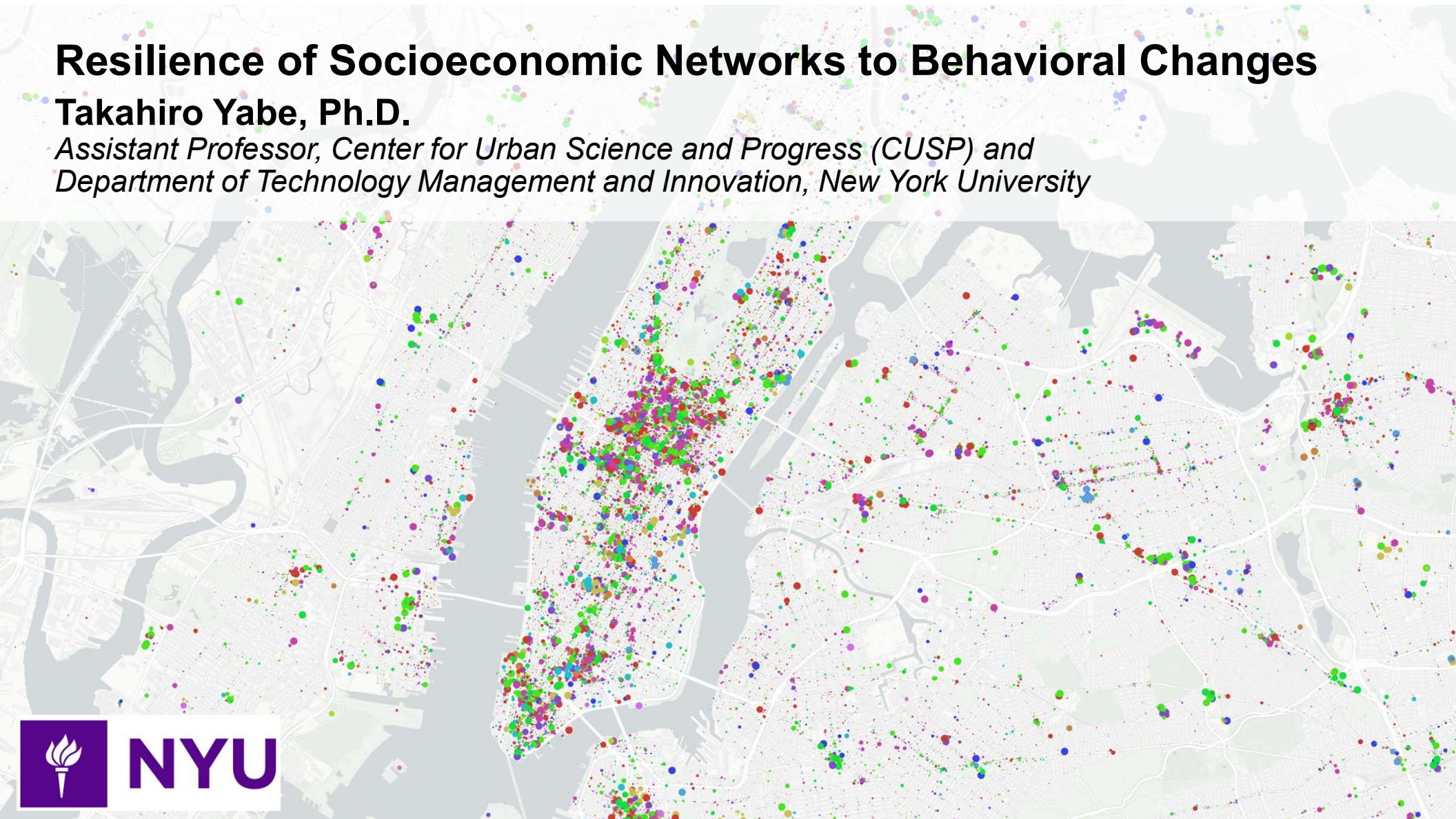


Resilience of Socioeconomic Networks to Behavioral Changes

Takahiro Yabe, Ph.D.

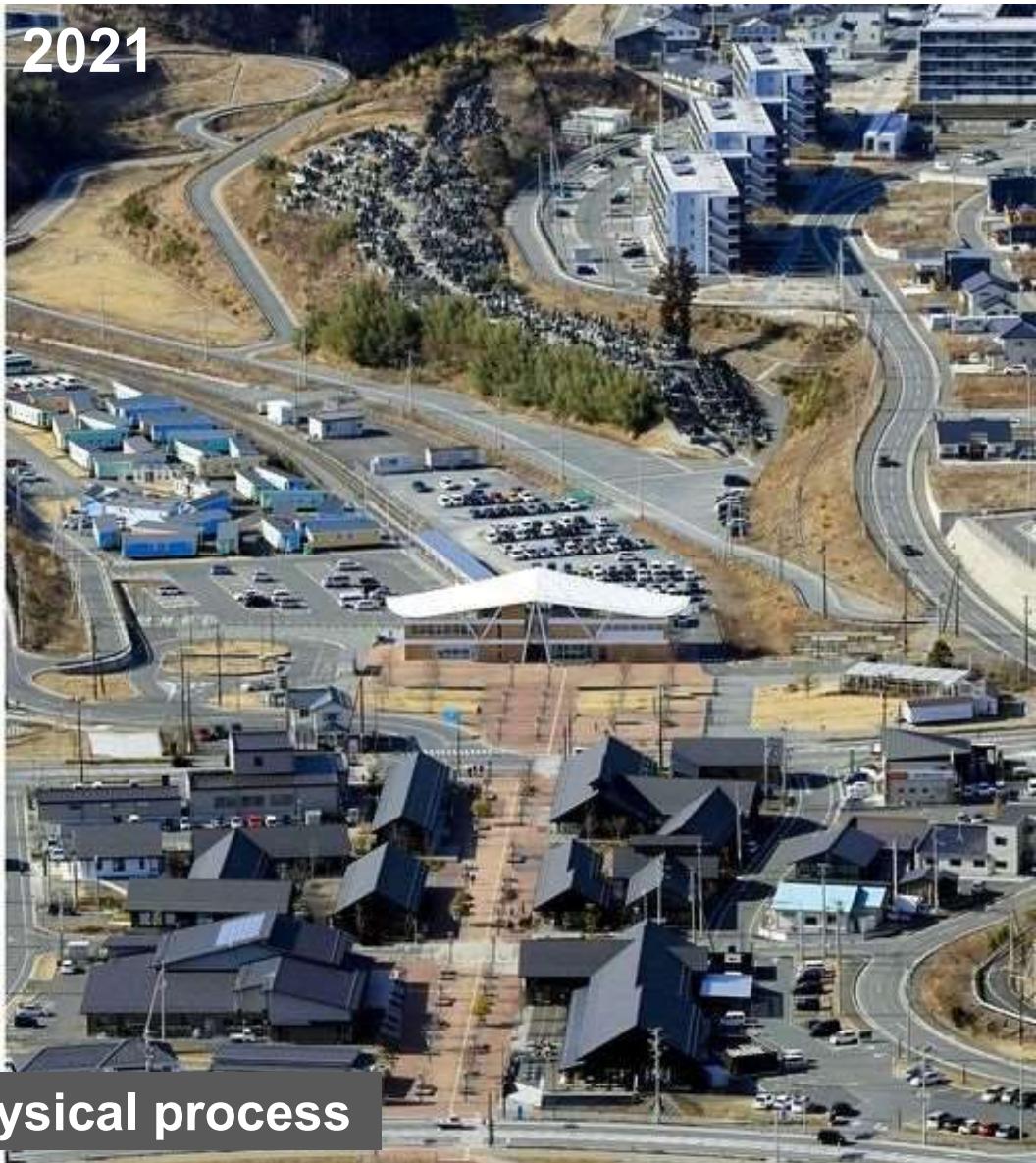
*Assistant Professor, Center for Urban Science and Progress (CUSP) and
Department of Technology Management and Innovation, New York University*



2011

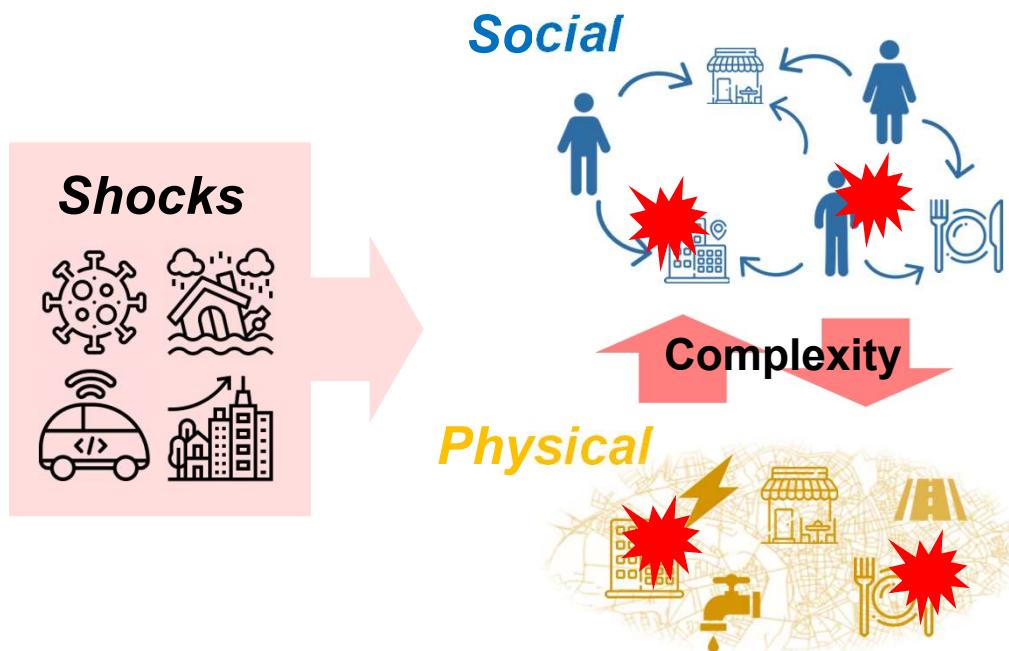


2021



Disaster recovery is a complex socio-physical process

Lab's mission: Develop counterfactual simulators of urban complex systems using data and (gen-)AI

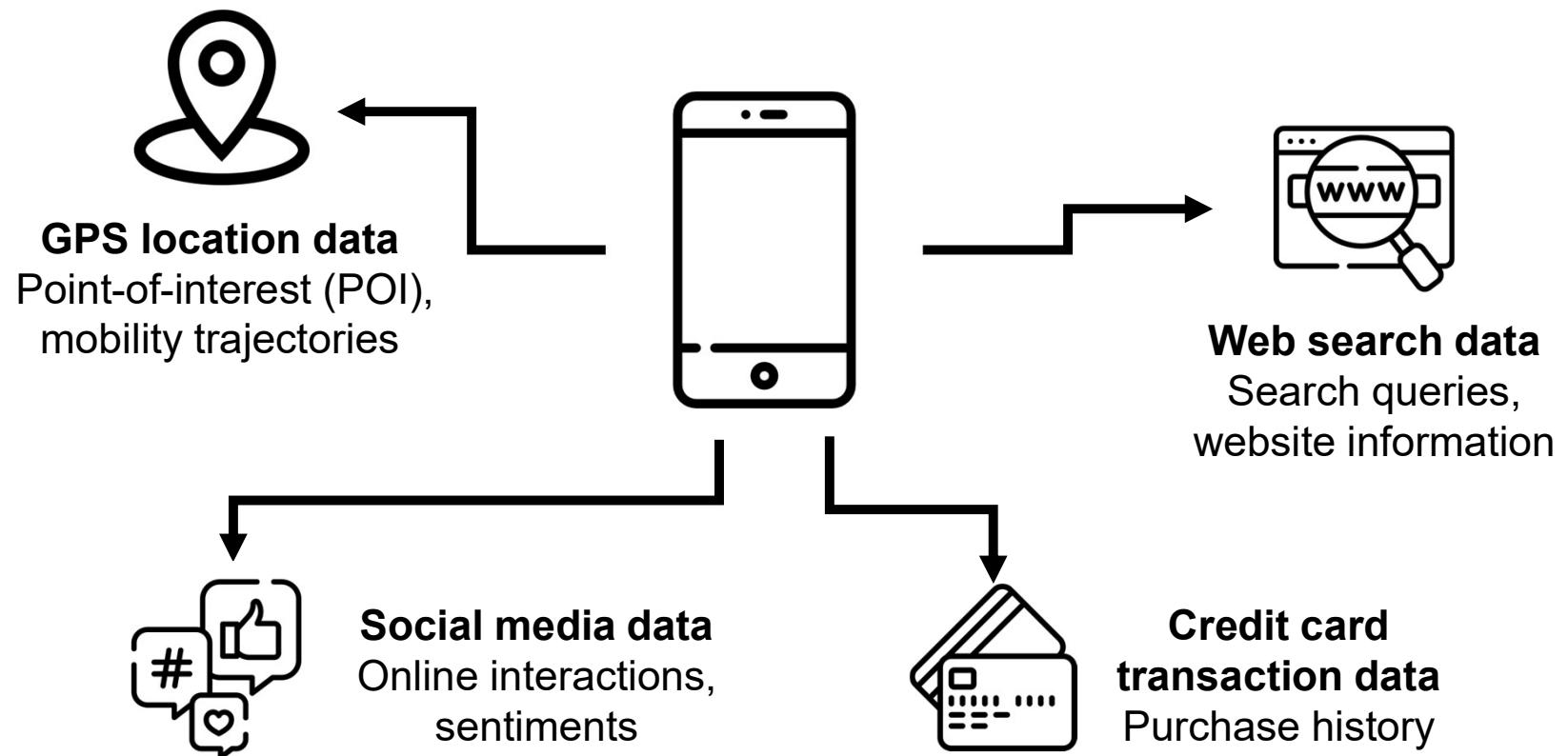


Guiding questions

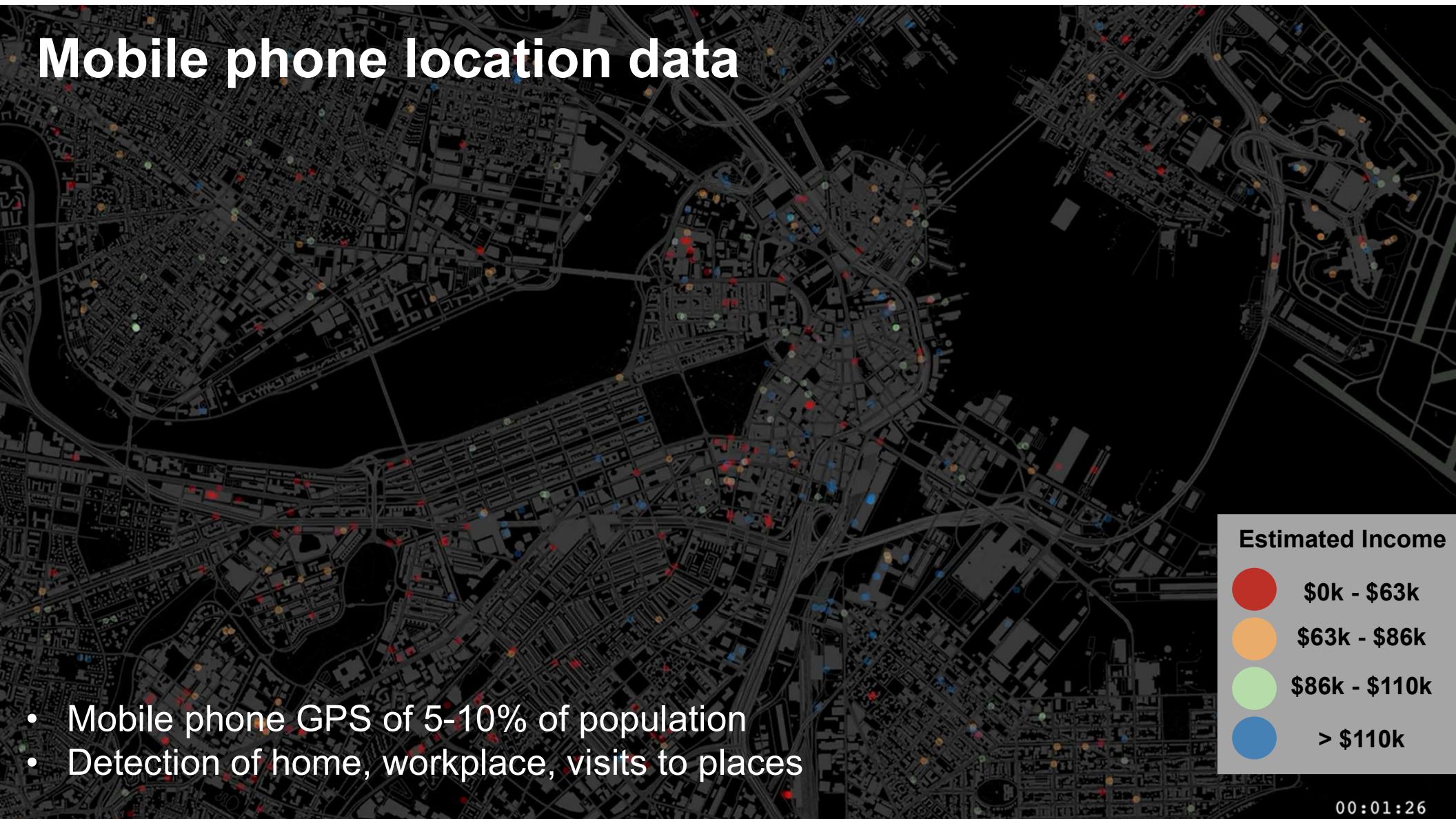
- How do disruptions cascade across time, space, systems?
- How do urban socio-physical systems re-organize, adapt, and find its new equilibrium?
- How can we determine effective urban interventions?

Predicting behavioral changes and economic impacts under hypothetical scenarios (e.g., disasters, redevelopment)

Fortunately, ... Opportunities in novel human behavior data



Mobile phone location data



- Mobile phone GPS of 5-10% of population
- Detection of home, workplace, visits to places

Research topics related to civil & urban engineering

Activities and mixing in urban spaces



- Joint work with NYC Parks
- How can we create parks that foster social interactions?
- Experienced segregation during the pandemic (*Nature Comms* '23)
- Predictability of income growth (*Nature Cities* 2024)

Resilience of economic systems



- Work with Downtown Brooklyn
- How can we prepare local business networks for future shocks?
- Dependency network shapes resilience (*Nature Hum. Behav.* 2024)
- Resilience of coupled socio-physical systems (*PNAS* 2022)

Hypothetical disaster mobility patterns



- Work with CrisisReady (NGO)
- Simulating disaster mobility patterns using generative AI
- Towards open benchmark datasets (*Nature Computational Science* 2024)
- Homogeneity of road network (*Nature Machine Intelligence* 2022)
- Cross-city learning (*KDD* 2022, 2020)



Article

<https://doi.org/10.1038/s41562-024-02072-7>

Behaviour-based dependency networks between places shape urban economic resilience

Received: 29 November 2023

Takahiro Yabe , Bernardo García Bulle Bueno¹, Morgan R. Frank ,

Accepted: 22 October 2024

Alex Pentland & Esteban Moro

Published online: 23 December 2024

Disruptions, such as closures of businesses during pandemics, not only affect businesses and amenities directly but also influence how people move, spreading the impact to other businesses and increasing the overall economic shock. However, it is unclear how much businesses depend on each other during disruptions. Leveraging human mobility data and





High dependency of customers from offices

The Business Lunch May Be Going Out of Business

As remote work persists and business deals are sealed online, many upscale restaurants that catered to the nation's downtown office crowd are canceling the meal.

(*New York Times*, July 11 2022)

Similarly, nearby restaurant closed as well



... due to high dependency of customers from MIT

Hypothetical scenario: If a bus stop closes, how would local restaurants be affected?



**Can we measure such dependency relationships
& predict resilience to shocks?**

We quantify dependency using % of common visitors

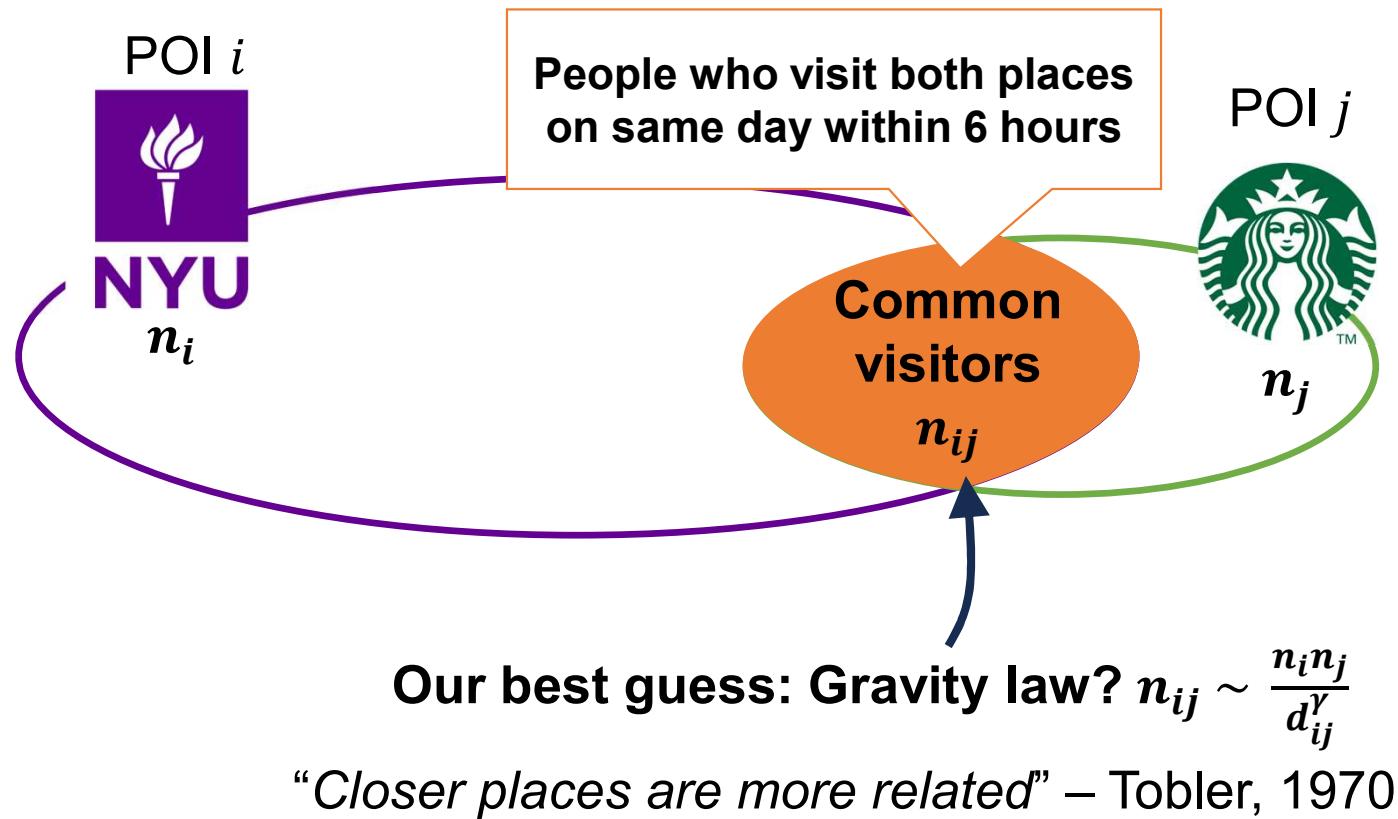


$$\text{Dependency: } w_{i \rightarrow j} = \frac{n_{ij}}{n_i}, \quad w_{j \rightarrow i} = \frac{n_{ij}}{n_j}$$

= “What % of customers at Starbucks comes from NYU?”

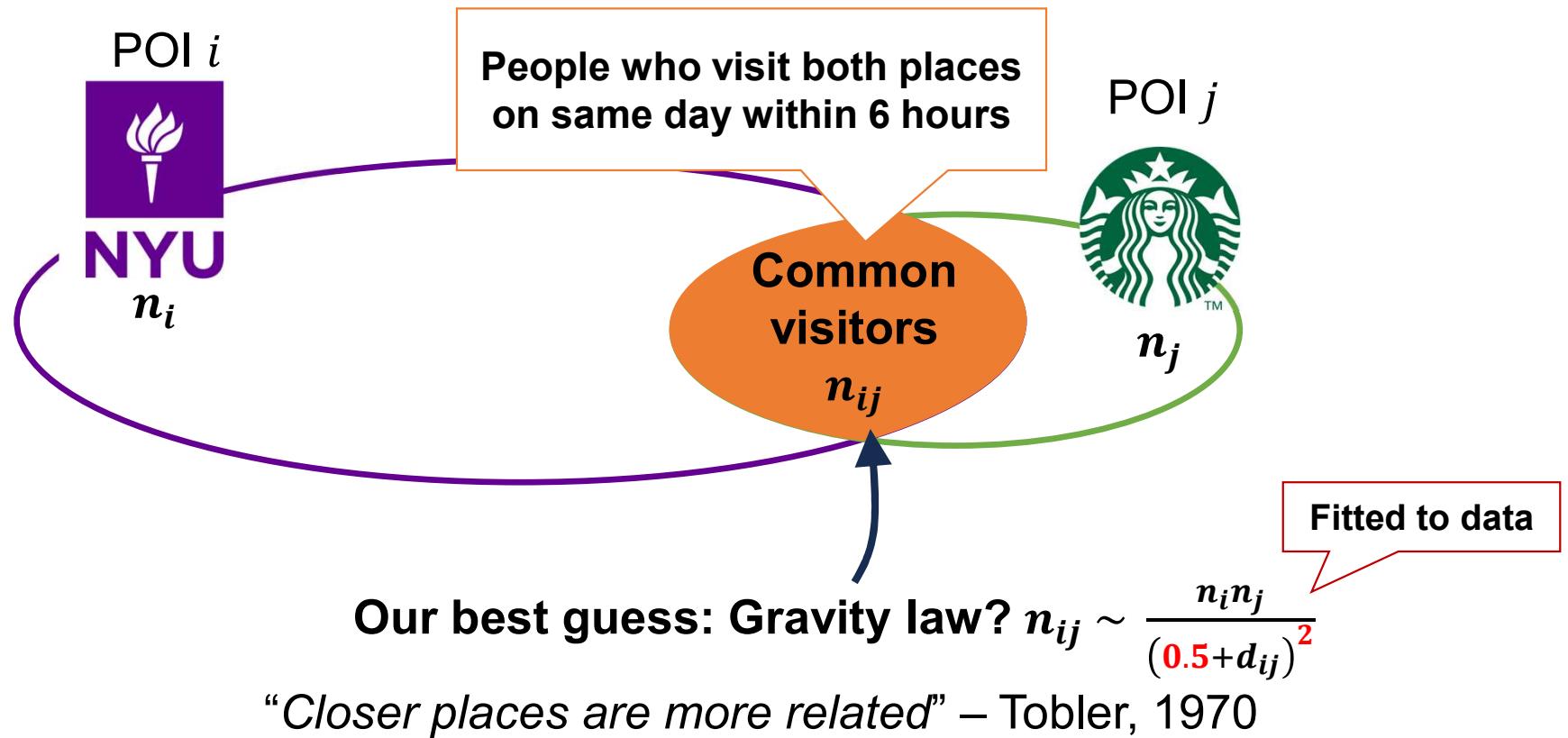
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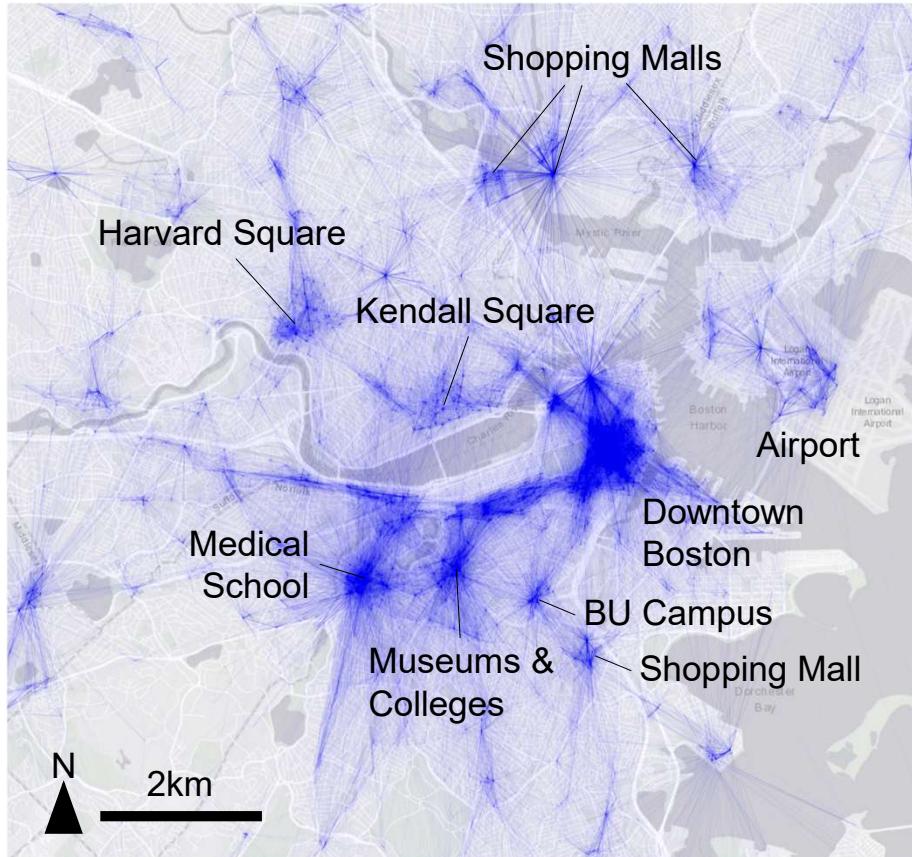
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We quantify dependency using % of common visitors

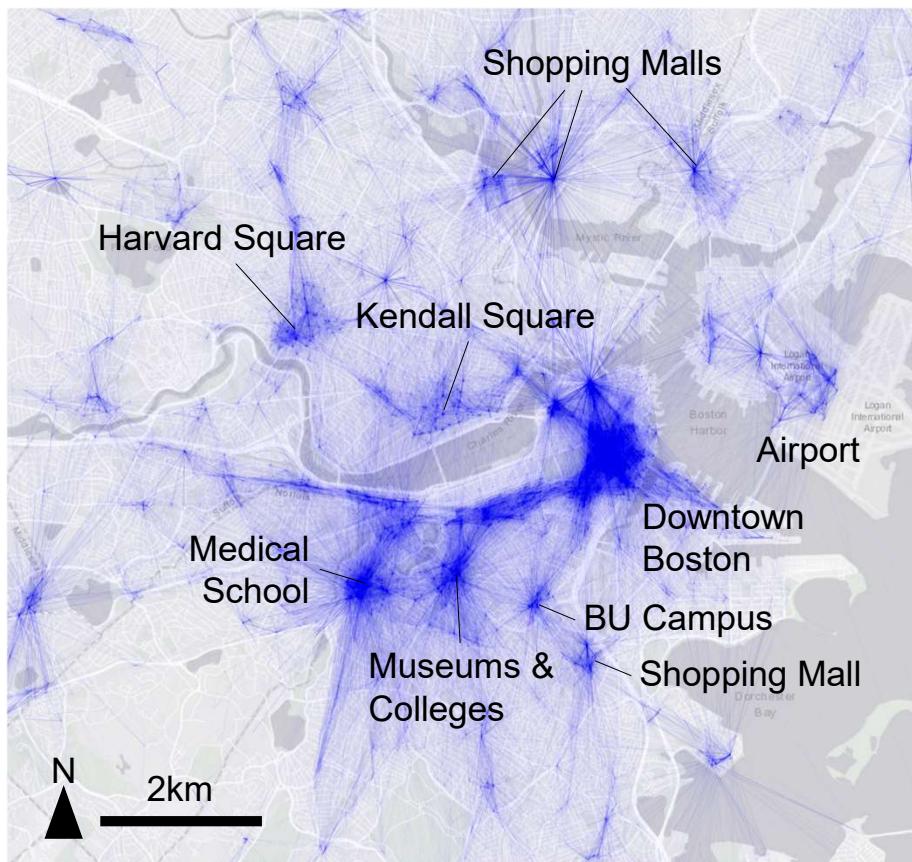


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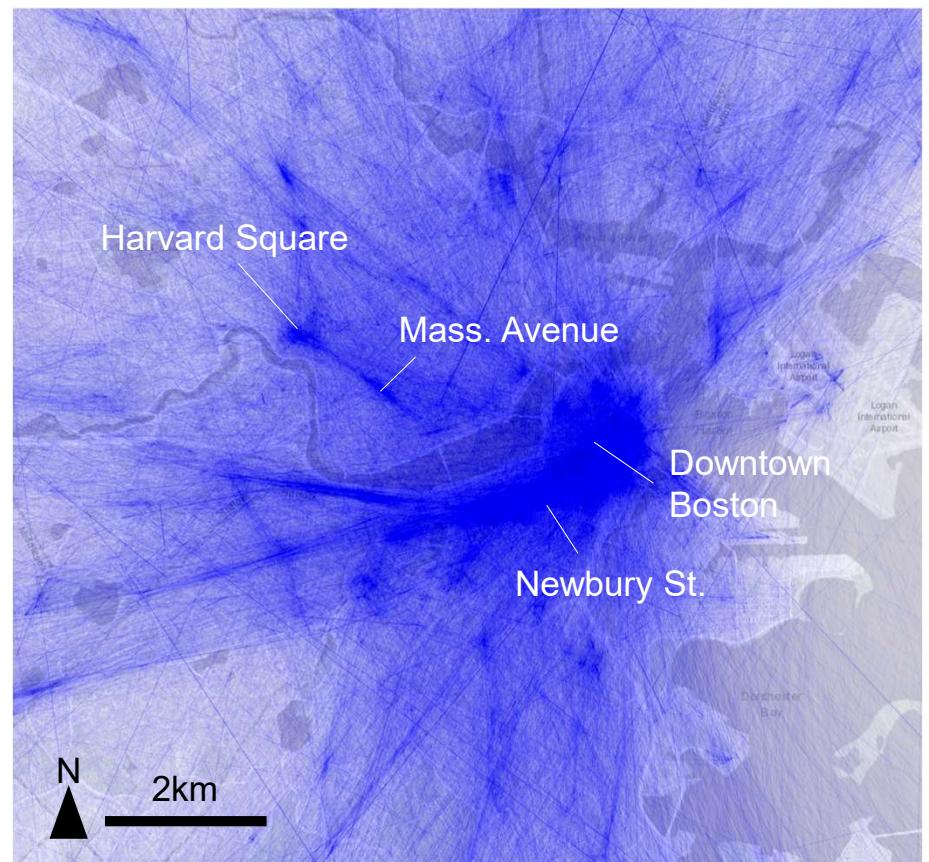
Gravity-based null network (Boston)



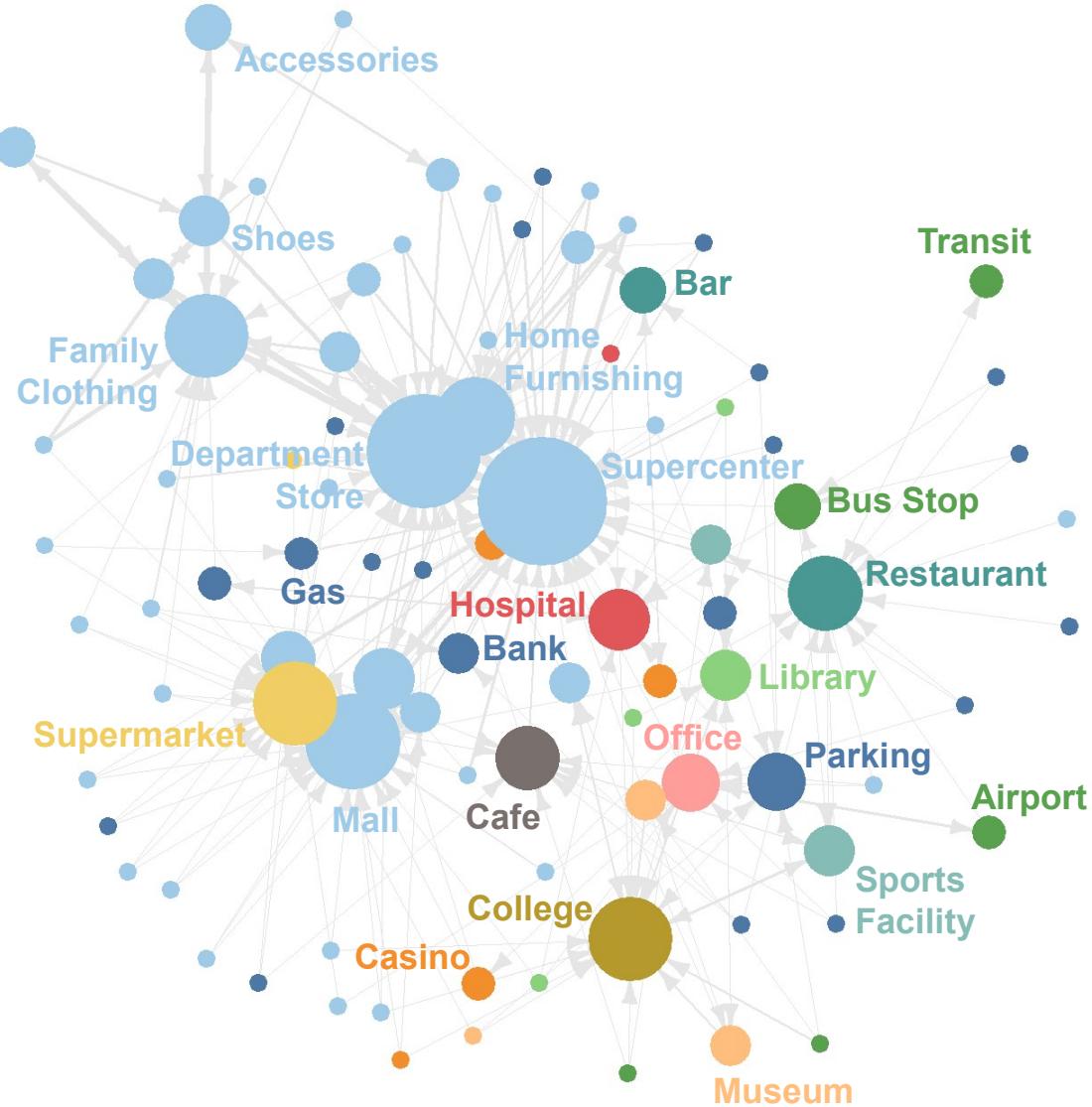
Gravity-based null network (Boston)



Empirical dependency network based on human mobility data (Boston)

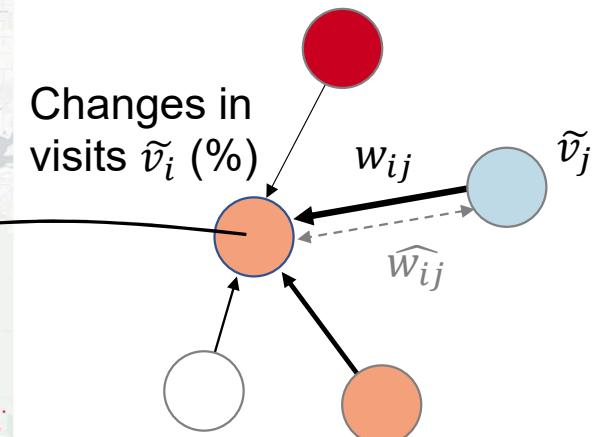
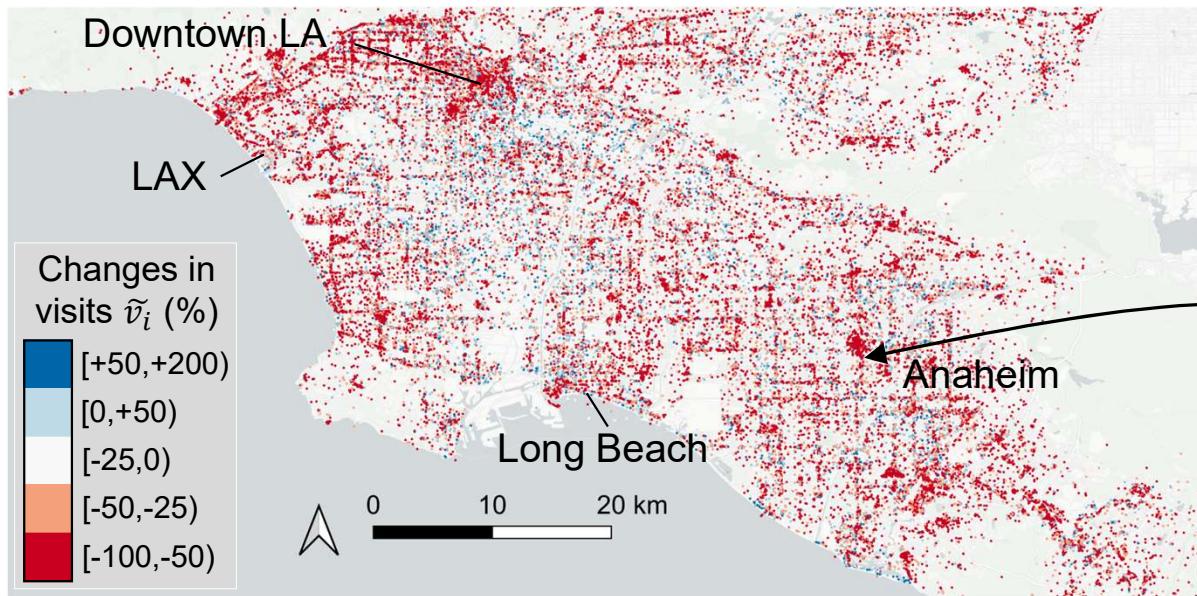


More long-distance dependencies, less local clustering!



- Supercenters and department stores dominate US cities
- Colleges, restaurants, cafes highly depended places

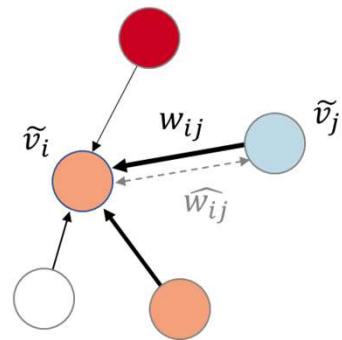
Predicting COVID-19 effects on businesses using dependency network



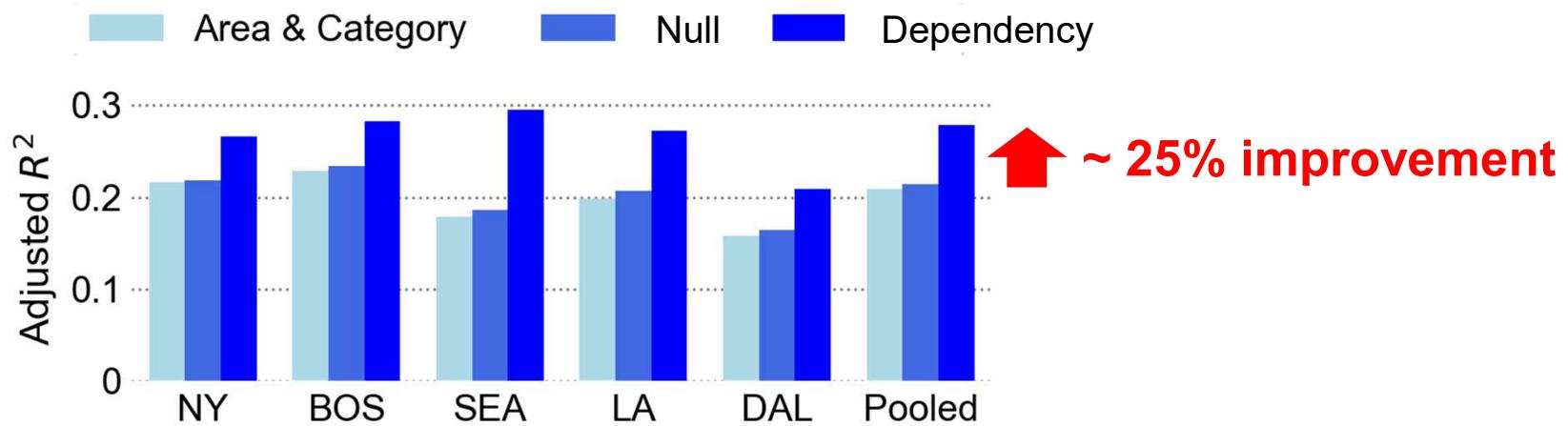
$$\text{Changes in visits to POI } i \text{ during COVID} \rightarrow \tilde{v}_i \sim \beta \underbrace{\sum_j w_{ij} \tilde{v}_j}_{\text{Weighted effects of alter nodes}} + \gamma_{\text{Category}_i} + \xi_{\text{Area}_i}$$

Category & area fixed effects

Improvement in model performance using dependency weights over distance-based weights



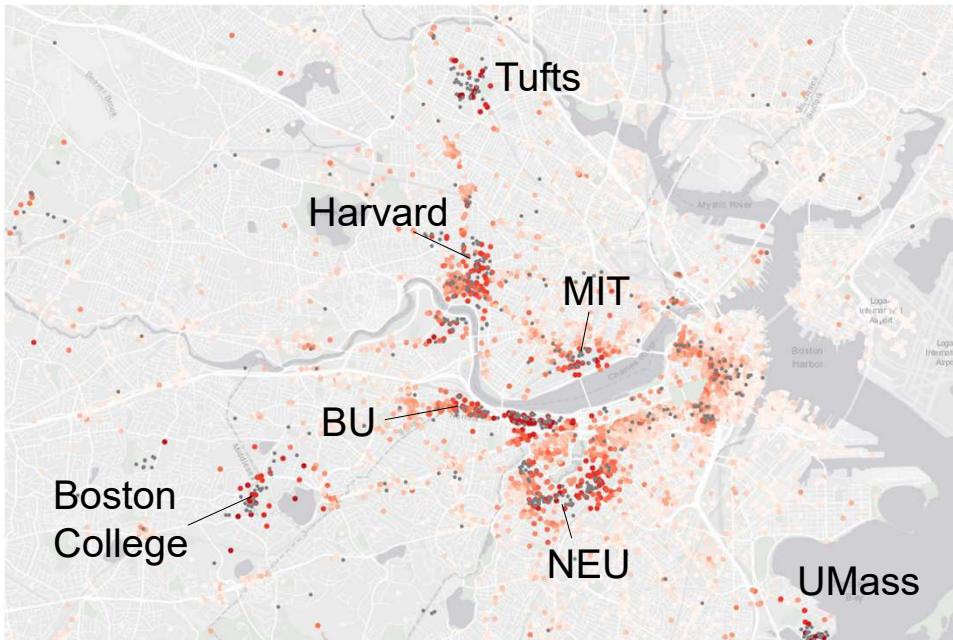
$$\tilde{v}_i \sim \beta \sum_j w_{ij} \tilde{v}_j + \gamma_{Category_i} + \xi_{Area_i}$$
$$\tilde{v}_i \sim \beta \sum_j \widehat{w}_{ij} \tilde{v}_j + \gamma_{Category_i} + \xi_{Area_i}$$



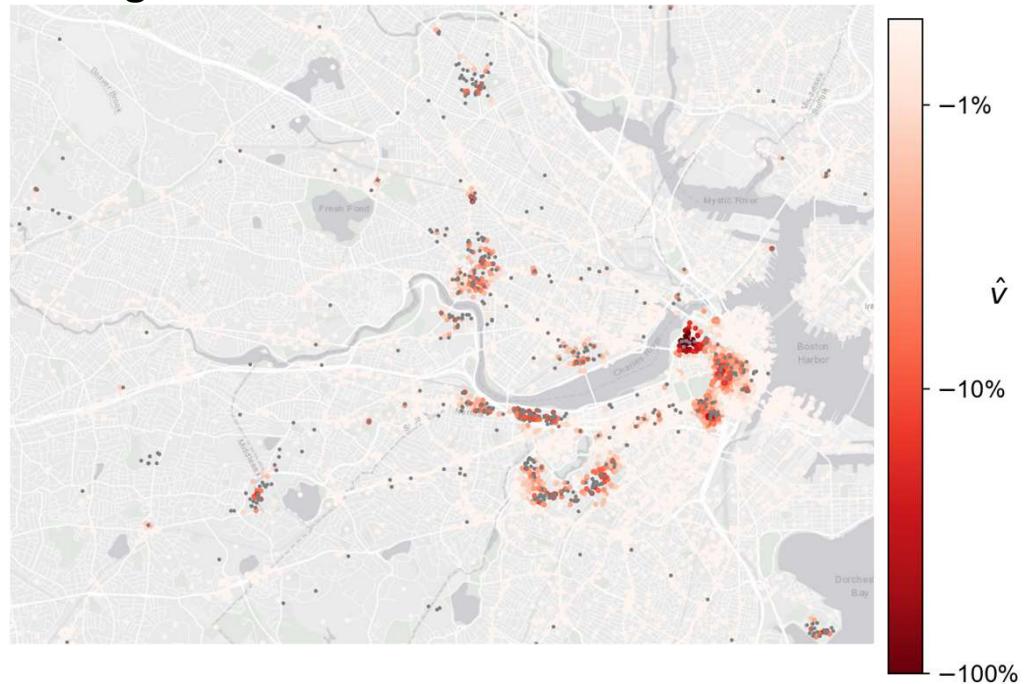
Propagation of shocks on dependency networks produce greater spillover effects

Spillover effects of 50% visit reduction to colleges using input-output:

Using the dependency network



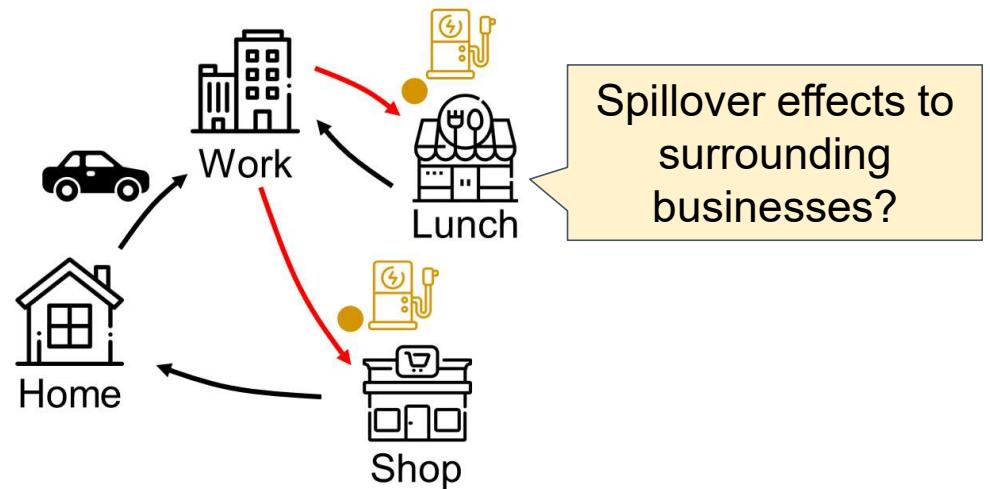
Using the distance network



Yabe, Takahiro, et al. "Behaviour-based dependency networks between places shape urban economic resilience." *Nature Human Behaviour* 9.3 (2025): 496-506.

Applications in urban transport planning Community-centric EV charging infrastructure

Q. how can we design EV charging infrastructure and behavioral incentives that benefits the community & local small and medium businesses?



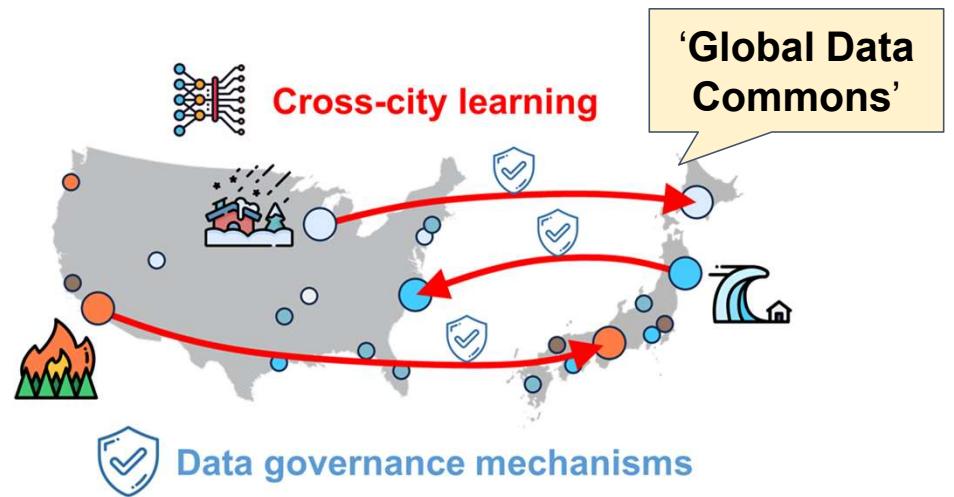
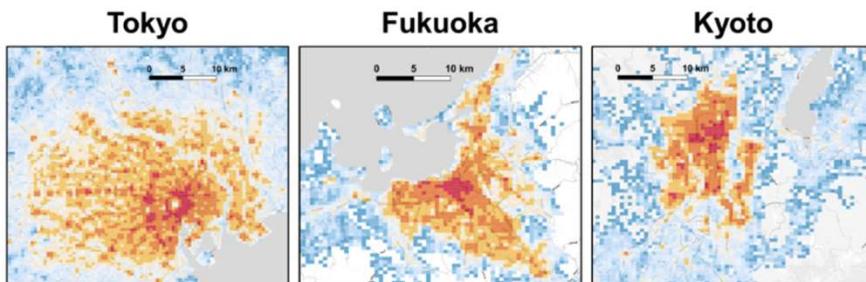
Collaborators:

- Prof. Joseph Chow (NYU)
- Prof. Jing Li (Tufts)
- Prof. Esteban Moro (NEU)



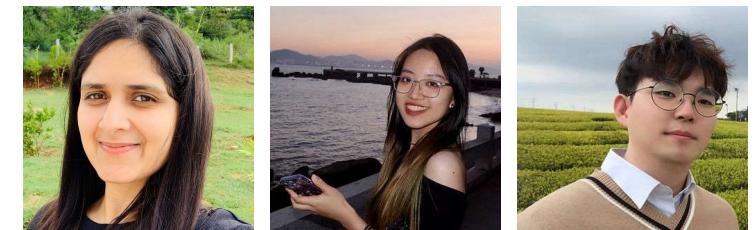
Ongoing project: Language model-driven simulation of human mobility patterns

Q. Can we simulate mobility dynamics using language based models, especially in unprecedented disaster scenarios?



Collaborators:

- Prof. Stefaan Verhulst (NYU)
- Prof. Jinhua Zhao (MIT)



GIS CUP 2025: Human Mobility Prediction Challenge

Takahiro Yabe New York University; Kota Tsubouchi, Toru Shimizu LY Corporation



- **Democratize & benchmark**
- Open data of individual human mobility derived from mobile phone data
 - >120,000 anonymized individuals, Over 60 days
- Task: prediction of future human mobility patterns
- Submission deadline: Sep 10



A screenshot of the ACM SIGSPATIAL Cup 2025 website. The header features the ACM SIGSPATIAL logo and the text "ACM SIGSPATIAL Cup 2025". Below the header is a navigation bar with links for Home, Problem, Dataset, Submission, Organizers, and FAQ. The main content area displays the text "ACM SIGSPATIAL Cup 2025: Human Mobility Prediction Challenge".

>150 teams, >400 participants in past 2 editions



Thank you!

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Resilient Urban Networks Lab members



Vaidehi Raipat



Callie Clark



Mavin De Silva



DongHak Lee



Malik Salman



Jiayi Weng



Mehak Sachdeva



Marcel Moran



Zhaoxi Zhang

PhD MS CUSP postdocs

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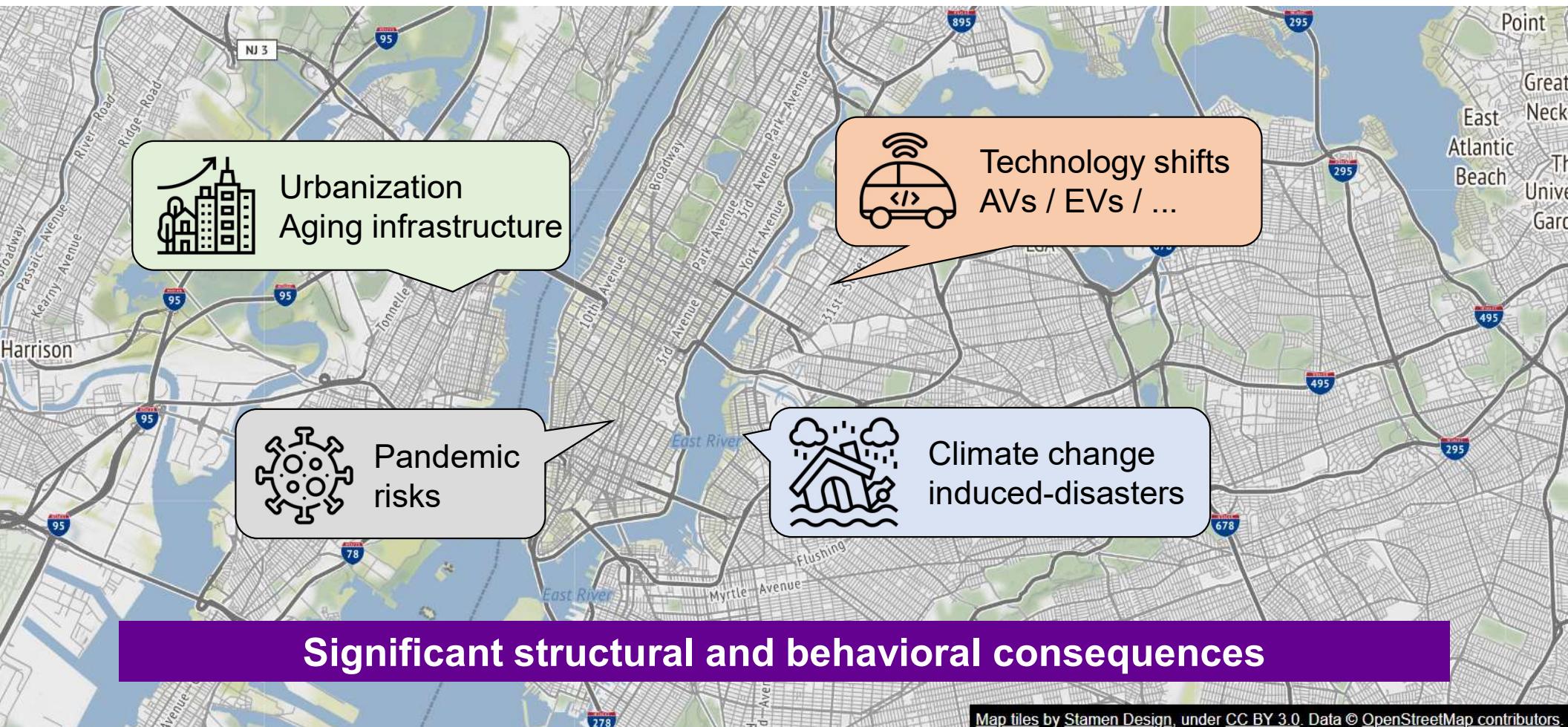
Resilient Urban Networks Lab



Center with ~20 faculty from CS, Eng, social science, ...



Cities are facing diverse and compounded challenges



Human behavior and social networks could amplify or alleviate the impact of shocks



Social influence, trust, misinformation is crucial in tsunami evacuation



Remote work
devastating local
businesses

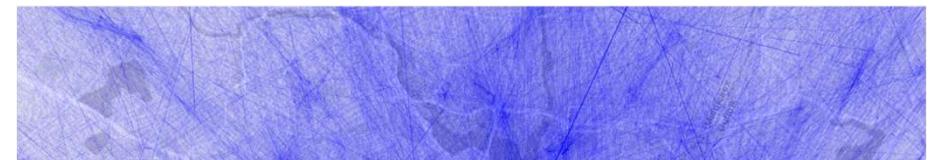


... But open streets could
boost local economy

Gravity-based null network (Boston)

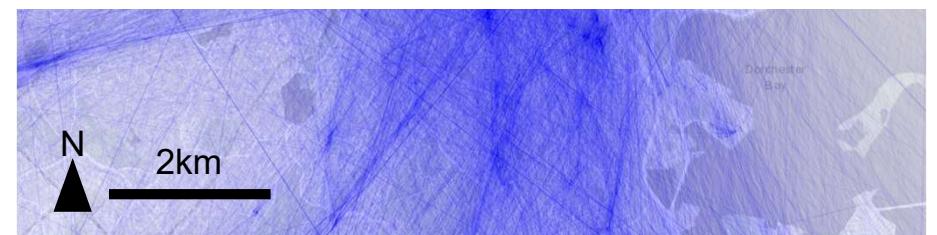


Empirical dependency network based on human mobility data (Boston)



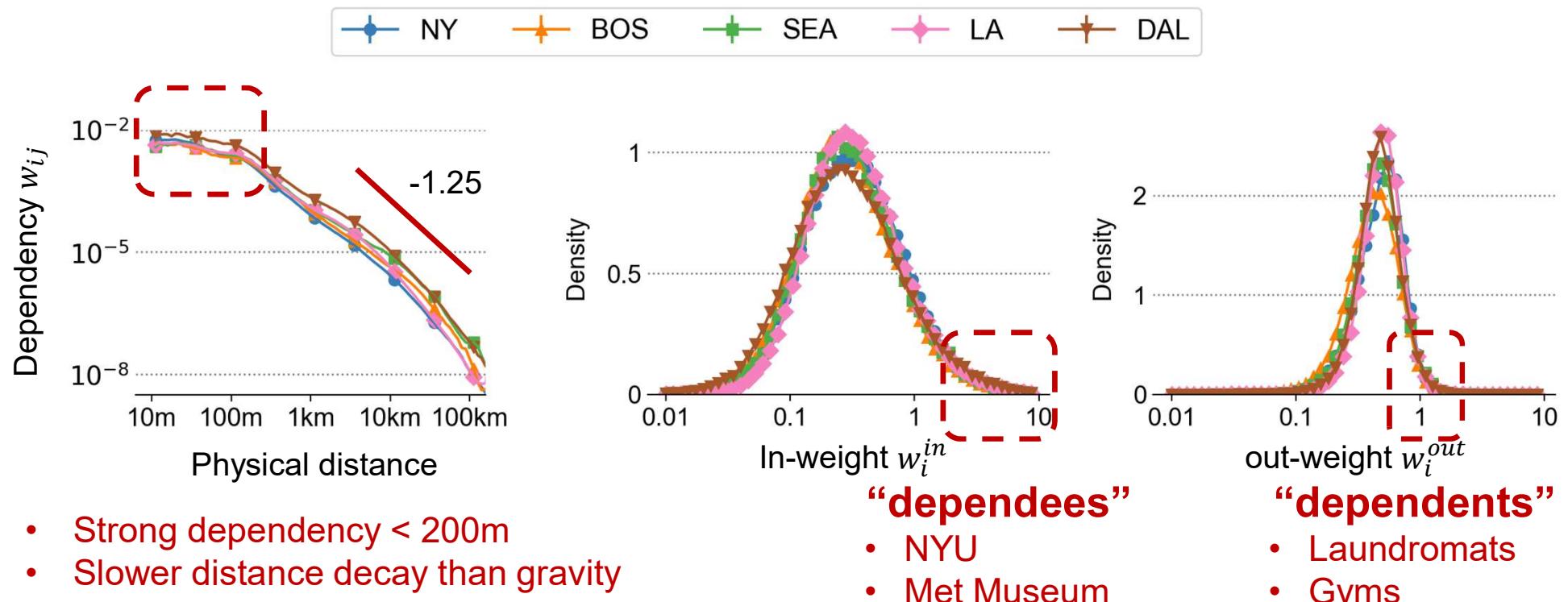
Today's talk:

- Network characteristics of the dependency network
 - Network properties: role of distance?
 - What industries are connected?
- Can it model shock cascades better?
- What consequences does this have?



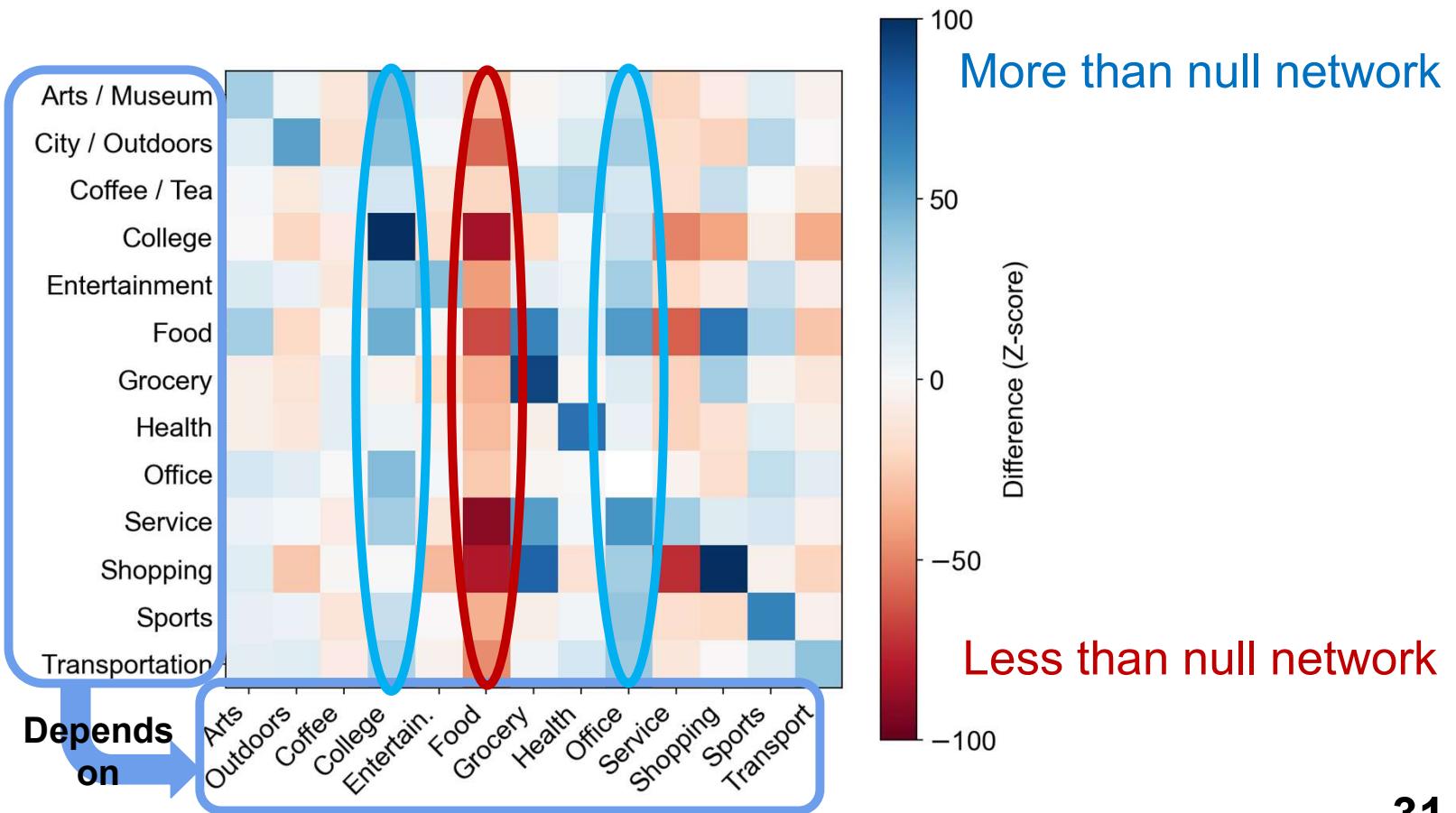
More long-distance dependencies, less local clustering!

Similar network characteristics across cities



Yabe, Takahiro, et al. "Behaviour-based dependency networks between places shape urban economic resilience." *Nature Human Behaviour* 9.3 (2025): 496-506.

Category pairs with excessive dependency compared to gravity null network



Can we model economic shock cascades better than co-location based models?



The Business Lunch May Be Going Out of Business

As remote work persists and business deals are sealed online, many upscale restaurants that catered to the nation's downtown office crowd are canceling the meal.

(*New York Times*, July 11 2022)

Invisible Urban Dependencies

How human behavior shapes economic resilience in cities

Places within cities are deeply interconnected, relying on each other through the flow of people and shared patronage, creating complex dependency networks between them. Leveraging large-scale mobility data, our research shows how businesses, amenities, and other urban points of interest (POIs) depend on each other, revealing connections that aren't always visible but have substantial economic impacts.

By analyzing these behavior-based dependency networks, we demonstrate how changes in foot traffic to one location—whether from temporary closures or shifts in consumer behavior—can affect the resilience of surrounding and far-away businesses. The dashboard offers interactive insights into these patterns, enabling users to see the reach of these dependencies, anticipate cascading effects, and explore strategies for fostering resilient, robust, adaptable urban systems.

Start →

Winchester
A story map by SUNLab at Northeastern University



Northeastern
University

<https://www.socialurban.net/dependency/>