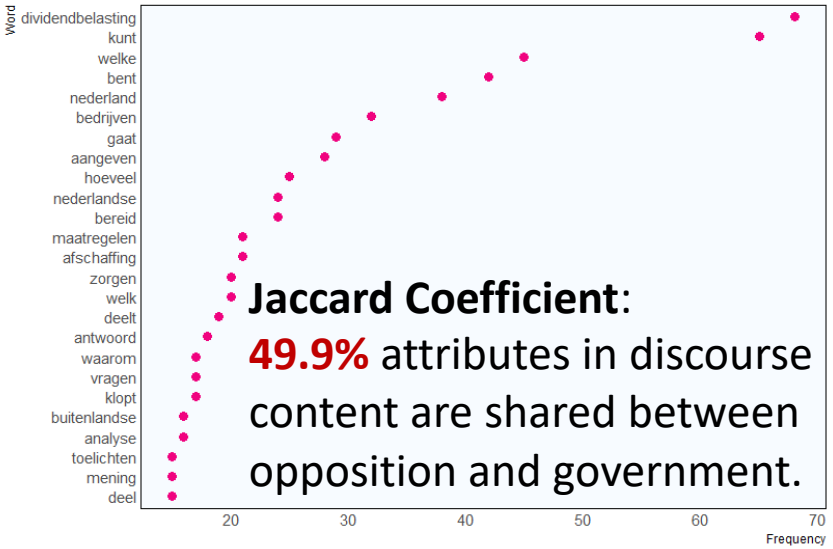


Clusters:
Political Elites, Political Party, Media, and People

Click this button

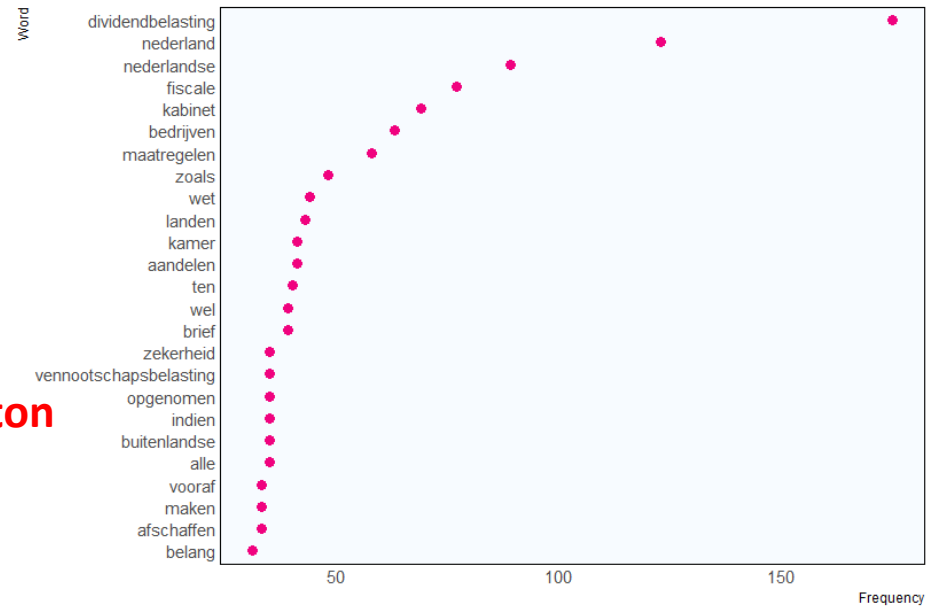


Concurrent Words in Opposition Question



Jaccard Coefficient:
49.9% attributes in discourse content are shared between opposition and government.

Concurrent Words in Coalition Response



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2. **Network Emergence**
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   ii. Network Visualization

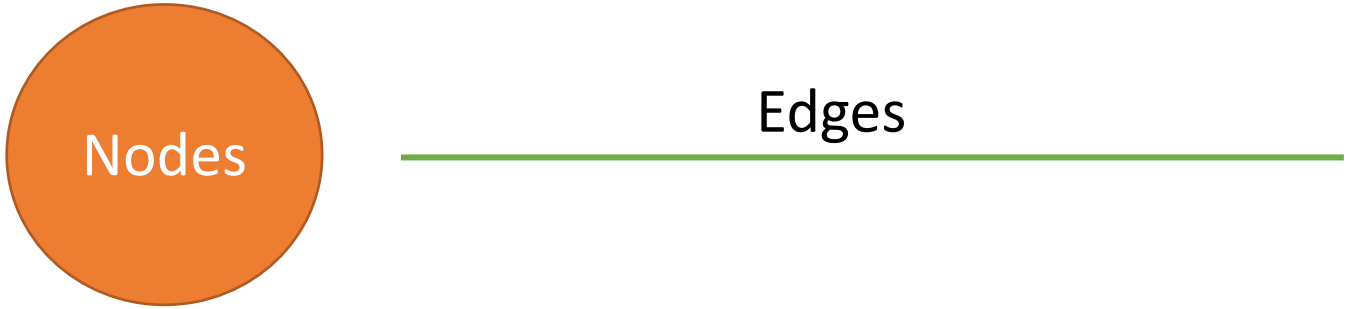
3. Research Overview
   i. Urban Complex System
   ii. Cities as Complex System

How could we make use of survey data in constructing a network?

1. Data Collection

https://forms.gle/9UjPgX19XXMiJWRe9

2. Network Construction



3. Network Visualization

A ROBUST NETWORK DESIGN FOR SYNCHROMODAL TRANSPORTATION

Rafiazka Hilman

Department of Network and Data Science, Central European University

Introduction

Dynamical system, besides structure, is embedded in transportation network in the form of **robustness**. It measures the ability of network to retain its basic functionality in the presence of failure on some of its components. **Transportation network** is also characterized by the formal representation of: i) **multilayer network**, given the availability of multimodal urban transportation (eg: road network → bus/ rail network → subway, train, and tram) as well as ii) **temporal network** where connections happen inhomogeneously in time. The conceptual underpinning of **synchromodal transportation** is proposed to investigate the robustness of timely switching possibility between modes.

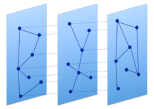
Model

Robustness (Min et al. (2018))

- Taking into account:
  - $\phi(\vec{k})$: the prob. that a node with degrees $\vec{k}$ is removed from the original network
  - f: a fraction of nodes being uniformly removed by chance
  - $\phi(\vec{k}) = f$ is random removal
  - $\phi(\vec{k}) = \Theta(K - K_c)$ is intentional attack by degree
- After node removal:
  - $H_i^{(t)}(\vec{x}) = \frac{1}{x_i}\frac{\partial}{\partial x_i} H_0(\vec{x})$ is the generating function for the remaining degrees
  - $v_i = 1 - H_1^{(t)}(1) + H_1^{(t)}(\vec{v})$ is the prob. does not belong to the giant component
  - $S = H_0(1) - H_0(\vec{v})$ is the size of giant component

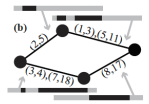
Multilayer Network (Kivela et al. (2014))

- A multilayer network $\mathcal{M} = (\mathcal{g}, C)$
  - a pair between a finite sequence of directed and weighted intralayer connection $\mathcal{g}^\alpha = (V^\alpha, \mathcal{E}^\alpha)$
  - interlayer connections $\mathcal{g}^\alpha$ and $\mathcal{g}^\beta$
  - the set of node $C = \{(\mathcal{E}_{\alpha\beta} \subseteq V^\alpha \, x \, V^\beta | \alpha \neq \beta)\}$

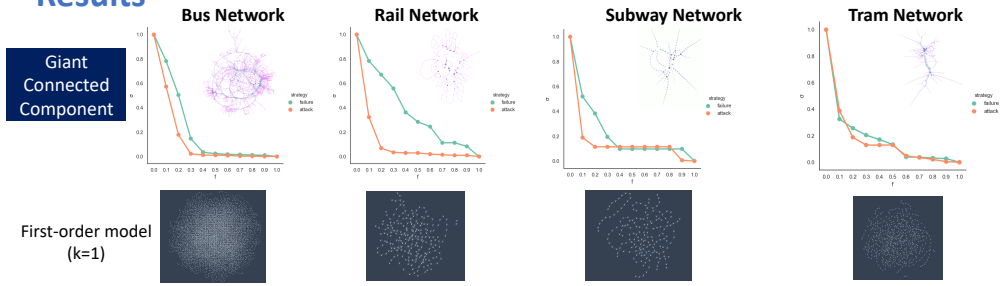


Temporal Network (Holme&Saramäki (2011))

- A temporal network with a set of N vertices *V* where only a handful of edges present at a timestep
  - interval graphs: the edges are active over a set of intervals $T_e = \{(t_1, t_1'), \ldots, (t_n, t_n')\}$
- Non-Markovian Higher-order Network Models
  - Correlations in the sequence of nodes traversed by paths.



Results



A network with high-resolution time-series is modeled as a non-Markovian higher-order to generalized higher-order dependencies in paths. The absence of transitive path in the k=1 evolves as a constraint in synchromodal urban transportation network.

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Transport Connectivity and Potential Multidimensional Social Contact

Rafiazka Hilman

Department of Network and Data Science, Central European University

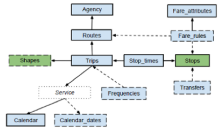
Introduction

Transport infrastructure, including prominent bus service, provides access to anyone to travel wherever in the city. Considering this embedded characteristic, issues related to transport accessibility and equality across neighbourhoods in the city remains important. Consequently, transportation serves as the backbone of social mixing process in society. The residents of relatively well-connected neighbourhood are exposed to higher potential social contact across multiple socioeconomic classes. This opportunity brings them to better understanding of social dynamics that might be in contrast to their own social attributes. It is in the interest of this research to generate visual representation of spatial correlations between neighbourhoods in the 4 largest urban regions in the Netherlands through the lenses of bus connectivity. Two entropy-based measures are proposed: Spatial Diversity Index and Economic Diversity Index. To capture this embedded property in transportation network, the General Transit Feed Specification (GTFS) is used as the main source of data in investigating transit accessibility formed on availability of transit provision in each neighbourhood. On top of that, socioeconomic profile of those areas is mapped out by clip-fitting spatial delineation of two raster layers provided by the Dutch Central Bureau of Statistics (CBS) namely neighbourhood (*buurt*) and urban regions (*stadsgewest*). With a multidimensional view on social mixing process, the role of public transportation in bridging inequality through potential social contact offers a renewed take on the importance of spatial connectivity.

Data

General Transit Feed Specification

GTFS



Socioeconomic and Demographic Data

Centraal Bureau voor de Statistiek



Methods

Spatial Diversity Index

Shannon's Entropy on Geolocation

$$\mathrm{SDI} = -\sum_{i=1}^{n} P(x_i) log P(x_i)$$

for each route and take the average value of route's SDI passing that neighbourhood as neighbourhood's SDI.

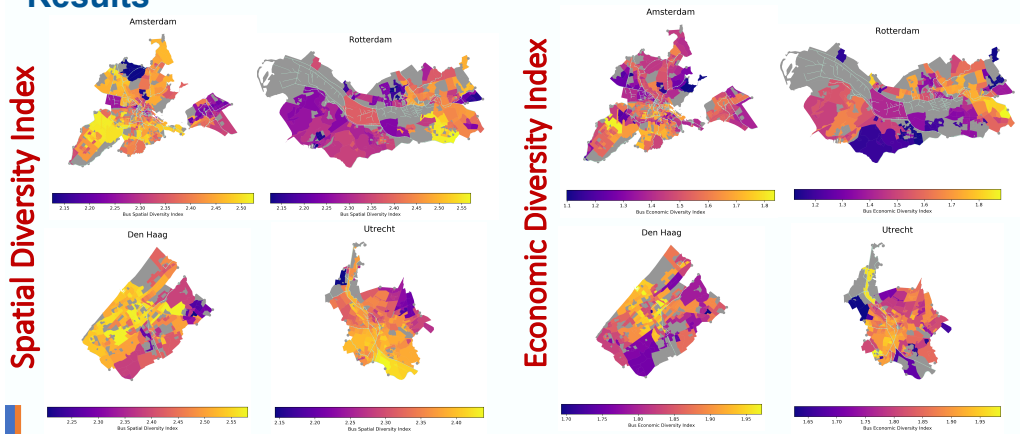
Economic Diversity Index

Shannon's Entropy on Economic Status

$$\mathrm{EDI} = -\sum_{i=1}^{n} P(s_i) log P(s_i)$$

for each route and take the average value of route's EDI passing that neighbourhood as neighbourhood's EDI.

Results



Neighbourhoods with lighter colour (higher index) have higher potential social contact with more diverse neighbourhoods, **spatial and economic wise**.



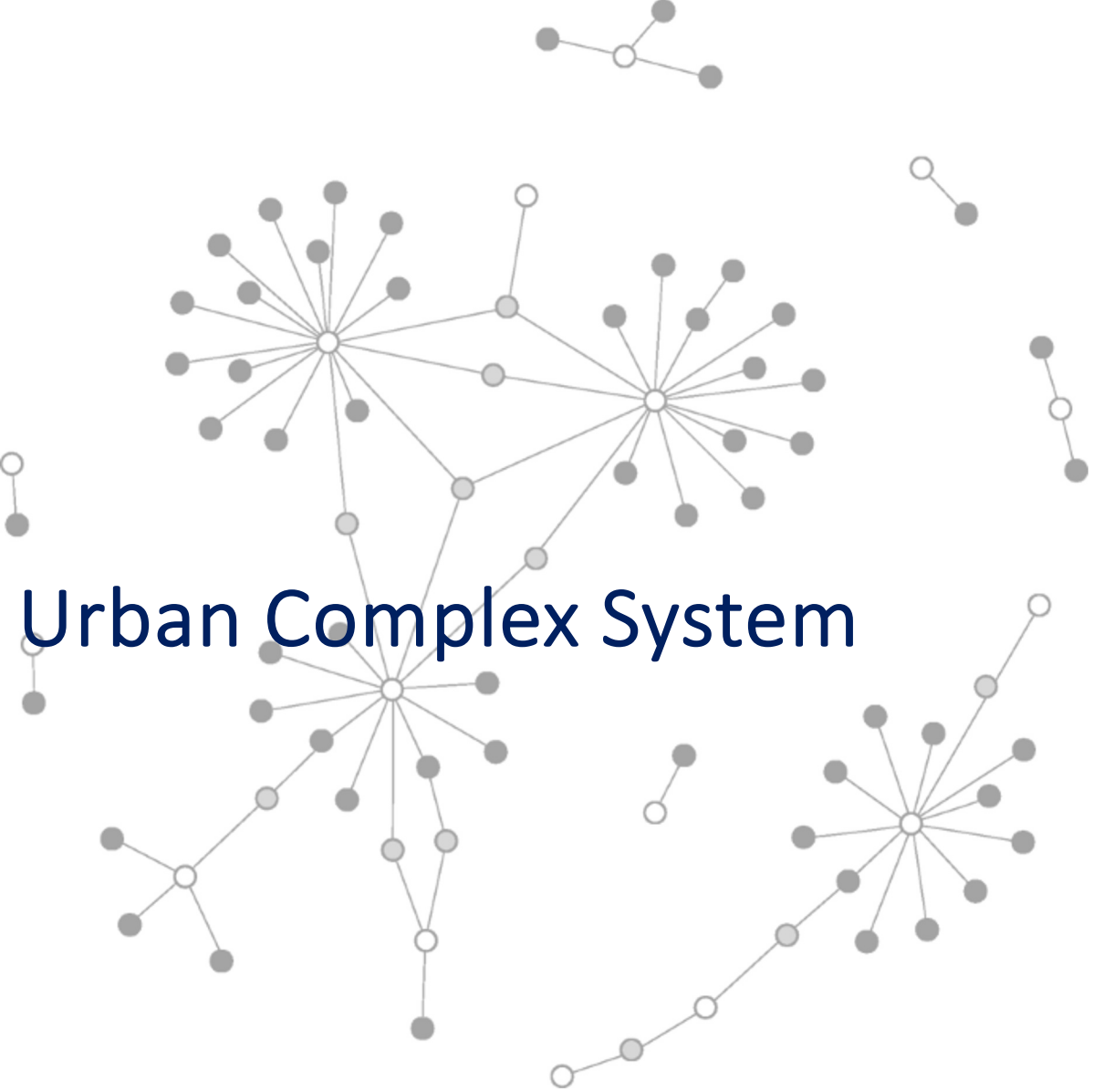
WOMEN in BIG DATA

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Urban Complex System

Transportation Network

Mobility Network

Social Network

Empirical Trajectory (Madness)

45 mins delay

ZRH → FRA → TSR

1st leg

cancelled

2nd leg

Local Synchronization

ZRH



chaotic disorder

3 of 4 service center were closed

2 times round trips for scanning

2 times round trips for passport control

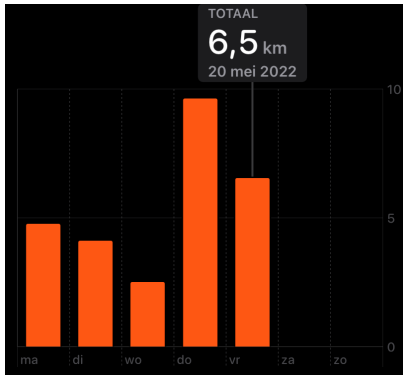


(un)walkability

preserving original mobility purpose

2nd leg replacement





Global Synchronization

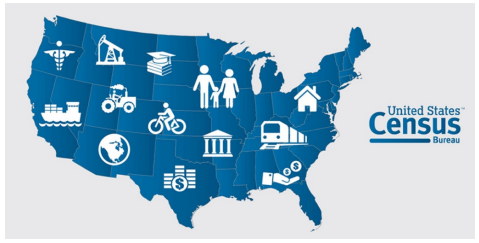
Urban Analytics Ecosystem: Data

Heterogeneous Source of Data

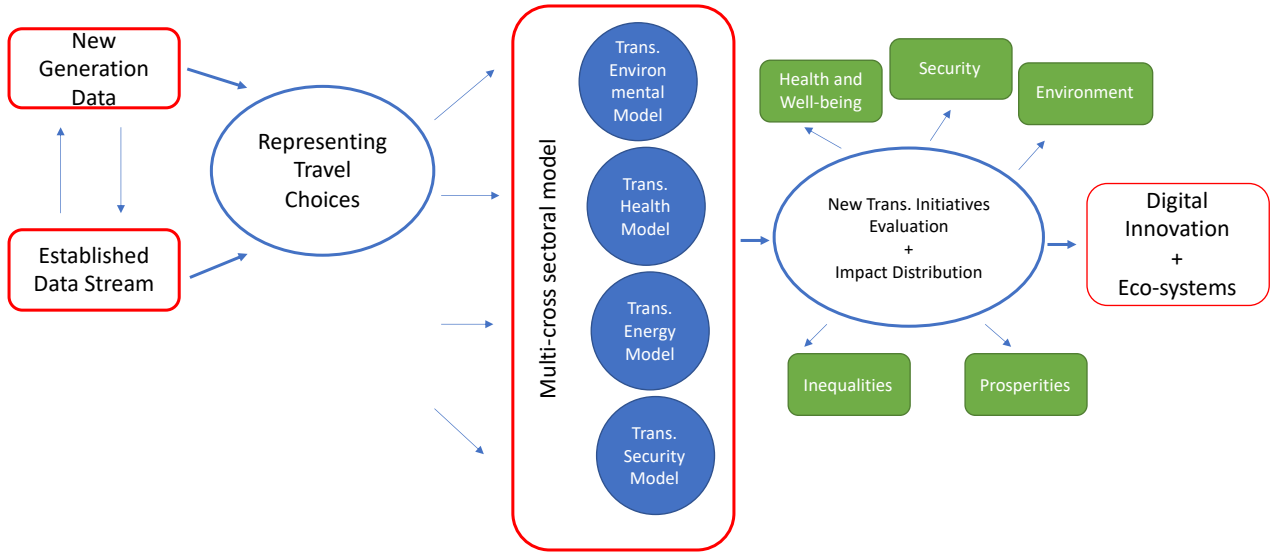
GTFS



waze

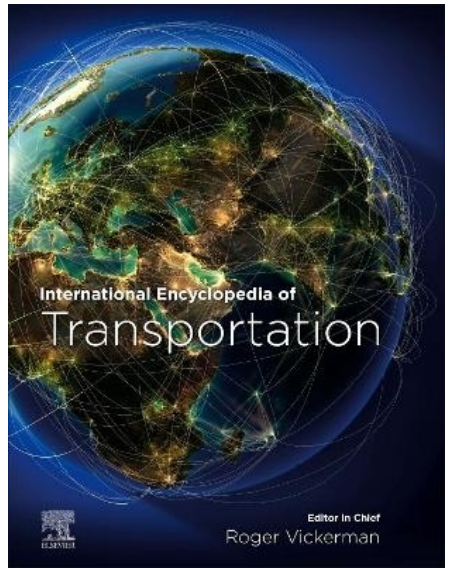


Data Infrastructure for Mobility

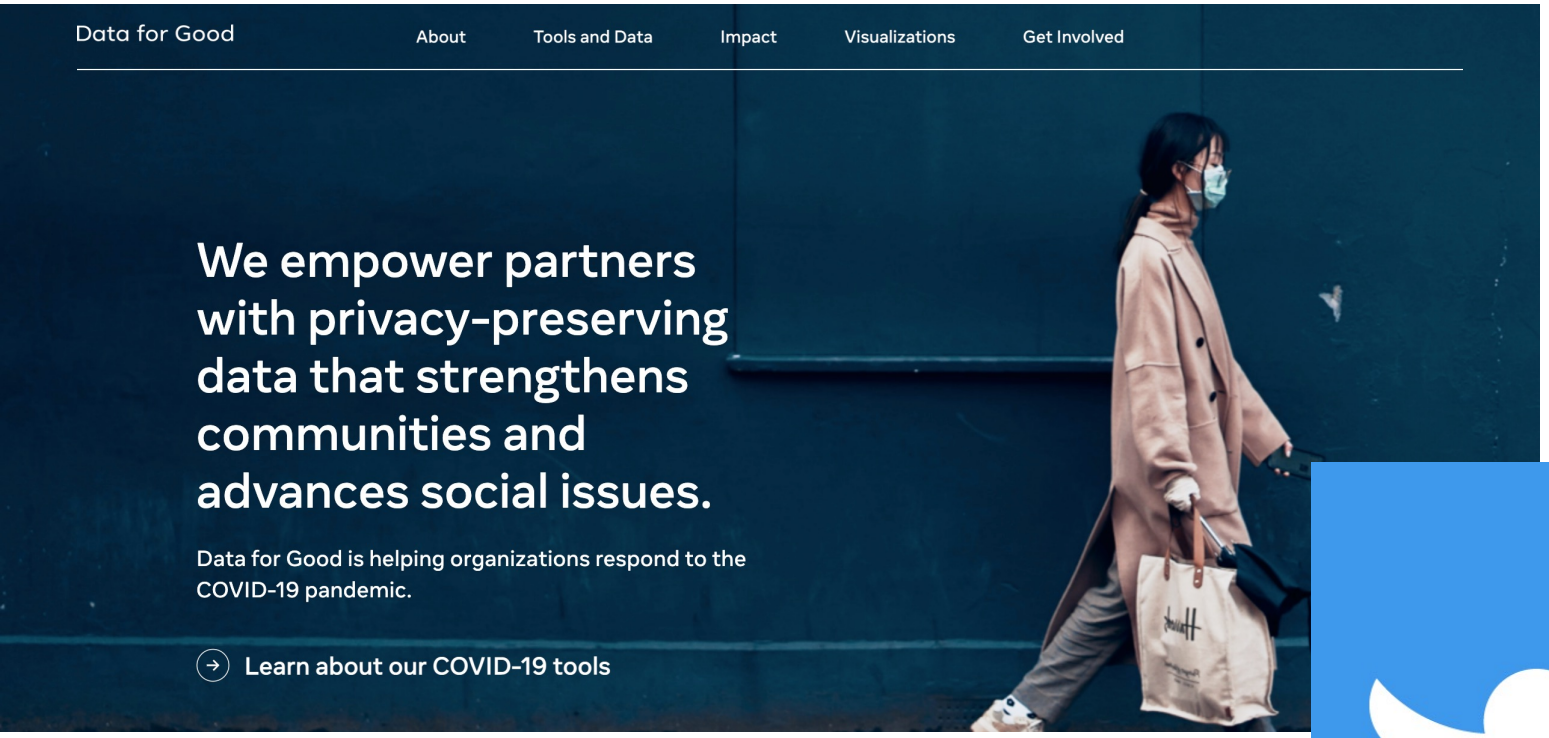


Source: The Alan Turing Institute (2019)

New and Emerging Data Forms (NEDF)



Data for Social Good



https://dataforgood.facebook.com/

Twitter API

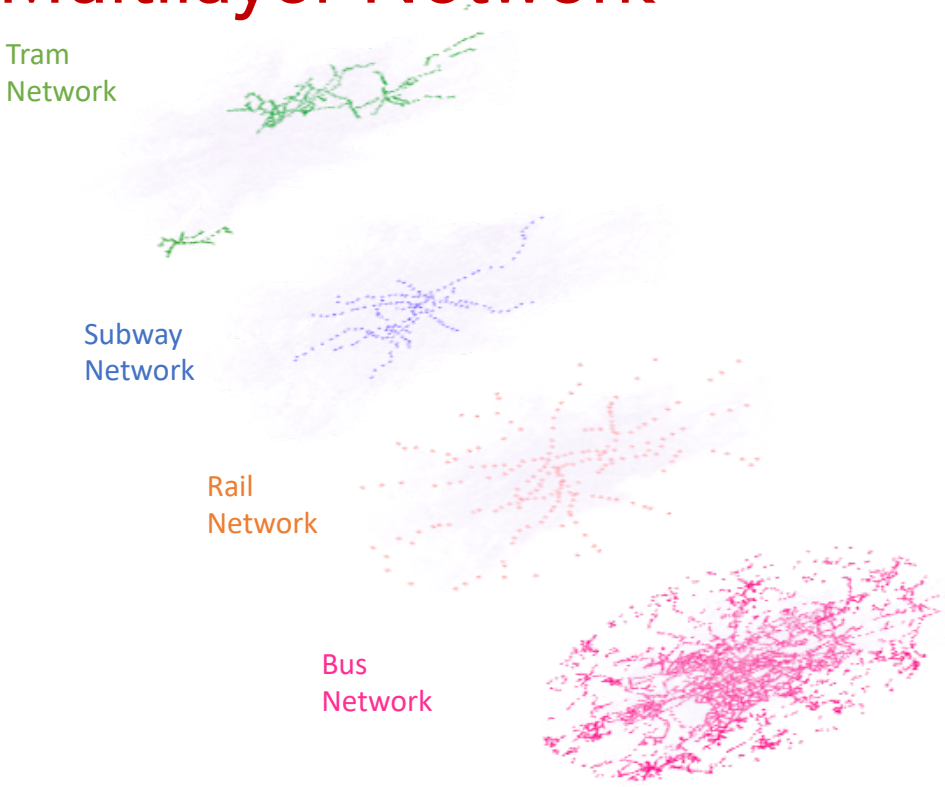
Academic Research product track

Advance your research objectives with public data on nearly any topic.

https://developer.twitter.com/en/docs/twitter-api

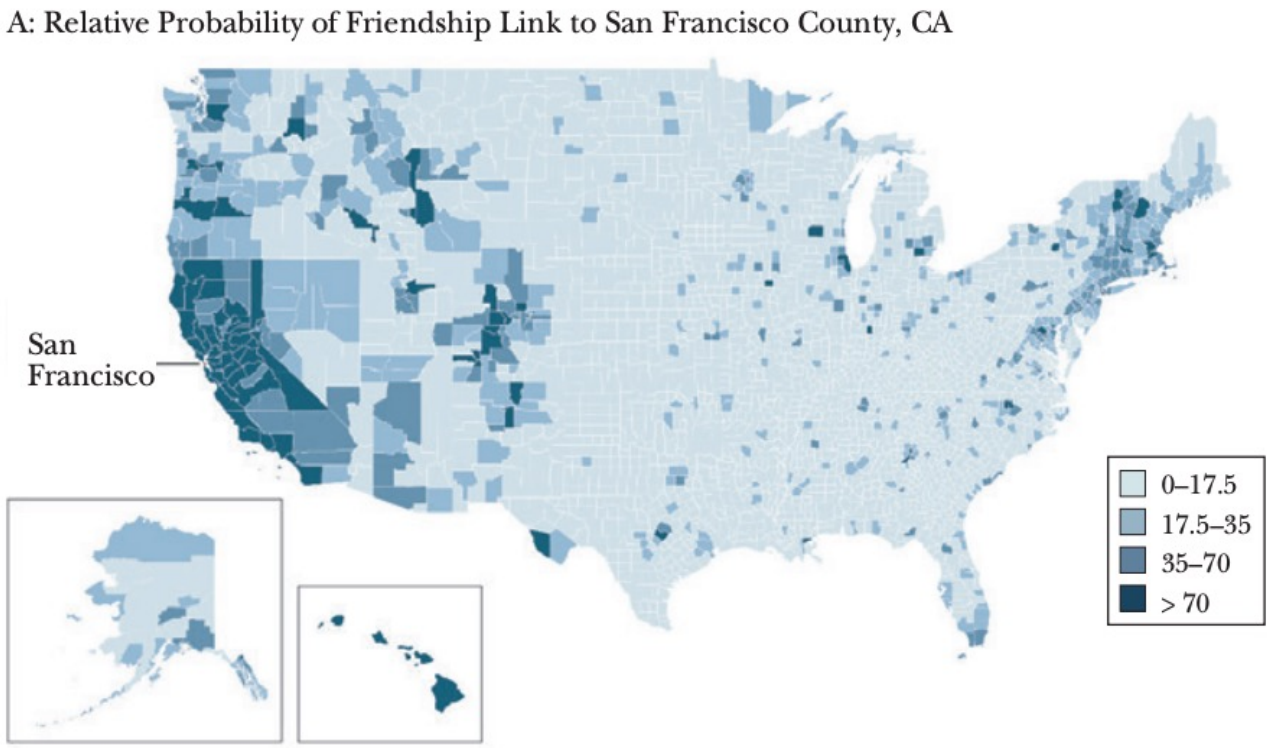
Urban Analytics Ecosystem: Toolbox

Multilayer Network



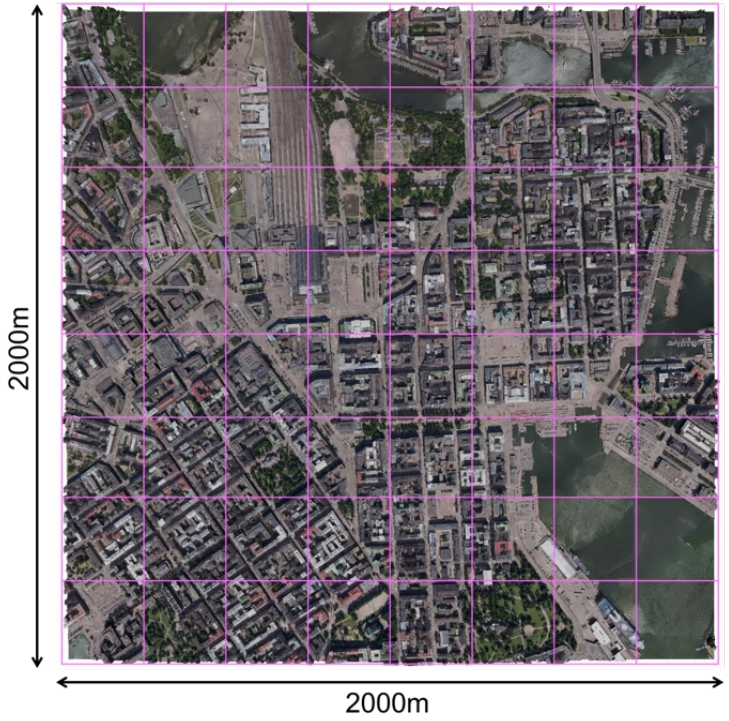
Multimodal Transportation in Berlin
Source: Hilman (2019)

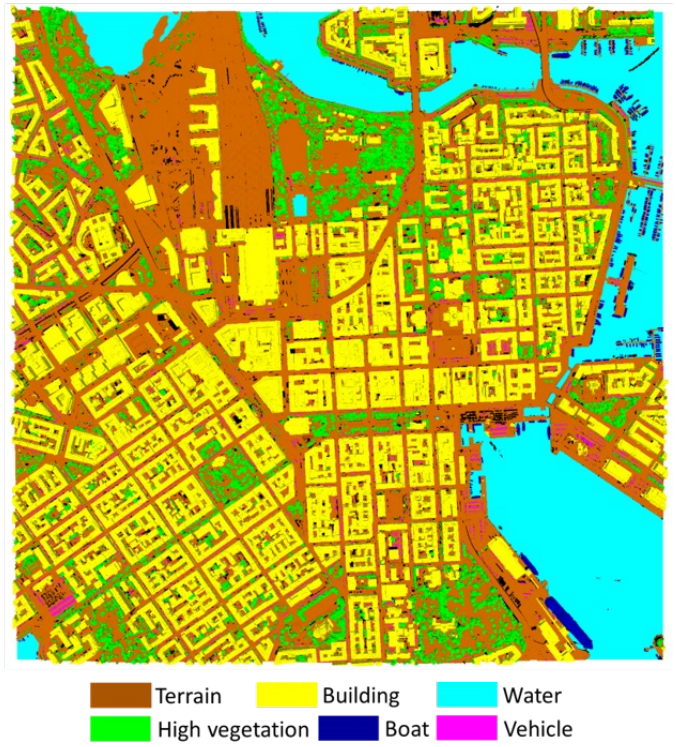
Social Network Analysis



Social Connectedness Index (SCI)
Source: Bailey et.al., (2018)

Image Recognition



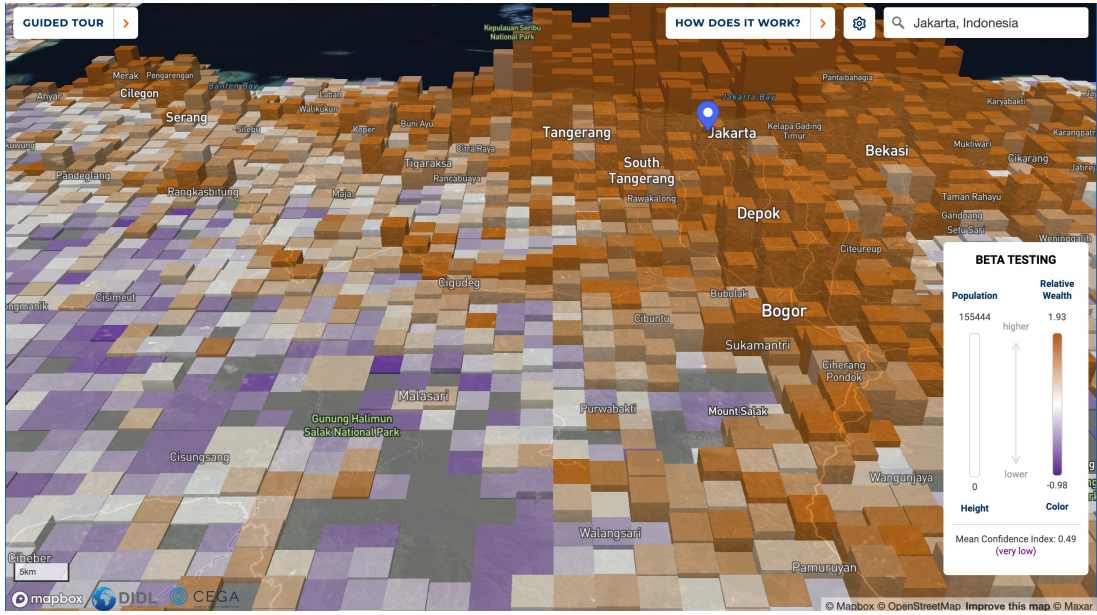


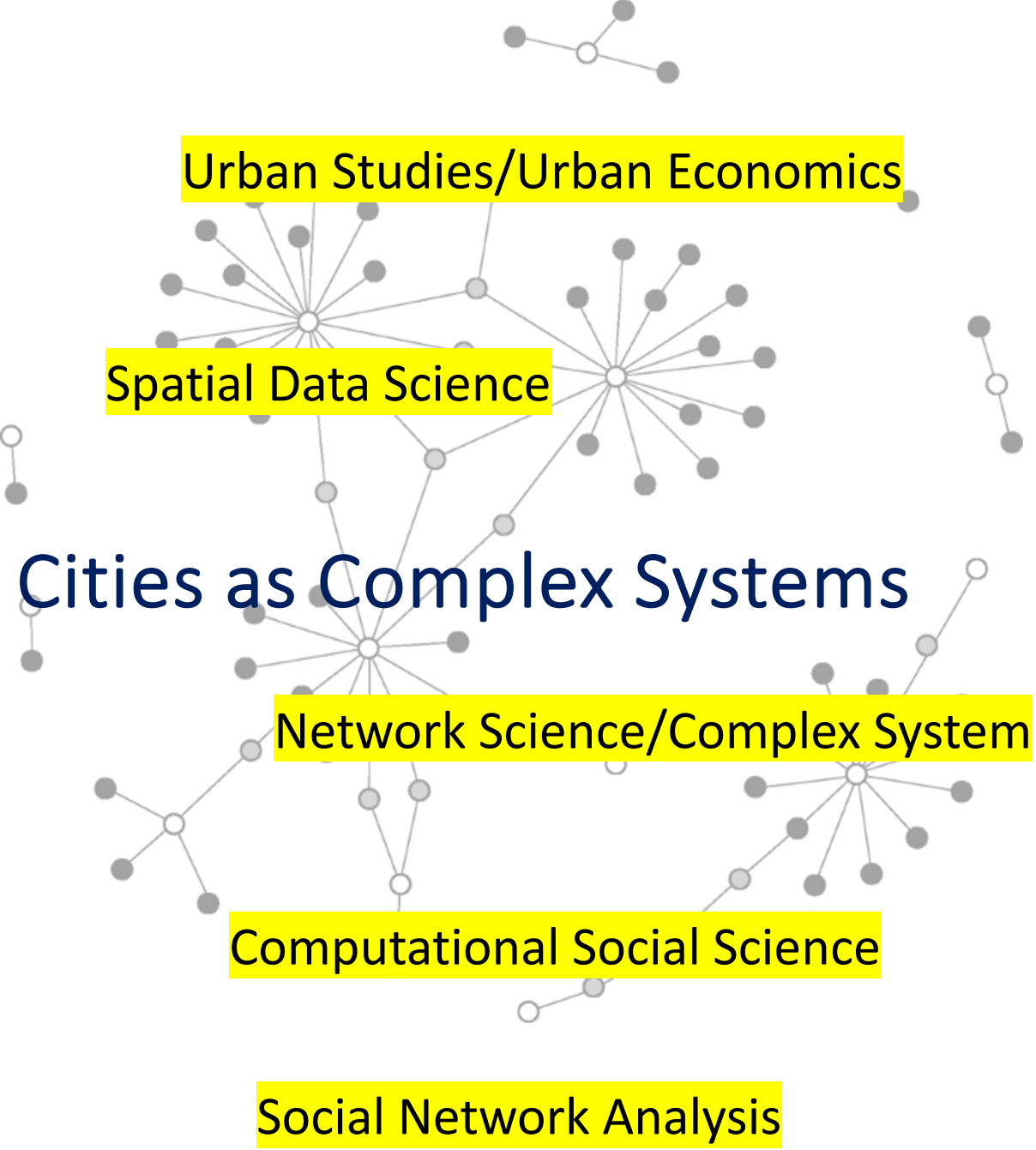
Semantic Urban Meshes

Source: Gao et. al (2021)

Relative Wealth Index

Source: Chi et. al (2021)





- Interdependencies in urban complexity
  - economic, social, demographic, infrastructural, etc.
- Scientific investigation in defining complex urban system
  - methodology (Drechsel and Kimms 2008 Bretschneider and Kimms 2011)
  - theory (Batty 2009; Portugali 2008, 2011)
  - empirical implication (de Roo et al. 2012; Schmidt and Walloth 2012)
- **How can complex urban systems be described and modelled?**

Research

City as social system



Socioeconomic Biases in Urban Mixing Patterns of US Metropolitan Areas

City as resilient system



COVID Induces Inequality in Mobility Adaptability Across Socioeconomic Classes

City as modular system



Stratified Mobility, Segregated Boundary, and Socioeconomic Mixing in US Cities

City as fractal system



Multiscale Spatial Distribution of Economic Diversity in New York

Socioeconomic biases in urban mixing patterns of US metropolitan areas

Rafiazka Millanida Hilman, Gerardo Iñiguez & Márton Karsai

EPJ Data Science **11**, Article number: 32 (2022) | Cite this article

City as Social System

How do socioeconomic attributes and geographic constraints affect the spatiotemporal process of individuals moving in urban spaces?

FOURSQUARE

American Community Survey

United States Census Bureau

City as Social System

Figure 1

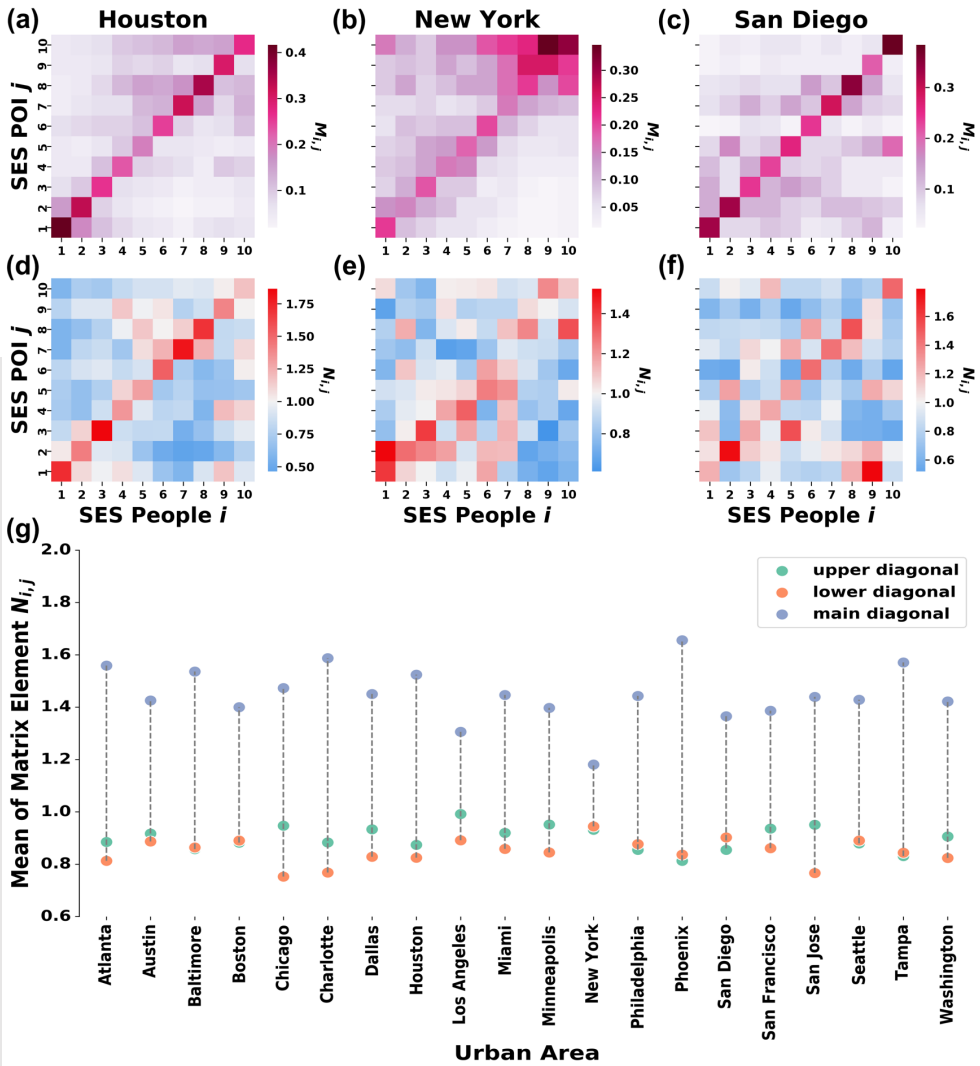
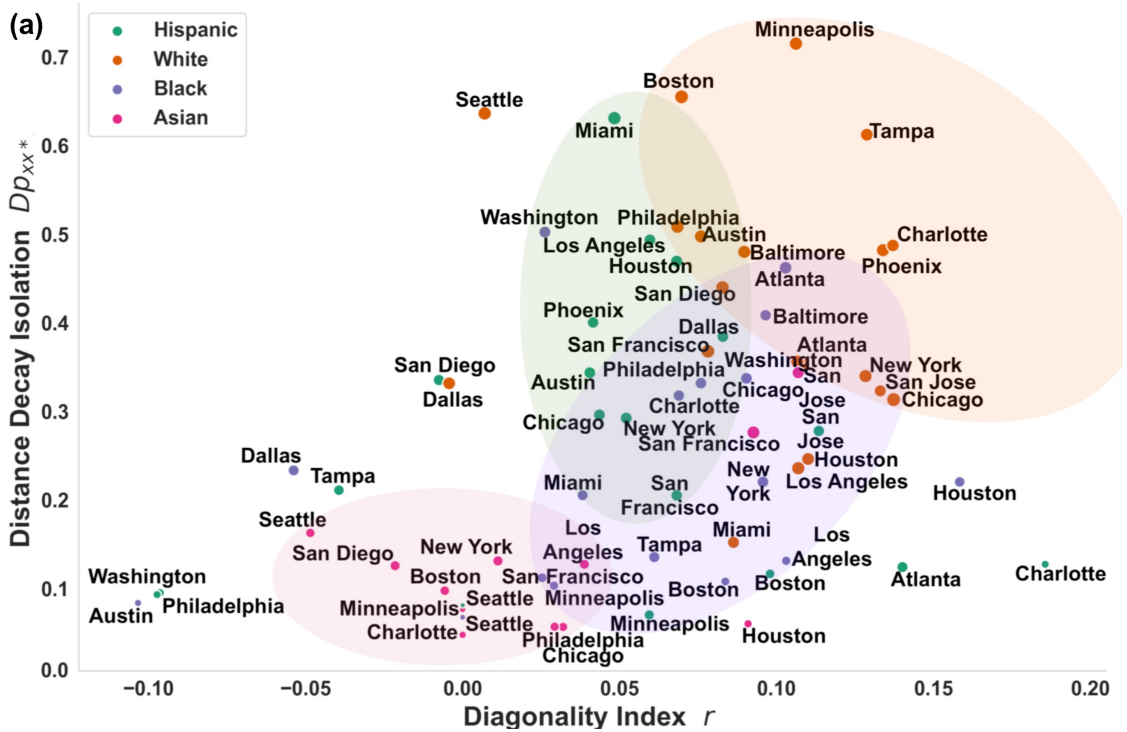


Figure 2



- Spatial exploration is dictated by socioeconomic class, indicating homophily mixing as an underlying mechanism of human mobility.
- Segregated mobility is bounded together with residential segregation and broadly contributes to the portrayal of inequality.

COVID Induces Residual Inequality in Mobility Response

Rafiazka Millanida Hilman[1], Manuel García-Herranz[2], Vedran Sekara[3], and Márton Karsai[1]
[1]Department of Network and Data Science, Central European University, 1100 Vienna, Austria
[2]UNICEF Innovation Office, 10017 New York, USA
[3]Department of Computer Science, IT University Copenhagen, 2300 Copenhagen, Denmark

City as Resilient System

How adjustment in mobility is made by individual in terms of spatial and socioeconomic space in response to external shock?

cuebiq

United States Census Bureau

Office for National Statistics

DANE

BADAN PUSAT STATISTIK

BLAVATNIK SCHOOL OF GOVERNMENT | UNIVERSITY OF OXFORD | OXFORD COVID-19 GOVERNMENT RESPONSE TRACKER

City as Resilient System

Figure 1

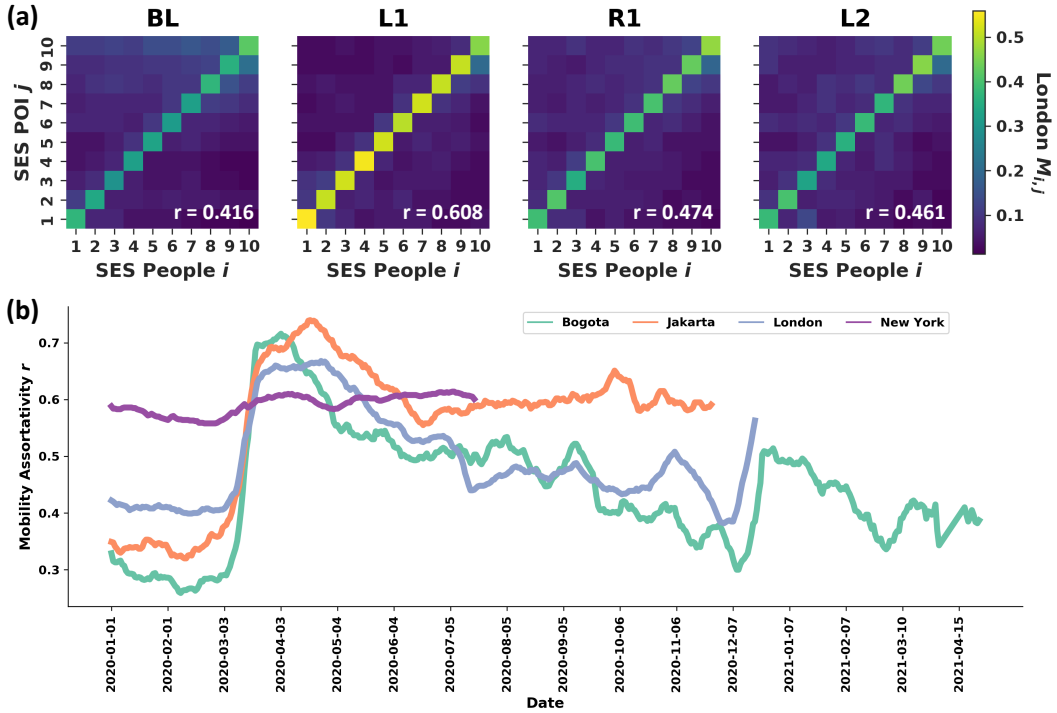
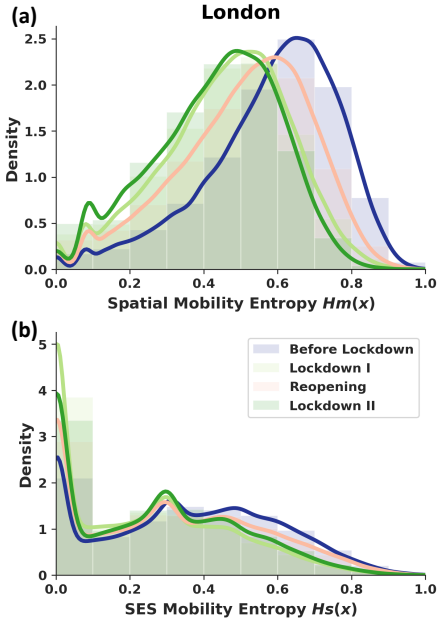
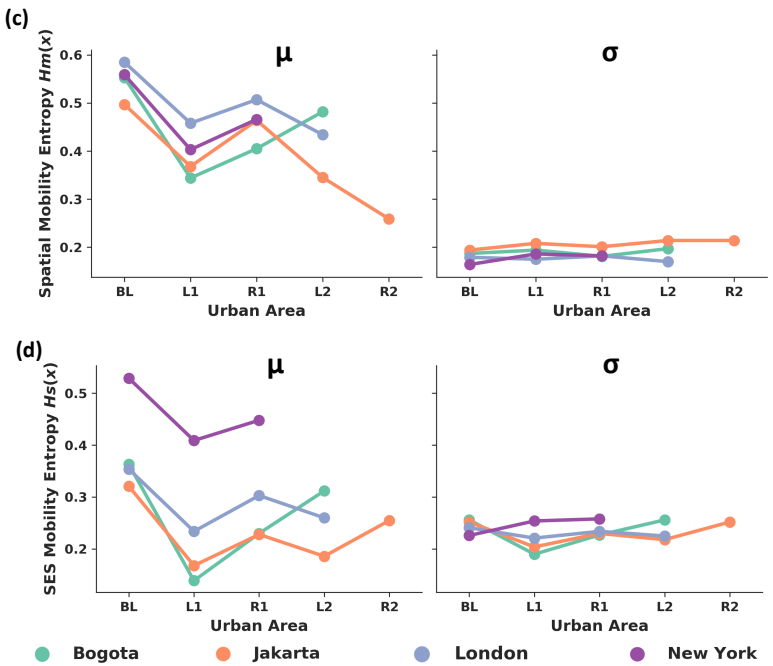


Figure 2





- The first lockdown induced considerable increase in mobility segregation, but the attempt to loosening mobility restriction did not necessarily diminish isolation within own neighbourhood, indicating that recovery is not fully made.
- Persistently lower heterogeneity in both locations and socioeconomic status of places visited by individual is also visible.

Stratified Mobility, Segregated Boundary, and Socioeconomic Mixing in New York

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Department of Urbanism, Delft University of Technology, 2628 CD Delft, The Netherlands

City as Modular System

How does human activity and urban structure shape the changing dynamics of stratified mobility flows?

SAFEGRAPH

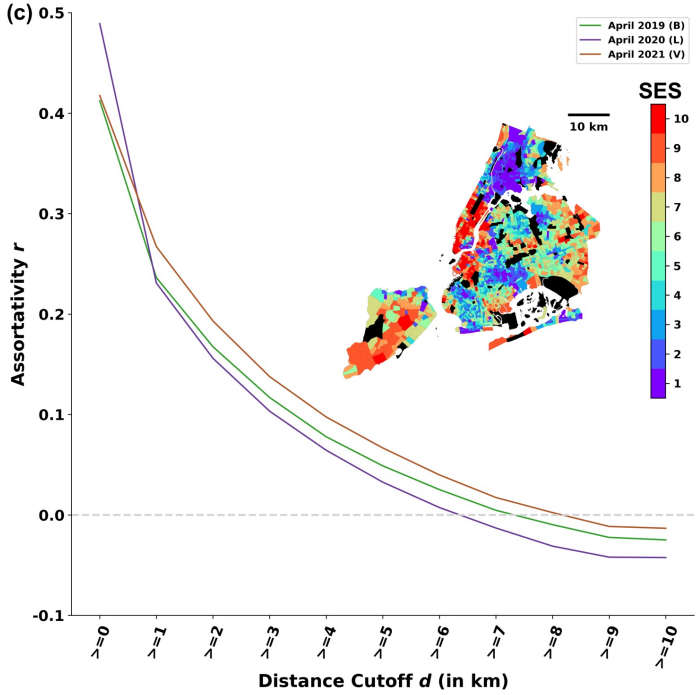
NYC OpenData

GTFS

OpenStreetMap

City as Modular System

Figure 1



$$T_{ij} \propto \frac{P_i P_j}{r_{ij}}$$

Gravity Model

Figure 2

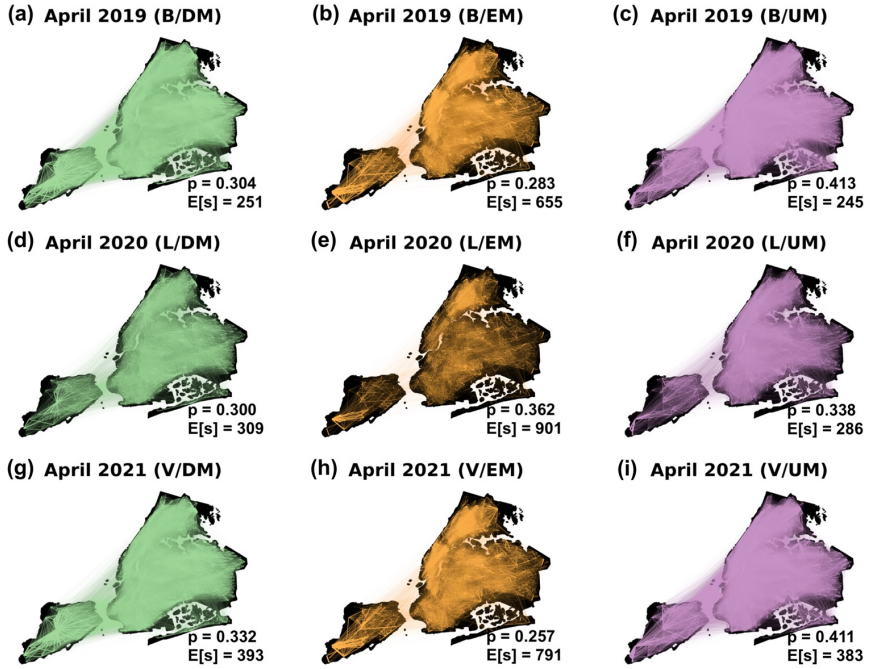
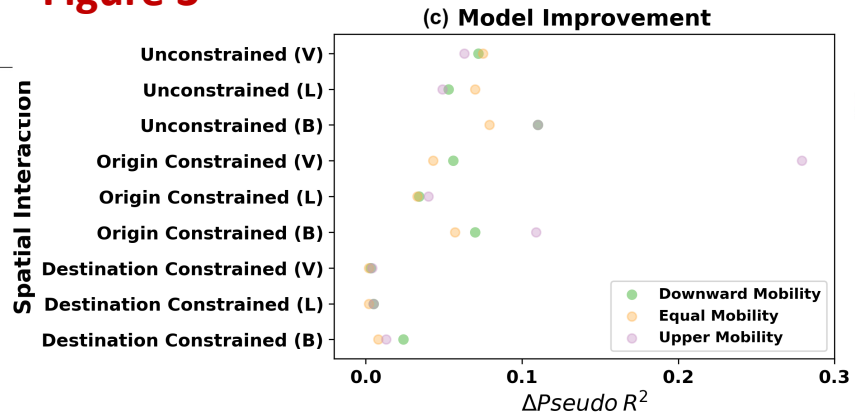


Figure 3



- Higher assortative mobility pattern driven by socioeconomic similarity occurs in short-distance trips (0<d<1).
- Higher assortative mobility permeates during lockdown (April 2020) as restrictions were imposed.
- Urban System Model performs better in predicting mobility flows.

Multiscale Spatial Distribution of Economic Diversity in New York

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City as Fractal System

How to quantify the sectoral effects of size, spatial, and scale that induces economic diversity?

SAFEGRAPH

NYC PLANNING

City as Fractal System

Figure 1

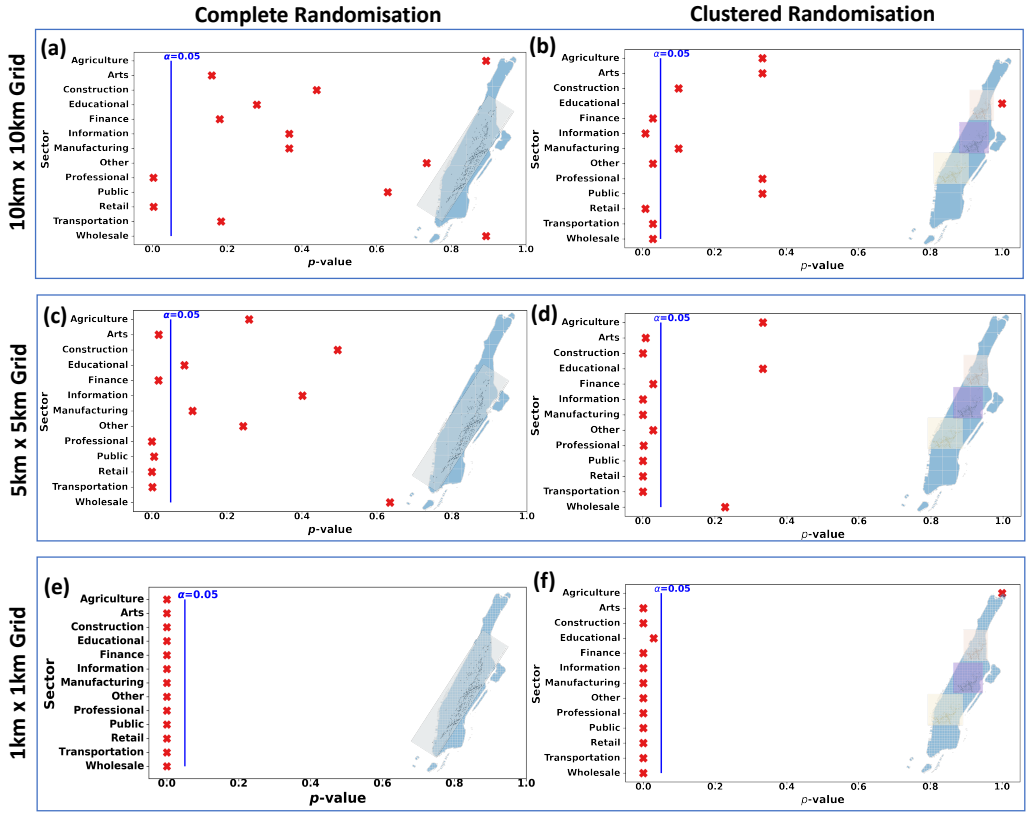


Figure 2

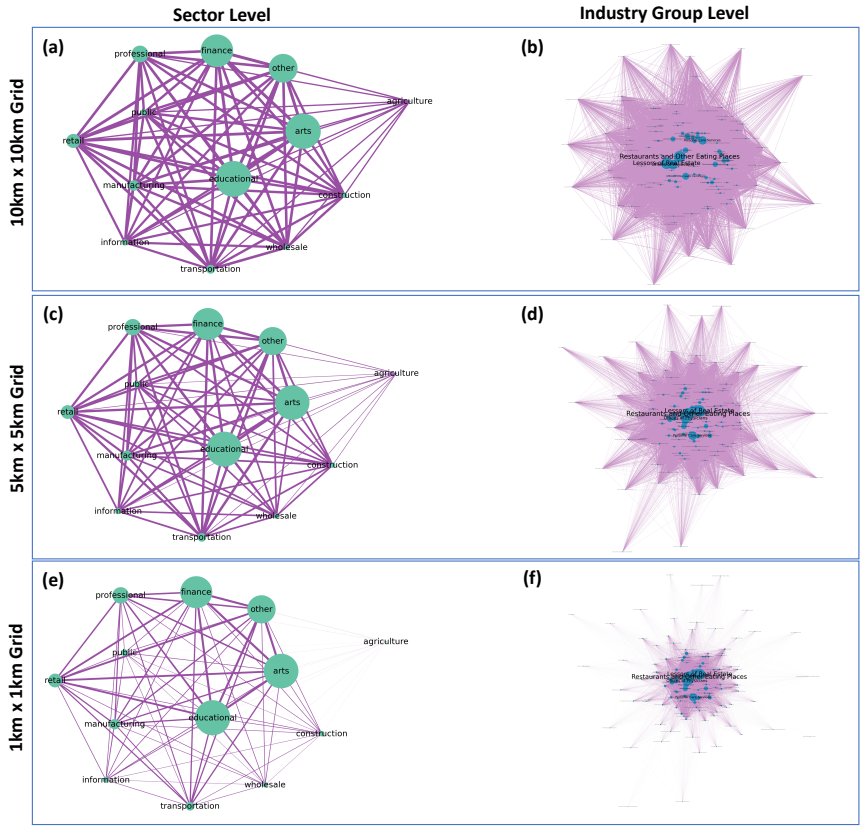
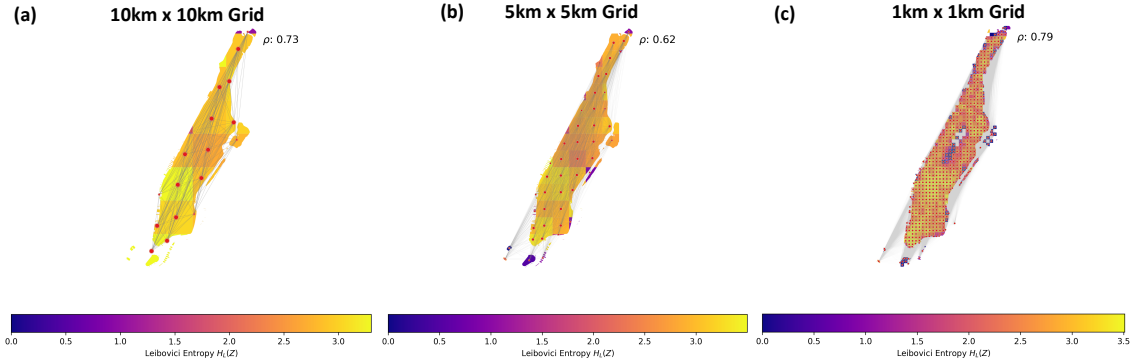


Figure 3



- Robust structure regardless spatial grid resolution: strong closely connected main nodes: arts, educational, finance, and other.
- High correlation between leibovici entropy and betweenness centrality → the importance of economic diversity in determining the centrality of each area → mediating the business interconnection across sectors.

Thank You

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