Science ingredients and research gaps in urban resilience and community sustainable development

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Mansueto Institute for Urban Innovation
We study the fundamental processes that drive, shape, and sustain cities.

At the Mansueto Institute for Urban Innovation, our researchers come from the social, natural, and computational sciences, along with the humanities. Together, we pursue innovative, interdisciplinary scholarship, develop new educational programs, and provide leadership and evidence to support global, sustainable urban development.
What are Cities?
What are Cities?
Frameworks and Goals for Modeling and Planning Urban Environments

Methods
- Computational Physical Modeling
  - infrastructure, transportation, buildings
- Characterization of homogeneous needs and behaviors
  - bird's eye view, planners perspective
- Optimization and Resilience
  - stability under shocks, focus on infrastructure

Goals
- Socioeconomic and environmental outcomes
- justice, equity and inequality
- systemic transformations: towards fair, prosperous and sustainable cities

Gap

Are methods adequate to the goals? How can we get closer?
Urban Science Ingredients

1. Connectivity
   - why cities exist
   - socioeconomic structure
   - scaling/agglomeration effects
   - what is accessible?
   - what is impossible?
   - what is known?
   - opportunity
   - segregation
   - exclusion

2. Costs vs. Benefits
   - how cities function
   - dynamical, short-term, heterogeneous equilibrium
   - choice of neighborhood
   - commuting and land uses
   - education and training
   - urban services: water, energy, sanitation, trash…
   - environmental quality and health
   - urban resilience and uncertainty

3. Information
   - how cities (create) change
   - long-term change
   - economic growth, human development
   - diversity
   - cultural and political change
   - innovation
   - technology
   - adaptation and growth

These ingredients - get us closer to the goals of urban modeling and planning
- frame the role and functions of multi-sector services as platforms, across scales
Urban Science: Integrating scales & disciplines

Scale |
--- |
Individual, household |
Neighborhood |
City |
Urban Systems (nations, globe) |

Integration |
--- |
health |
life-course |
human development |
segregation |
selection |
education |
contagion |
segregation |
mixing |
contagion |
migration |
trade & resource flows |
knowledge |
knowledge diffusion |
climate change |
biodiversity |

Mechanism |
--- |
cognition |
neighborhood effects |
scaling laws and agglomeration |
laws of geography |

- 10^9 billions
- 10^6 millions
- 10^3 thousands
- 10^0 one
Science ingredients and research gaps
in urban resilience and community sustainable development

3 research gaps:

1. Flip: from top down view to human centric approach

2. Flip: from detailed modeling to high-precision, real time data

3. Flip: from temporal averages to high frequency, stochastic indicators

These gaps all deal with integrating scales across population sizes, geographies and time
1. From top down view to human centric approach

- Job
- Health
- Transportation
- Education
- Shopping
- Clean Air
- Water
- Housing
- Recreation
- Child Care
- Safety
- Nature
- Education
- Transportation

Must be done for different people:
- young/old
- rich/poor
- different neighborhoods
- gender
- native/migrant

Space + Time + Budget + Information ➔ Quality of Life

human centric approach requires fine multi-sector integration
Measuring the Human Development of Chicago neighborhoods

(strategy: “localization” of sustainable development goals)

better than Norway
worse than China or Mexico

credit: Neil Sheth (UChicago)

life expectancy, education and real incomes

See also: Brelsford et al  PNAS 2017; K. Seto Editor
2. From detailed modeling to high-precision, real time data

Requires sensing infrastructure and data:
- mobile phones
- remote and aerial sensing
- sensor networks

data mostly generated and owned by corporations

Requires new computational methods:
- Bayesian data assimilation
- anomaly detection and recovery
- statistical learning and AI

not just modeling but also learning from data
Systems Dynamics for Learning and Control of Epidemics

A. Reported total cases:
- \( T_{t+1} \)
- \( T_{t} \)
- \( T_{t-1} \)

Observed new cases:
- \( \Delta T_{t+1} \)
- \( \Delta T_{t} \)

New Transmissibility:
- \( R_{t+1} \)
- \( R_{t} \)
- \( R_{t-1} \)

Policy and Behavior:
- \( P_{t+1} \)
- \( P_{t} \)
- \( P_{t-1} \)

B. Bayesian Estimation
- new observation \( \Delta T_{t+1} \)
- parameter estimation \( p(R_{t} | \Delta T_{t+1}, \Delta T_{t}) \)

Learning of model parameters
- anomaly?
- case prediction \( p(\Delta T_{t+1} | \Delta T_{t}, b_{t}) \)
- transmissibility changes \( R_{t} \)

Learning of Policies and behaviors
- adaptive control \( p(P^{*}_{t} | R_{\text{target}} < 1) \)
- statistical learning \( p(R_{t} | P_{t}) \)
- public health policy, behavior \( P_{t} \)

3. From temporal averages to high frequency, stochastic indicators

Real time environmental monitoring

COVID modeling

The share of adults not working because of the effect of the coronavirus pandemic on business conditions is declining

Share of U.S. population 18-64 years old not working in the previous 7 days due to caregiving or their employer was affected by the coronavirus pandemic, by gender

Real time socioeconomic monitoring

Census Pulse survey

Human Development, Prosperity, Equity are complex long term phenomena:

What are the long term consequences of these short time, stochastic trends?
How can we predict how they integrate over life courses? How can we affect positive change?
Data Reporting Platform

Los Angeles is the first city in the world to report SDG data at the indicator level using an open source platform [Open SDG].

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Percentage</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below National Poverty Line</td>
<td>16.5%</td>
<td>All SDG 1 Data</td>
</tr>
<tr>
<td>Access to Fresh Fruits and Vegetables</td>
<td>76%</td>
<td>All SDG 2 Data</td>
</tr>
<tr>
<td>Health Insured</td>
<td>89%</td>
<td>All SDG 3 Data</td>
</tr>
<tr>
<td>Bachelor's Degree Attainment</td>
<td>36%</td>
<td>All SDG 4 Data</td>
</tr>
<tr>
<td>Women in Managerial Positions</td>
<td>45%</td>
<td>All SDG 5 Data</td>
</tr>
<tr>
<td>Access to Clean Water</td>
<td>100%</td>
<td>All SDG 6 Data</td>
</tr>
<tr>
<td>Renewable Energy Sources</td>
<td>30%</td>
<td>All SDG 7 Data</td>
</tr>
<tr>
<td>Median Annual Earnings</td>
<td>$36,390</td>
<td>All SDG 8 Data</td>
</tr>
<tr>
<td>Broadband Internet Subscription</td>
<td>90%</td>
<td>All SDG 9 Data</td>
</tr>
<tr>
<td>Gini Coefficient</td>
<td>0.52</td>
<td>All SDG 10 Data</td>
</tr>
<tr>
<td>Unsheltered Homeless Population</td>
<td>28,852</td>
<td>All SDG 11 Data</td>
</tr>
<tr>
<td>Recycling Rate</td>
<td>15%</td>
<td>All SDG 12 Data</td>
</tr>
</tbody>
</table>

and many more…

A new way of doing policy?

LA100: The Los Angeles 100% Renewable Energy Study

The Los Angeles 100% Renewable Energy Study
Barcelona: annual tracking of sustainable development goals

**Attending to homeless people**

**INDICATOR 111:** All homeless people not assisted by XAPSSL

**INDICATOR 112:** Reduce the number of homeless Barcelona residents to below 500

**More employment and fair pay**

**INDICATOR 851:** Get unemployment to below 70,000 people (in thousands, right axis)

**INDICATOR 852:** Reduce the working poverty rate to below 10%

**INDICATOR 853:** Eradicate the gender wage gap

**INDICATOR 854:** Over 1,000 people contracted by the Job Placement network - XB (right axis)
Thoughts and Concepts for Discussion

1. Emerging Science of Cities with New (modeling) Ingredients and Theoretical Perspectives

emphasizing human experience in urban complex environments
structural position, capabilities, knowledge and opportunities, equity across scales
social, physical, environmental, coproduction

2. Research Gaps and Opportunities

new data: faster, more detailed, more heterogeneous, mode local, more global
new statistical modeling with data assimilation and learning
new strategies for data-driven policy making with multi-sector models “in the loop”
Introduction to Urban Science
Evidence and Theory of Cities as Complex Systems
Luís M. A. Bettencourt
2021

A novel, integrative approach to cities as complex adaptive systems, applicable to issues ranging from innovation to economic prosperity to settlement patterns.