New York University
Center for Urban Science + Progress

Foundations of Urban Science
FALL 2013

Mondays 9am to 11:30am (some Wednesdays 9am to 11:30am)
Location: NYU MAGNET, 2 Metrotech Center, Room 820

Instructors:
Michael Batty, University College London; CUSP Visiting Scholar
Luis Bettencourt, Santa Fe Institute; CUSP Visiting Scholar
Constantine E. Kontokosta, NYU CUSP
Steven Koonin, NYU CUSP
Jose Lobo, Arizona State University and Santa Fe Institute; CUSP Visiting Scholar
Geoffrey West, Santa Fe Institute; CUSP Visiting Scholar

Teaching Assistant:
Rishee Jain, Postdoctoral Fellow, NYU CUSP

Office hours: Thursdays, 1pm to 3pm
Office location: NYU CUSP, 1 Metrotech Center, 19th Floor

Course Description

A Science of Cities is an idealized conceptual framework based on underlying principles that leads to a quantitative, predictive, unifying, coarse-grained, base-line understanding of the structure, dynamics, growth and organization of cities, including their inter-relationship both within and across different urban systems. Among its many features, it would recognize cities as multi-dimensional complex adaptive systems whose emergent properties act over many spatio-temporal scales. A critical feature is the integration of this paradigm, inspired by the mathematical, physical and biological sciences, with the wealth of traditional, sometimes more qualitative and phenomenological, ideas and concepts that have been successfully developed in the social sciences including Geography, Urban Planning, Economics, Sociology, etc.

This course explores a systems approach (physical, economic, social, political, etc.) to the growth and decay of cities and describes emerging frameworks for a unified theory of city form and function. It discusses economic theories of the city and emerging models of city function, growth, and the dynamics of complex sociotechnical systems. Topics include spatial growth models, scaling and size distributions, networks and flows, entropy in urban systems, and an introduction to spatial interaction models. Specific applications of urban models to domains, such as transportation and sustainable development, are provided, together with empirical examples. Basic principles of systems analysis are discussed.

Prerequisites

- Graduate standing in CUSP. Non-CUSP students by permission of the CUSP Program Director.

Course Objectives

- Understand the theoretical models of urban form and the application of systems theory to cities, and their limitations
- Understand the underlying drivers of city growth, adaptation, and resilience
- Recognize the elements of a unified theory of cities, building on analogous models in the natural world
- Develop and apply models of the various urban domains and their interactions
- Gain knowledge in the human and social behavioral influences and interactions within urban systems
- Understand diverse (political, social, economic, infrastructural) conceptualizations of the city through the history of ideas in urbanism and urban sciences.
- Appreciate the scope of current urban data worldwide, issues and future possibilities

Course Requirements

In addition to weekly readings, lectures, and scheduled recitation sections, the course requirements include four individual assignments and a final paper. Class discussion is an integral part of the course and will factor into the final grade. Students are expected to attend all classes and complete all readings prior to the session indicated in the course outline below. The two individual assignments are designed to develop the skills needed to effectively analyze and evaluate risk and opportunity at critical stages of new ventures and projects.

A Note on Written Submission and Presentation Requirements:

All written work will be submitted at the beginning of class. Written submissions should be double-spaced in Times New Roman 12-point font, with 1" margins. All charts, graphs, and tables should be included at the end of the paper and referenced in the text. They are not counted against the page limits. Pages and charts should be numbered appropriately. All sources used should be appropriately cited in the text and included in a list of references at the end of the paper. Spelling, grammar, format, and style of the written work will all factor into the grade, so please be make sure to leave sufficient time to proof-read and edit your work.

Grading

All requirements must be completed by the date specified and handed in at the beginning of class or they will not be counted toward the final grade. No late assignments will be accepted.

- Assignments – 40%
- Final Paper – 40%
- Discussion sessions/recitations – 10%
- Class participation and attendance – 10%

NYU Classes

You must have access to the NYU Classes site (http://classes.nyu.edu/). All announcements and class-related documents (supplemental and suggested readings, discussion questions, etc.) will be posted there.

Some class announcements will be distributed via NYU e-mail. Thus, it is important that you actively use your NYU e-mail account, or have appropriate forwarding set up on NYU Home (https://home.nyu.edu/).

Required and Suggested Texts (subject to change)
Selections from texts below are indicated in the Course Outline.

E. Glaeser, *Triumph of the City: How Our Greatest Invention Makes Us Richer, Smarter, Greener, Healthier, and Happier.* (Penguin Books, NY 2012).

Macionis JJ, Parillo VN, *Cities and Urban Life* (Pearson Education, Upper Saddle River, NJ, 1998).

Kevin Lynch, *The Image of the City* (MIT Press, Cambridge MA,1960)

L. Mumford, *The City in History* (Harcourt, NY,1961)

J. Kotkin, *The City: A Global History* (Modern Library, New York, 2006)

J. Jacobs, *The Life and Death of Great American Cities* (Random House, NY, 1961).

S. Angel, *Planet of Cities* (Lincoln Institute, Cambridge, MA, 2012).

Note: If you cannot find the texts at the NYU Bookstore, they are readily available from online booksellers.

Other required readings will be posted on Blackboard or distributed in class.

Statement of Academic Integrity
NYU CUSP values both open inquiry and academic integrity. Students graduate programs are expected to follow standards of excellence set forth by New York University. Such standards include respect, honesty, and responsibility. The program does not tolerate violations to academic integrity including:

- Plagiarism
- Cheating on an exam
- Submitting your own work toward requirements in more than one course without prior approval from the instructor
- Collaborating with other students for work expected to be completed individually
- Giving your work to another student to submit as his/her own
- Purchasing or using papers or work online or from a commercial firm and presenting it as your own work

Students are expected to familiarize themselves with the University's policy on academic integrity and CUSP's policies on plagiarism as they will be expected to adhere to such policies at all times – as a student and an alumni of New York University.

The University's policies concerning plagiarism, in particular, will be strictly followed. Please consult the *Chicago Manual of Style* for guidelines on citations. Do not hesitate to ask if you have any questions regarding writing style, citations, or any academic policies.

Course Outline (subject to change)

Session 1 – September 9th (Steven Koonin)

Topics: Urban Science – What are the Big Questions?

Session 2 – September 16th (Edward Glaeser, Harvard University)

Topics: Why Cities?

Readings: E. Glaeser, *Triumph of the City: How Our Greatest Invention Makes Us Richer, Smarter, Greener, Healthier, and Happier.* (Penguin Books, NY 2012).

Assignment: Discussion Paper – Can there be a Science of Cities? (2-3 pages max.)

Session 3 – September 23rd (Jose Lobo)

Topics: **Size matters -** *From Small Settlements to Megacities: Why Do Human Beings Agglomerate?*

Cities represent a distinctive and relatively recent form of agglomeration but human beings have been agglomerating (living, working and interacting in close physical proximity outside the bounds of familial relationships) for thousands of years before cities. Why? What are the biological, sociological, cultural and technological factors that have facilitated such a phenomenon? What are the advantages of agglomerating? The lecture will cover evidence and arguments from the fields of archaeology, anthropology, sociology and economics as to why human beings have agglomerated, and consider how the processes generating agglomeration throughout *Homo Sapiens* history are relevant to understand modern cities.

Readings: Boyd, R., Richerson, P., & Henrich, J. (2011). The Cultural Niche: Why Social Learning is Essential for Human Adaptation. (J. C. Avise, Ed.) *PNAS* .

Davis, K. The Origin and Growth of Urbanization in the World . *The American Journal of Sociology , 60* (5), 429-437.

Sibly, R. M.. *Metabolic ecology: a scaling approach*. Chichester, West Sussex: Wiley-Blackwell, 2012. Print. Chapter 20

Smith, Michael. *Sprawl, Squatters and Sustainable Cities: Can Archaelogical Data Shed Light on Modern Urban Issues?* Cambridge Archaeological Journal 20:2, 229–53

Smith, M. (2012). The Role of Ancient Cities in Reseach on Contemporary Urbanization . *UGEO Viewpoints , 8*.

Session 4 – September 25th (Jose Lobo)

Topics: **Size matters -** *Population Size and the Productivity of Cities*

One of the most salient characteristics of a city is its population size, which is both a consequent and a determinant of the myriad of socio-economic activities occurring in urban settings. There is an extensive literature in urban economics, economic

geography and regional science that has studied the effects of urban population size on productivity, innovation and wealth creation. This lecture will review some of this literature as backdrop for engaging with a recent approach to studying the importance of urban population size: *scaling analysis*. The empirical results obtained by applying the scaling perspective, and theorizing about them, animates the view that the functional role of cities in human societies, as well as some of the general aspects of their internal organization, may be universal: they may be expected to develop in urban systems that arose and evolved independently and hold across time, culture and level of technology.

Readings: Abel, J., Dey, I., & Gabe, T. (2012). Productivity and the Density of Human Capital . *Journal of Regional Science , 52* (4), 562-586.

Carneiro, R. (1999, April 27). The Transition from Quantity to Quality: A Neglected Casual Mechanism in Accounting for Social Evolution . *American Museum of Natural History* .

Jones, C., & Romer, P. (2010). The New Kaldor Facts: Ideas, Institutions, Population, and Human Capital . *American Economic Journal: Macroeconomics* .

Kremer, M. (1993). Population Growth and Technological Change: One Million B.C. to 1990. *Journal of Economics , 108* (3), 681-716.

Quigley, J. (1998). Urban Diversity and Economic Growth . *Journal of Economic Perspectives , 12* (2), 127-138.

Recitation 1 – September 30th

Topics: Urban Theory: Why are there Cities?
Assignment: Assignment #1
Short essay (3-5 pages): what sort of problems faced by early modern humans did agglomeration/nucleation help address? Which problems did it create? Are the reasons why humans still come together in cities different from those that drove them to become urban dwellers in the past?

Session 5 – October 7th (Luis Bettencourt)

Topics: The State of Urban Data Worldwide
1) Types of Urban Data:
- Data at the city level: official data, census, statistical bureaus, others.
- Data at the neighborhood level: census blocks, tracts, neighborhoods, informal settlements.
- Data for individuals (social networks, surveys, detailed census and enumerations)

2) How to organize and analyze data:
- Average trends
- Statistical characterization and deviations from averages.
- Change over time

3) How to construct Urban Indices: some of their properties.

Readings: Luís M. A. Bettencourt, José Lobo, Dirk Helbing, Christian Kühnert, and Geoffrey B. West Growth, innovation, scaling, and the pace of life in cities PNAS 2007 104 (17) 7301-7306; 2007.

Bettencourt LMA, Lobo J, Strumsky D, West GB (2010) Urban Scaling and Its Deviations: Revealing the Structure of Wealth, Innovation and Crime across Cities. PLoS ONE 5(11): e13541. doi:10.1371/journal.pone.0013541

Gomez-Lievano A, Youn H, Bettencourt LMA (2012) The Statistics of Urban Scaling and Their Connection to Zipf's Law. PLoS ONE 7(7): e40393. doi:10.1371/journal.pone.0040393

See also Supplement in :
Luís M. A. Bettencourt **The Origins of Scaling in Cities** Science 21 June 2013: **340** (6139), 1438-1441.

NY Hero Highlight: Willam H. Whyte, The Social Life of Small Urban Spaces (Washington, D.C.: The Conservation Foundation, 1980.)

Session 6 – October 9th (Luis Bettencourt)

Topics: Unified Theory of City Function

1) Introduction and Historical Perspective: The general functions of cities
The many functions of the city: political organization, defense, economic development, culture, innovation, economies of scale in costs, etc.

2) Simple models of city form and function:
- The isolated state (von Thunen)
- The commuting, monocentric city (Alonso)
- The economic city: production functions (Solow). Extensions to Economic Geography.
- The city in sociology (Simmel, Wirth).
- The city as organized complexity (Jacobs).

3) A Modern Synthesis (unified theory):
- The city as a social network embedded in space and time
- The general properties of urban infrastructure
- Costs and benefits of social interaction in urban infrastructural spaces
- Deriving scaling relations for urban quantities

4) The city seen from within*
- The image of the city (Lynch): How people experience urban space.
- Mixing and Heterogeneity, segregation and development.
- The emergence of statistical urban patterns for individuals and neighborhoods.

Readings: M. Fujita, P. Krugman,, A. J. Venables "The Spatial Economy" (MIT Press, Cambridge MA, 2001).

Luís M. A. Bettencourt The Origins of Scaling in Cities Science 21 June 2013: 340 (6139), 1438-1441.

No Class (NYU Fall Break) – October 14th

Recitation 2 – October 21st

Topics: Urban Data and Unified Theory of City Function
Assignment: Assignment #2

Session 7 – October 28th (Geoffrey West)

Topics: **Towards a Science of Cities; the Role of Scaling**

- The Nature of Scientific Explanation and its Importance for Cities; Cities as complex adaptive evolving systems.
- What would constitute a "Science of Cities and Urbanisation"?
- The search for regularities and systematic behaviour.
- Why is Scaling important?
- The "Theory" of Scaling.
- Illustrative examples from physics, engineering, daily life, …
- The special role of power laws; relationship to self-similarity and fractals.
- Organisms, ecosystems and social insect communities as metaphors/models for cities and companies.
- Adaptability, evolvability, metabolism and resilience.
- The theory of scaling in Biology; networks, invariants and optimization principles.
- Growth, mortality, aging and repair.
- Scaling in cities and companies; are they just big organisms?

Readings: G. B. West, "Scale and Dimension from Animals to Quarks." in *Particle Physics: A Los Alamos Primer*, Cambridge Univ. Press (1986).

G. B. West, J. H. Brown Life's universal scaling laws Physics Today 57 (9), 36-43.

C. Kühnert, D. Helbing, G. B. West Scaling laws in urban supply networks Physica A: 363 (1), 96-103.

Session 8 – October 30th (Geoffrey West)

Topics: **Towards a Science of Cities; Extensions to Growth and Sustainability**

- Superlinear vs Sublinear Scaling
- Infrastructure (energy, resources, transport, buildings, etc) vs. socio-economic (wages, disease, innovation, etc).

- The integration of "Metabolism" of the city with its "Genomics" (the "Urbome").
- Infrastructural networks vs. Social networks; what, if anything, do cities optimize?
- Collective behaviour: cities as agglomerations of people and businesses; urban systems as agglomerations of cities.
- Diversity and individuality of cities.
- Growth and the Pace of Life.
- Is continuous open-ended growth of cities conceivable? The role of innovation and its relationship to growth and sustainability.

Readings: L. Bettencourt, G. West A unified theory of urban living Nature 467 (7318), 912-913.

L. M. A. Bettencourt, G. B. West Bigger cities do more with less Scientific American 305 (3), 52-53.

Recitation 3 – November 4th

Topics: Scaling Laws and Urban Sustainability
Assignment: Assignment #3

Session 9 – November 11th (Michael Batty)

Topics: **Networks and Spatial Interaction Modeling**

This session will be divided into two parts: first we will review networks and flows which form the basis for transportation of many kinds, involving people, materials goods and information. This will be built on basic notions of network science. Second we will introduce spatial interactions models which are methods for simulating flows on networks. The gravitational hypothesis will be introduced, and then ways of generating families of spatial interaction models will be presented. The idea of entropy maximising will be introduced. Links to discrete choice theory will be established. Then ideas of complexity and scaling through power laws will be highlighted, and this will establish the context for linking these models to earlier ideas about size, scale and growth. Examples include migration, traffic, and retailing.

Readings: Batty, M. (2008) Spatial Interaction, in K. K. Kemp (Editor) **Encyclopaedia of Geographic Information Science**, Sage. Los Angeles, CA, 416-418

Batty, M. (2010) "Cities as Complex Systems: Scaling, Interactions, Networks, Dynamics and Urban Morphologies", In R. Meyers (Editor) **Encyclopedia of Complexity and Systems Science**, Volume 1, pp 1041-1071, Springer, Berlin, DE.

Wegener, M. (2005) Urban Land Use Transportation Models, in D. J. Maguire, M. F. Goodchild, and M. Batty (Editors) **GIS, Spatial Analysis, and Modeling**, ESRI Press, Redlands, CA, 203-220.

Wilson, A. G. (2012) The Science of Cities and Regions: Lectures on Mathematical Model Design, Springer Briefs in Geography, New York
These references will be online at www.spatialcomplexity.info

Session 10 – November 18th (Michael Batty)

Topics: **Land Use Transportation Models**

Ideas about stitching and coupling spatial interaction models with urban economic models to form land use transport models. We first introduce cross sectional static Lowry-like models, then move to more integrated forms such as TRANUS and MEPLAN. We will examine quasi dynamics extensions of these models and then introduce large scale models from the land use side such as URBANSIM and then from the transport side such as MATSIM. These models introduce disaggregation, microsimulation and agent-based modelling and we will flag in passing the development of cellular automata (CA) models of urban development which link back to scaling, dynamics and emergence, concepts that come from complexity theory. We will introduce applications of all these models types as examples and link these ideas **to** adaptation and resilience**.**

Readings: Batty, M. (1997) Cellular Automata and Urban Form: A Primer, **Journal of the American Planning Association**, **63**, 266-274.

Batty, M. (2007) **Cities and Complexity** (MIT Press, Cambridge, MA)

Batty, M. (2009) Urban Modeling, in R. Kitchin and N. Thrift (Eds) **International Encyclopaedia of Human Geography**, Volume 12, Elsevier, Oxford, 51–58.

Hunt, J. D., Kriger, D. S. and Miller, E. J.(2005) Current Operational Urban Land-Use-Transport Modelling Frameworks: A Review, **Transport Reviews**, **25**, 3, 329-376.

Iacono, M., Levinson, D., and El-Geneidy, A. (2008) Models of Transportation and Land Use Change: A Guide to the Territory, **Journal of Planning Literature**, **22**, 323-340,

Recitation 4 – November 25th

Topics: Spatial Modeling and Systems Interactions
Assignment: Assignment #4

Session 11 – December 2nd (Jose Lobo)

Topics: **Human Capital, Creativity and Invention-** *Human Capital and Creative Occupations as Drivers of Urban Development*

According to current thinking in economics and social science broadly, the underlying driver of economic development is highly skilled and educated individuals, often referred to (rather blandly) as "human capital." Places that have more of it thrive, while those with less stagnate or decline. While there is a general consensus on the importance of "human capital" to urban development, debate has rages as to how to measure it---educational versus occupational measures---and what are the factors that affect its distribution across urban areas. This lecture will examine the relationship of these two these two alternative measures of human capital and

urban economic performance (measured through income and wages), what each measure of human capital captures (and what it does not), and what social, economic and even cultural characteristics of urban areas foster or hinder the accumulation of human capital.

Readings: Florida, R., Mellander, C., & Stolarick, K. (2008). Inside the Black Box of Regional Development-- Human Capital, the Creative Class, and Tolerance . *Journal of Economic Geography , 8*, 615-649.

Glaeser, E., & Saiz, A. (2003, December). The Rise of the Skilled City.

Session 12 – December 4th (Jose Lobo)

Topics: **Human Capital, Creativity and Invention-** *Invention in the City*

Technological change is widely seen as major drivers of economic development. Technology is the application of scientific and engineering knowledge to the development of a machine, procedure, artifact or material. An invention consists of a novel bundling of technologies to achieve a goal. Some inventions, those that are patented, leave behind a documentary trail. The statutory definition of a patentable invention, according to U.S. law, states that it must be novel, non-obvious and useful. The granting of a patent therefore heralds the arrival of a new process, method, machine, manufacture of composition of matter (the categories of inventions eligible for the protection of a U.S. patent). As a consequence patents have become a widely used metric in studies of the "knowledge economy." A salient characteristic of patenting activity in the United States is that it has been an urban phenomenon and remains so today with over 90% of all patents granted by the U.S. Patent Office authored by inventors residing in urban areas. This lecture will cover the insights learned as to what features of urban economies foster invention and insights into the invention process gleaned from studying invention in cities.

Readings: Bettencourt, L., Lobo, J., & Strumsky, D. (2007). Invention in the City: Increasing Returns to Patenting as a Scaling Function of Metropolitan Size. *Research Policy, 36*, 107-120.

Lobo, J., & Strumsky, D. (2008). Metropolitan Patenting, Inventor Agglomeratoin and Social Networks: A Tale of Two Effects . *Journal of Urban Economic , 63*, 871-884.

Rothwell, J., Lobo, J., Strumsky, D., & Muro, M. (2013, February). Patenting Prosperity: Invention and Economic Performance in the United States and its Metropolitan Areas. *Metropolitan Policy Program*.

Session 13 – December 9th (Steven Koonin/Constantine Kontokosta)

Topics: Wrap-up and synthesis; Final Paper; Application of models to the real-world urban context: New York City as the living lab
Readings: TBA
Assignment: Final Paper due 12/16 by 5pm.
Course concludes