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Editorial

Complex urban systems: a living lab to understand urban processes and solve complex urban problems

Kurt H. Becker[1,2,3,a], Juan P. Bello[4,5,6,b], and Maurizio Porfiri[2,4,7,c]

[1] Department of Applied Physics, New York University Tandon School of Engineering, Brooklyn, NY 11201, USA
[2] Department of Mechanical and Aerospace Engineering, New York University Tandon School of Engineering, Brooklyn, NY 11201, USA
[3] Institute for Invention, Innovation, and Entrepreneurship, New York University Tandon School of Engineering, Brooklyn, NY 11201, USA
[4] Center for Urban Science and Progress, New York University Tandon School of Engineering, Brooklyn, NY 11201, USA
[5] Department of Computer Science and Engineering, New York University Tandon School of Engineering, Brooklyn, NY 11201, USA
[6] Department of Music Technology, New York University Steinhardt School of Culture, Education, and Human Development, New York, NY 10003, USA
[7] Department of Biomedical Engineering, New York University Tandon School of Engineering, Brooklyn, NY 11201, USA

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Editorial:
The rapid trend of urbanization that will see 68% of the world's population living in cities by 2050 [1] poses numerous challenges to our cities and to the local governments that bear responsibility for addressing the needs of its citizens. Science and technology play a key role in helping us increase our understanding of urban processes and in solving complex urban problems, such as facilitating the reliable transportation of people and goods, securing availability of electrical power and water that meet the needs of the growing population and related waste disposal needs, ensuring the health and wellness of the urban populations (in particular of older adults and people with disabilities), making our cities more accessible and inclusive, preparing for the expected waves of migration due to environmental change, and supporting local governments to be more responsive to the needs of the citizens they serve. None of these challenges can be addressed in isolation: urban environments represent complex, intertwined social-economic-technical-environmental systems that require a new inter-/cross-disciplinary paradigm of scientific and technological approaches.

The articles in this issue provide a snapshot of ongoing methodological and translational research on complex urban systems, along with an outlook about this exciting, growing field of research that brings together data scientists, engineers, environmental scientists, mathematicians, physicists, and policy experts. This Special Issue gives but a small glimpse into the constellation of challenges that complex urban systems are faced with and must address and provides examples of cutting edge research results that respond to these challenges.

The article "Research Universities, Incubators of (Urban) Innovation" by Becker [2] describes how research universities have built a vibrant culture and the nurturing environment that supports academic innovation and entrepreneurship. In several illustrative case studies, it is shown how new products, processes, and services that either came out of academic research or were developed with the help of academic researchers can provide solutions to some of the challenges faced by urban environments, particularly in big cities. Specifically, the case studies address the charging of electric vehicles, data collection and surveillance using unmanned, autonomous vehicles, energy management in multi-dwelling buildings, waste-to-food conversion, and peak energy demand management in urban settings.

Kitzmann et al. content that a transformation of the economic, societal, and political landscape towards sustainable practices is needed to maintain the civilization-friendly Holocene state in which the Earth has existed for a long time in their article "Detecting Contagious Spreading of Urban Innovation on the Global City Network" [3]. Urban systems are main drivers of planetary boundary transgressions that harm the environment and thus challenge the way of life we have come to take for granted. However, at the same time, cities can play an important role as active agents in a comprehensible global sustainability transformation with their

[a] e-mail: kurt.becker@nyu.edu (corresponding author)
[b] e-mail: jpbello@nuy.edu
[c] e-mail: mporfiri@nyu.edu

very high potential for impactful change as centers of knowledge and innovation and being home to significant financial and other economic resources.

Porfiri and collaborators address different aspects of how the response to the COVID-19 pandemic impacted society and the political landscape in the US in two articles. The article "Analysis of Lockdown Perception in the United States during the COVID-19 Pandemic" [4] presents a spatio-temporal analysis of 1.3 million geolocalized Twitter data about lockdowns from January to May 2020, which is used to isolate the mechanisms underlying the acceptance of public health interventions by different segments of the population. A second article "Quantifying the Role of the COVID-19 Pandemic in the 2020 US Presidential Election" [5] establishes a spatial information-theoretic approach to examine the link between voting behavior and COVID-19 incidence rates in the 2020 presidential elections. Surprisingly, the analysis does not support the commonly held belief that President Donald Trump lost the election because of the way he responded to the pandemic. It rather points in the opposite direction, that is the incumbent President lost more ground to his opponent Joe Biden in counties with lower COVID-19 infections.

The article by Clark et al. "A Network Spatial Analysis Simulating Response Times to Call for Service at Variable Staffing Levels" [6] responds to the recent discussions around the slogan "Defunding the Police". It addresses the balance between reducing policy presence to reduce incidents of police brutality versus public safety concerns because of longer response times. Using Chicago's large, open-source police incident response database as a network, the authors simulate the response time of police from stations to incidents. The authors' model shows that the current response time distribution can be maintained with a 30–60% reduction in police staffing levels when combined with a partial re-allocation of incidents to alternate responders.

He et al address the need to obtain accurate traffic prediction and early surge detection data, which are vital in the design of public transit dispatch systems in the article "Ridership Prediction and Anomaly Detection in Transportation Hubs: An Application to New York City" [7]. A framework for edge-level traffic prediction is introduced that incorporates a pipeline of network aggregation, non-linear modeling and final edge-level disaggregation and is tested by applying it to the for-hire vehicle and taxi ridership datasets from two New York City airports.

Rodriguez et al. introduce JamVis, a web-based visual analytics framework that leverages a multi-modal spatio-temporal data to monitor and understand traffic dynamics and the cause of traffic jams in their article "JamVis: Exploration and Visualization of Traffic Jams" [8]. The tool is validated in three case studies analyzing different traffic events in Rio de Janeiro. In a similar vein, Kardous et al. simulate traffic on a ring road using human-driven as well as autonomous vehicles in their article "A Rigorous Multi-population Multi-lane Traffic Model and its mean-field limit for Dissipation of Waves via Autonomous Vehicles" [9]. The objective is to minimize stop-and-go traffic pattern by optimizing lane switching.

The article by Alessandroni et al. "Analytical Fault-impact Model for the Electrical Grid" [10] addresses the challenges faced by distribution system operators (DSO) due to the increase in renewable energy sources and the rising electricity use by a growing urban population. The role of these operators is expected to expand from being mere distributors to dispatchers that must manage unexpected surges in demand while maintaining a resilient system with built-in redundancy. The authors describe the need for optimal sizing and positioning of both automatic and remote-controlled switches, as well as a knowledge of the effects of various operational variables on the network.

The article "Managing Wind Resource Variation for Rooftop Turbine Placement" by Laefer and co-workers [11] explores ways to improve the poor performance of most roof-integrated wind turbines (RIWTs), which typically achieve only around 10% of the designed capacity, mostly because of poor turbine placement and a lack of precise wind power information. The authors used terrestrial laser scanning to capture the geometry of a cluster of complex suburban buildings with ground elevation changes of up to 1.4 m. The data were used in a computational fluid dynamic model for detailed wind flow field simulation using a Navier–Stokes solver. The results of their study offer insight into the disappointing performance of many RIWT installations, along with a pathway to optimize RIWT placement to avoid non-viable installations and improve cost recovery period predictions.

Ruiz-Marin and collaborators proposes a statistical technique to identify potential causal relationships when georeferenced data are available, but with no time dimension in their article "Spatial Partial Causality" [12]. As an example, the authors focus on identifying those determinants that can potentially bear a causal role when explaining the dynamics of housing price changes in a given location as an example. A non-parametric statistical test is used in conjunction with the Frisch–Waugh–Lovell (FWL) theorem to examine the price determinants of 20,433 California homes in a particular location. The results suggest a causal relationship (in terms of spatial information) from income to prices.

Howe and co-workers aim to enable holistic research on city dynamics, steering artificial intelligence (AI) research attention away from project-oriented, societally harmful applications (such as facial recognition) and towards foundational questions in mobility, participatory governance, and justice in their article "Integrative Urban AI to Expand coverage, Access, and Equity of Urban Data" [13]. By making available high-quality, multi-variate, cross-scale data for research, the authors link the macro study of cities as complex systems with the reductionist view of cities as an assembly of independent prediction tasks. Four research areas in AI for cities are identified as key enablers: interpolation and extrapolation of spatio-temporal data, using neuro-linguistic programming (NLP) techniques to model speech- and text-intensive governance activities, exploiting ontology modeling in learning tasks, and understanding the interaction of fairness and interpretability in sensitive contexts.

The challenges posed by the complex and intertwined social-economic-technical-environmental urban systems for its citizens and for local governments will only become more pressing in the future. Solutions require a close collaboration between academia, the private sector, and government. Leveraging the creative and innovative spirit found in our research universities across eh globe will play a key role in in providing the basis for many scientific breakthroughs, inventions, and technological innovations that will address these problems.

Government mandates can also provide an opportunity for new innovative approaches. For example, in 2019, the City Council in New York City passed Local Law 97 [14] as part of the Climate Mobilization Act, an ambitious and far reaching law to reduce greenhouse gas (GHG) emissions from existing buildings, which account for more than 1/3 of all GHG emissions in New York City. The law impacts buildings over 25,000 square feet, of which there are roughly 60,000 in New York City (60% residential and 40% commercial). The main objective of this law is to reduce building-based GHG emissions by 40% by 2030 from a 2005 baseline. Compliance with Local Law 97 presents an enormous challenge for building owners and building operators. Satisfying the legal requirements can stimulate academic researchers to join forces with the private sector and government to—among other things— conceive, reduce to practice, test, and deploy new solutions around more efficient manufacturing protocols, smart sensing networks and monitoring/control systems combined with data science methodologies and AI together with innovative financial models to pay for improvements to building and to amortize the costs of implementing the new solutions.

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