# *Computational Urban Science*

***Graduate course***
***NETS 7983 Topics***
Spring 2025
Max enrollment: 15
Day(s): Tuesdays 3-6:30pm

Instructors: **Esteban Moro & Hamish Gibbs**
Network Science Institute
Northeastern University
e.moroegido@northeastern.edu
estebanmoro.org

**Course Description:**
This course introduces students to the growing field of Computational Urban Science. Students will learn how to collect and critically analyze urban data using a range of techniques, including Geographical Information Systems, Network Science, Machine Learning, Spatial Models, and Causal Techniques. We will discuss how these techniques can be used by urban planners, social scientists, and urban geographers to understand the network dynamics of cities and design new interventions and policies. Students will have access to unique large datasets, offering the opportunity to work with real-world urban data. Homework assignments will involve coding in the R/Python programming languages to analyze these datasets for specific use cases. There will be a final homework assignment based on the use of large urban datasets for a specific comprehensive application covered in the course (see option list below).

**Course Learning Outcomes:**
After the course the students will be able to:

- **Collect and Analyze Urban Data**: using GIS, spatial models, spatial visualization, and network science techniques, using tools like R and Python and software libraries for visualization and analysis or urban data.
- **Use Computational Social Science tools for urban insights**: apply machine learning, spatial analysis, network science, and causal inference techniques to extract insights from urban big data.
- **Understand Urban Dynamics:** analyze complex urban phenomena like mobility patterns, social urban networks, lifestyle patterns, urban decision-making using computational models to inform urban policy and planning.
- **Develop urban data solutions:** design and implement data-driven solutions for urban challenges, such as sustainability, transportation, epidemics, resilience by creating models and simulations
- **Design and evaluate urban interventions:** use causal inference methods to evaluate the impact of interventions and policies in urban contexts.
- **Collaborate and communicate effectively:** coordinate in multidisciplinary teams to solve urban problems and communicate findings clearly through reports, decision-making tools, or participation in urban challenges.

**Prerequisites:**
Knowledge of Networks (PHYS/NETS 5116N, or equivalent), statistics (INSH 5301 or CS 6220, or equivalent), and spatial analysis (GIS) are preferred but not required.

Material and hands-on exercises during class will be in R and sometimes in Python. Thus, a good understanding and working knowledge of programming, data science, and statistical tools is recommended, especially in R. Contact the instructor if you are uncertain about your background or need some material to get up to speed with R.

**Instructors:**
**Esteban Moro** is a full professor and director of the Social Urban Networks (SUN) group at the Network Science Institute at Northeastern University and affiliated faculty at the MIT Media Lab. He was previously a professor and researcher at the Department of Mathematics at Universidad Carlos III de Madrid, the Sociotechnical Systems Research Center at MIT, and the University of Oxford. He holds a Ph.D. in Physics. Esteban's work lies in the intersection of big data and computational social science, with particular attention to human dynamics, collective intelligence, social networks, and urban mobility in problems like viral marketing, natural disaster management, or economic segregation in cities. He has received numerous awards for his research, and his work has appeared in major journals and is regularly covered by media outlets.

**Hamish Gibbs** is is a Postdoctoral Researcher in the Social and Urban Networks Group. His research focuses on identifying and mitigating biases in large-scale mobile phone data to enhance their reliability and effectiveness for monitoring human mobility. His work aims to improve the accuracy of mobility data as a tool for informing public policy decisions, with a focus on public health emergencies. During the COVID-19 pandemic, Hamish worked as a research assistant at the London School of Hygiene and Tropical Medicine. He received his PhD from University College London where his thesis focused on addressing bias in large-scale mobility datasets, using mobility data for infectious disease modeling, and improving the privacy of mobility data used in public health emergencies.

**Schedule:**

*Intro*

- [Week 1] Why urban areas? Urban areas are becoming more important due to larger cities and the increasing availability of data.
- [Week 1] Why this course? Geographical and spatial thinking: everything happens somewhere, and urban dynamics are distinct from other problems:
  - Spatial data and models differ in origin, analysis, and interpretation.
  - Urban areas are complex: urban social problems are intertwined and networked.
- [Week 1] How? Beyond the “what”: using Urban Big Data and Computational Social Science to uncover the “why.” Inference and causal techniques for urban problems.

*Urban Data*

- [Week 2] Geographical: Maps, Open Street Map, Points of Interest.
- [Week 2] Context: Census Data, Satellite Data (Pollution/Weather).
- [Week 3-4] Activity: Mobile phone data (Location-based services, GPS, CDR, etc.), mobility data (Census data), geo-localized social media data, credit card data, etc.
- [Week 4] Legal/Ethical considerations: representativity, bias, privacy, legal frameworks.

*Computational Methods for Urban Data*

- [Week 5] Analysis:
  - Geographical Information Systems (GIS).
  - Visualization and processing of urban data.
  - Spatial and demographic clustering.
  - Semantic analysis of mobility traces, flows, areas, and user behaviors.
- [Week 6] Inference:
  - Spatial and urban machine learning.
  - Predictability and uncertainty of urban behaviors.
  - Spatial regressions/machine learning/deep learning methods for urban problems.
  - Algorithmic fairness for urban data.
- [Week 6-7] Causal:
  - Experiments, quasi-experiments, natural experiments in urban problems.
  - Regression discontinuity, DiD (Difference-in-Differences), instrumental variables for urban spatial data.
  - Causal evaluation of interventions in urban areas.

>> Assignment 1 announced after week 6. Due week 8.

*Models for Urban Systems:*

- [Week 8] Mobility models for groups and individual urban behavior: Gravity, Exploration and Preferential Return, Radiation models, Deep Learning models.

- [Week 9] Social Models: Spatial Social Networks, Spatial Segregation Models.
- [Week 9] Network models: Spatial Networks, mobility flow networks.
- [Week 10] Agent-based models: Transportation models, segregation models, epidemics.
- [Week 10] Hypothesis testing and counterfactuals using urban models.

>> Assignment 2 announced after week 10. Due week 12.

*Applications*

- [Week 11] Recommendation / Geomarketing in Urban areas.
- [Week 12] Sustainability / Environmental justice.
- [Week 12] Residential and behavioral segregation / Inequality
- [Week 13] Epidemic spreading in cities
- [Week 14] Climate Change / Resilience / Natural Disasters.
- [Week 15] Analysis of Policy Interventions in Transportation.

>> Final project declarations are due by Week 14. Final presentations in week 16.

**Assignments and Final Project:**

*Homework Assignments:*

- Two assignments involving analysis, modeling, and applications on relevant urban problems. Assignments will include visualization and coding in R/Python to analyze various large urban datasets.

*Final Project (different options):*

- A comprehensive assignment based on using large urban datasets for a specific application chosen from the topics discussed in the course.
- Creating a web-based decision-making platform using urban data.
- Participation in an Urban Data Challenge or collaboration with city halls, companies, agencies, or government teams.

**Communication:**

We will use Canvas and Slack to communicate. Canvas is for official announcements and private communications with the instructor/students. We will use Slack for daily information, Q&As, team discussions, and casual conversations. Although it is optional to complete the course, using Slack is encouraged to get the most helpful information. The address for the course's Slack workspace is [https://netsi-cus-course.slack.com](https://netsi-cus-course.slack.com). Join using the following link: [https://join.slack.com/t/netsi-cus-course/signup](https://join.slack.com/t/netsi-cus-course/signup). Anyone with a northeastern.edu email address can join. Contact the instructor if you have any issues or restrictions regarding using Slack or other email domains.

**Class structure:**
This is once-a-week class course. Each class has two blocks: in the first one, some introduction to the topic and a review of reading material will be presented by the instructor(s). The second hands-on part will use coding and urban data to test the topic's ideas, concepts, and applications.

**Grading:**
Grading in this course will be as follows.

- Attendance and Participation: 20%.
- Homework assignments: 20% each.
- Final project: 40%.

**Course materials:**

There are no required materials for this course. Here is the most relevant and general. More specific materials will be given/introduced for each class.

- Salganik, Matthew J. *Bit by bit: Social research in the digital age*. Princeton University Press, 2019.
- Batty, Michael. *The Computable City: Histories, Technologies, Stories, Predictions*. MIT Press, 2024.
- Bettencourt, Luís MA. *Introduction to urban science: evidence and theory of cities as complex systems*. MIT Press (2021).
- O'Brien, Daniel T. *Urban informatics: using big data to understand and serve communities*. Chapman and Hall/CRC, 2022.
- Rey, Sergio, Dani Arribas-Bel, and Levi John Wolf. *Geographic data science with Python*. Chapman and Hall/CRC, 2023.
- Pebesma, Edzer, and Roger Bivand. *Spatial data science: With applications in R*. Chapman and Hall/CRC, 2023.
- Lovelace, Robin, Jakub Nowosad, and Jannes Muenchow. *Geocomputation with R*. Chapman and Hall/CRC, 2019.
- Cunningham, Scott. *Causal inference: The mixtape*. Yale University Press, 2021.
- Facure, Matheus. *Causal Inference in Python*. " O'Reilly Media, Inc.", 2023.
- Barthélemy, Marc. "Spatial networks." *Physics reports* 499.1-3 (2011): 1-101.
- Barbosa, Hugo, et al. "Human mobility: Models and applications." *Physics Reports* 734 (2018): 1-74.