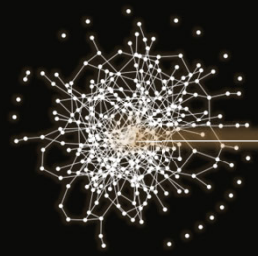
Georgia Tech School of Civil and Environmental Engineering
College of Engineering

Smart City Digital Twins

Toward More Sustainable, Resilient, and Livable Columbus

SMART Uptown Columbus
Georgia Smart Communities Challenge Webinar
January 24, 2020



John E. Taylor, PhD
Frederick L. Olmsted Professor of Civil & Environmental Engineering
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Director, Network Dynamics Lab
Urban Analytics Lead, CODA

Neda Madi, PhD
City Infrastructure Analytics Director
Network Dynamics Lab

Smart Buildings

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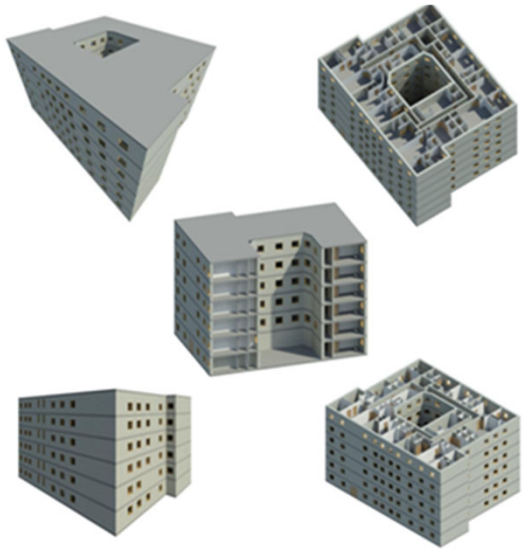
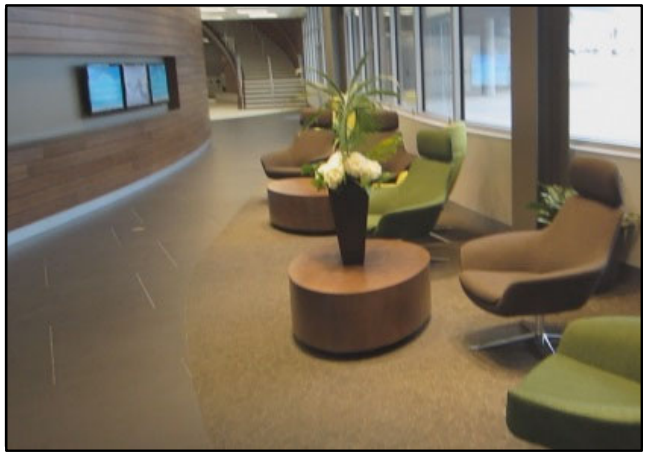


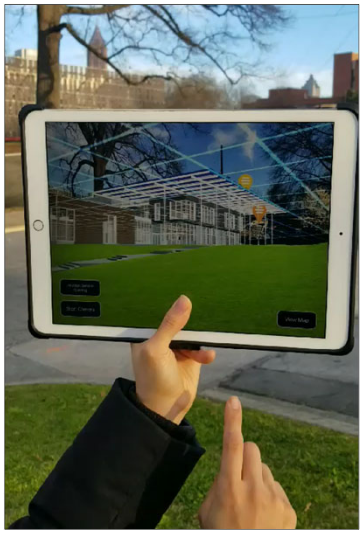
Representative Publication:

Taylor, J. and Bernstein, P. "Paradigm Trajectories of Building Information Modeling Practice in Project Networks," *ASCE Journal of Management in Engineering* (2009), 25(2): 69-76. doi.org/10.1061/(ASCE)0742-597X(2009)25:2(69).



Representative Publication:

Iorio, J., Peschiera, G., Taylor, J. and Korpela, L. "Factors Impacting Usage Patterns of Collaborative Tools Designed to Support Global Virtual Design Project Networks." *ITCON* (2011), 16: 209-230.

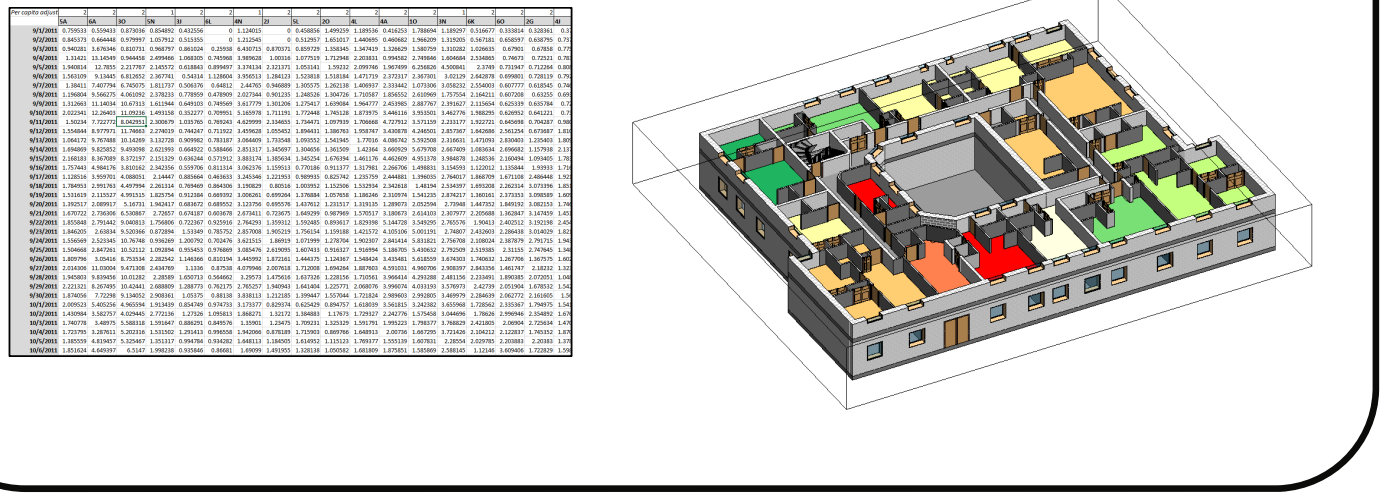


Representative Publication:

Ha, S., Mohammadi, N., Soysal, S., Taylor, J., Francisco, A., Flanagan, S., and Yapici, S. (2018). "Exploring Future Stakeholder Feedback on Performance-based Design across the Virtuality Continuum." *35th CIB W78 2018 International Conference*, 1-3 October 2018, Chicago, IL..

Representative Publication:

Taylor, J., et al. "CyberGRID: A Virtual Workspace for Architecture, Engineering and Construction." In *ASCE Transforming Engineering Education* (2017) (Eds) Mutis, I., Fruchter, R. Behzadan, A. Menassa, C. ASCE, Reston, VA, ISBN 9780784414866.

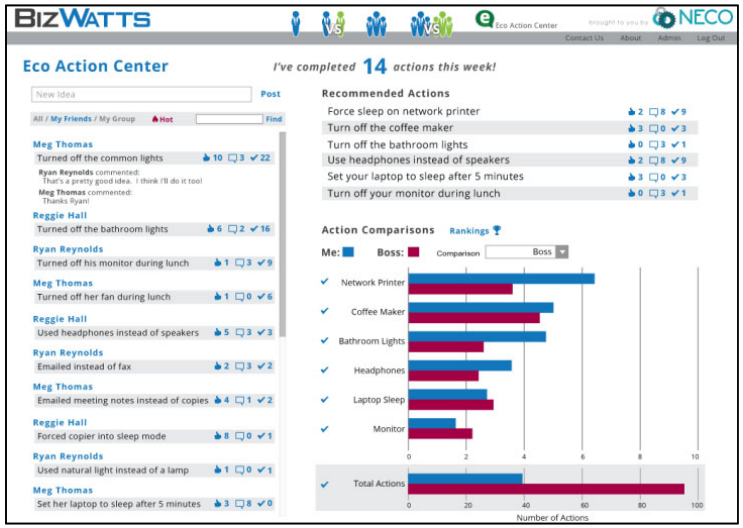


Representative Publication:

Francisco, A., Truong, H., Khosrowpour, A., Taylor, J. and Mohammadi, N. (2018). "Occupant Perceptions of Building Information Model-based Energy Visualizations in Eco-feedback Systems," *Applied Energy*, 221: 220-228.

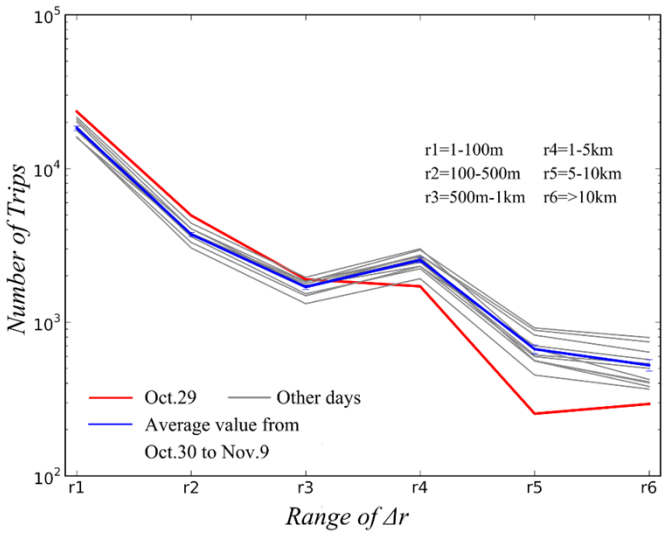
Representative Publication:

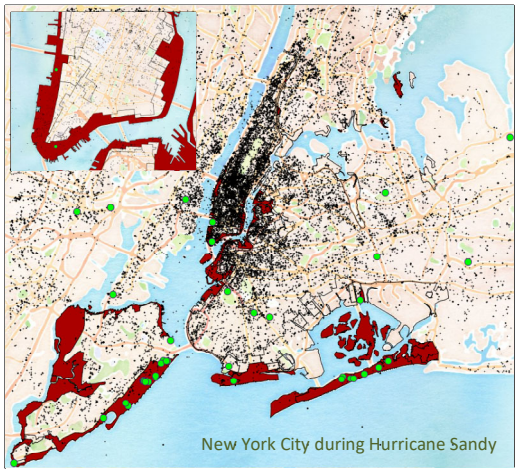
Gulbinas, R., Jain, R., Taylor, J., Peschiera, G. and Golparvar-Fard, M. (2014). "Network Eco-Informatics: Development of a Social Eco-Feedback System to Drive Energy Efficiency in Residential Buildings," *ASCE Journal of Computing in Civil Engineering*, 28(1): 89-98.



Representative Publication:

Gulbinas, R., Jain, R. and Taylor, J. (2014). "BizWatts: A Modular Socio-technical Energy Management System for Empowering Commercial Building Occupants to Conserve Energy," *Applied Energy*, 136: 1076-1084.



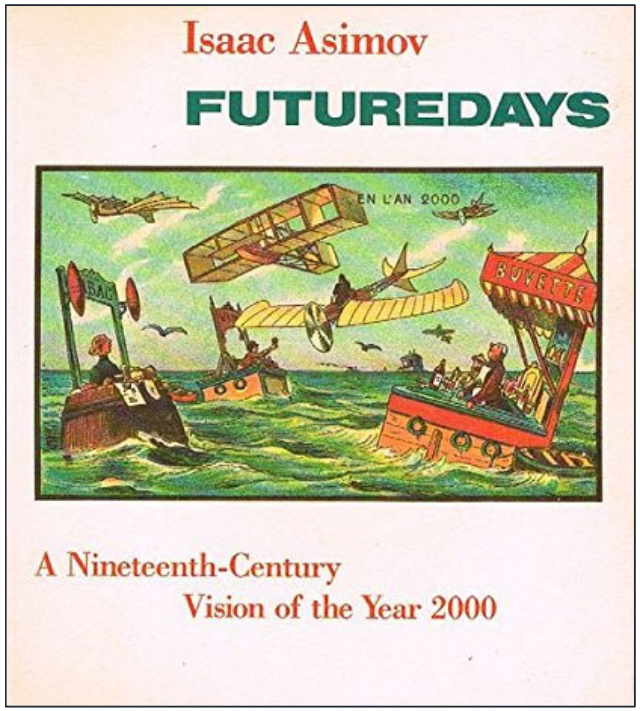


Representative Publication:

Wang, Q. and Taylor, J. "Quantifying Human Mobility Perturbation and Resilience in Hurricane Sandy," *PLOS ONE* (2014), 9(11): e112608. doi: 10.1371/journal.pone.0112608.

Examine, model and improve systemic changes occurring at the intersection between human and engineered networks…

at/across scales to achieve smart, sustainable, resilient & livable cities


Isaac Asimov
FUTUREDAYS
EN L'AN 2000
A Nineteenth-Century
Vision of the Year 2000

Smart City
Digital Twin

Why Focus on Cities?

We need to meet the growing needs of our burgeoning urban populations

www.nationalgeographic.com—Image courtesy Markley Boyer, Mannahatta Project/Wildlife Conservation Society

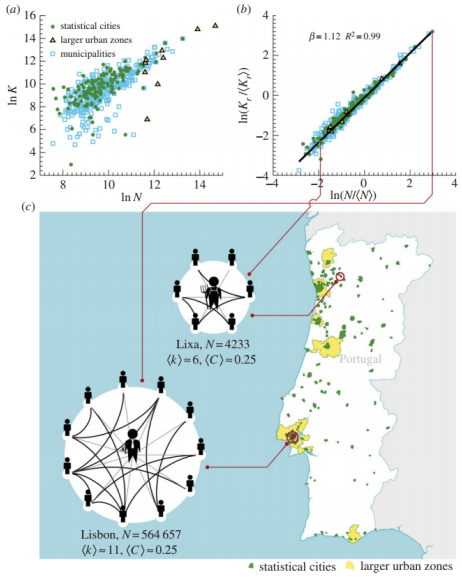
UP TO

70%

Of the world population is going to live in cities by 2050–A 2.5 billion increase [UN, 2014]

Scale of Urbanization

How does population scaling in cities impact human and engineered networks?



Human interactions & Socioeconomic activity scale super-linearly with city population size (α=1.15)

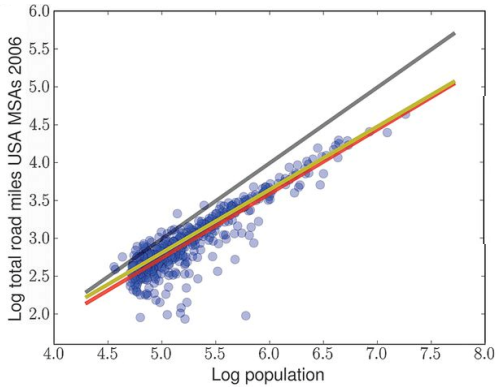
[Schläpfer et al., 2014; Bettencourt & West, 2010]

Income
Wealth
Innovation

15%

Crime
Pollution
Disease

15%



15%

Physical infrastructure and energy use scale sub-linearly with city population size (α=0.85)

[Bettencourt 2013; West, 2017]

The number of human interactions scales inversely to the degree that infrastructure scales with city population size… *Dynamics occurring at the Human and Engineered Network interface.*

Smart City Digital Twins

Can we expand building/community scale work to *Digital Twin* and integrate infrastructure / human / data dimensions?

1 What Happens?

2 Why it Happens?

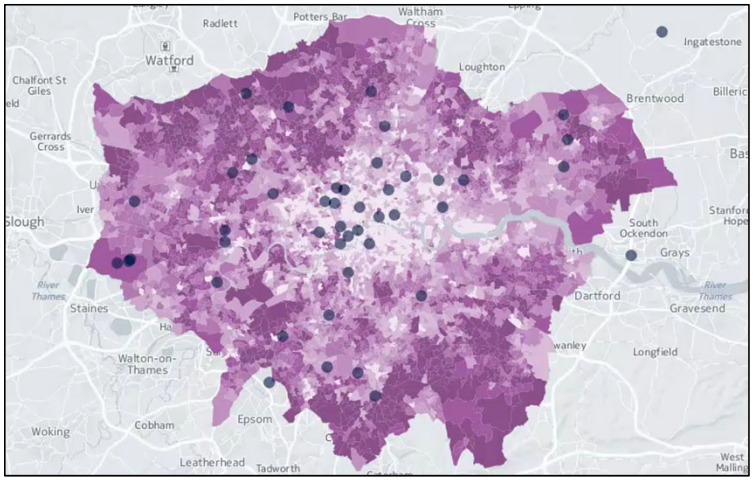
3 What if____ Happens?

4 Interventions

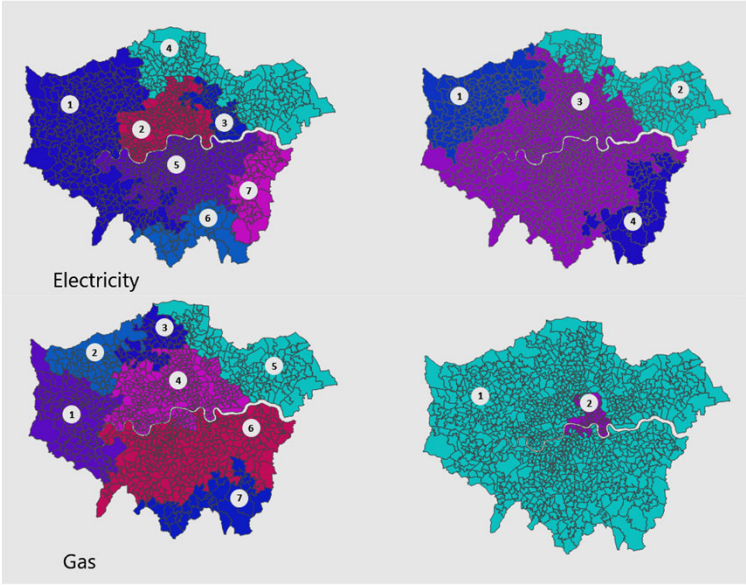
"A *Digital Twin* is a…pairing of the virtual and physical worlds [that] allows analysis of data and monitoring of systems to head off problems before they even occur, prevent downtime, develop new opportunities and even plan for the future by using simulations." [Forbes, 2017]

"A *Smart City Digital Twin* is a smart, IoT-enabled, data-rich virtual platform of a city that can be used to replicate and simulate changes at the human-infrastructure interface that can improve resilience, sustainability, and livability in the real city." [Mohammadi & Taylor, 2017]

Toward Smarter, More Sustainable, Resilient & Livable Cities

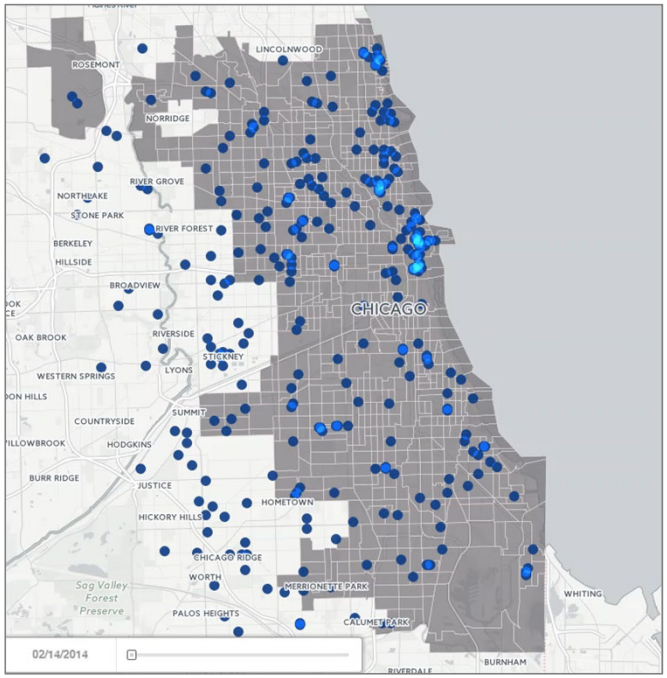


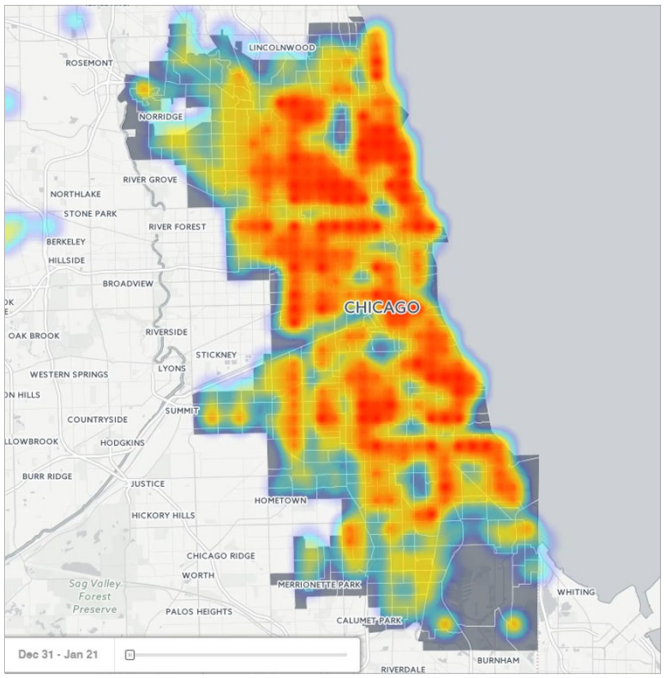
18,810,222 Positional Records
6,446,331 Meters
4,835 Spatial Divisions



Representative Publication:

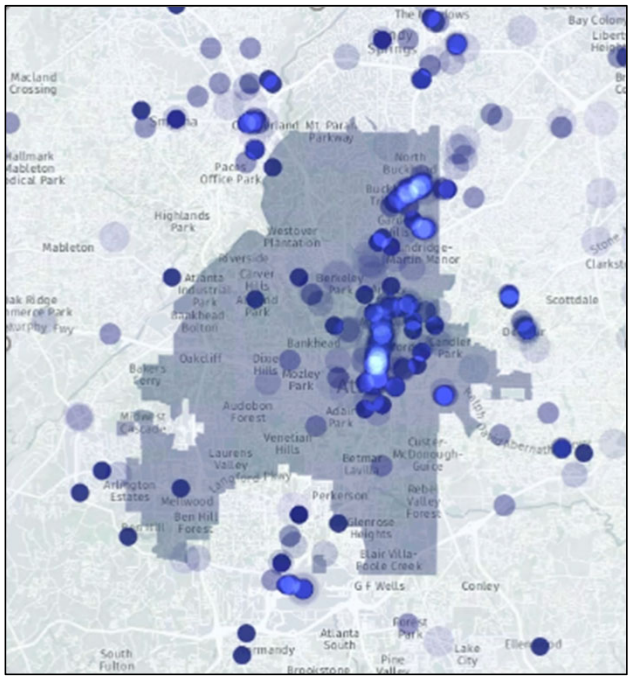
Mohammadi, N. and Taylor, J. "Recurrent Mobility: Urban Conduits for Diffusion of Energy Efficiency," Nature *Scientific Reports*, 9: 20247 (2019). doi:10.1038/s41598-019-56372-4.





Representative Publication:

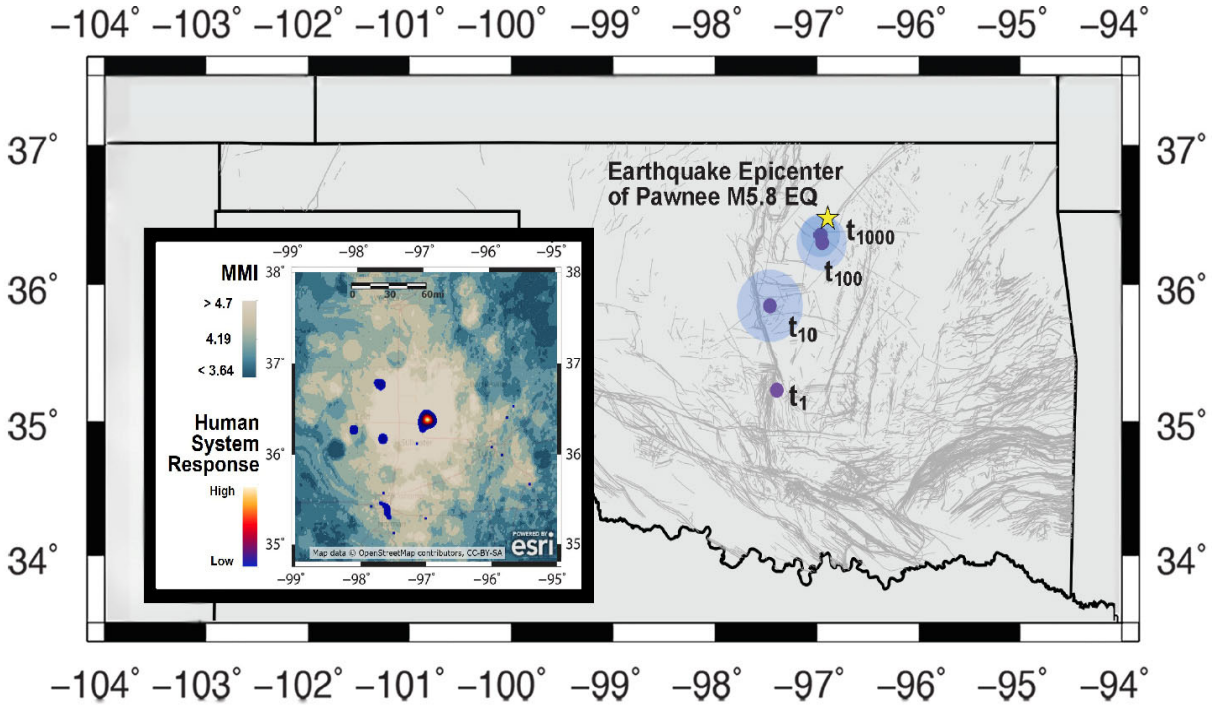
Mohammadi, N. and Taylor, J. "Urban Energy Flux: Spatiotemporal Fluctuations of Building Energy Consumption and Human Mobility-Driven Prediction," *Applied Energy* (2017), 195: 810-818. doi.org/10.1016/j.apenergy.2017.03.044.



2014
2016

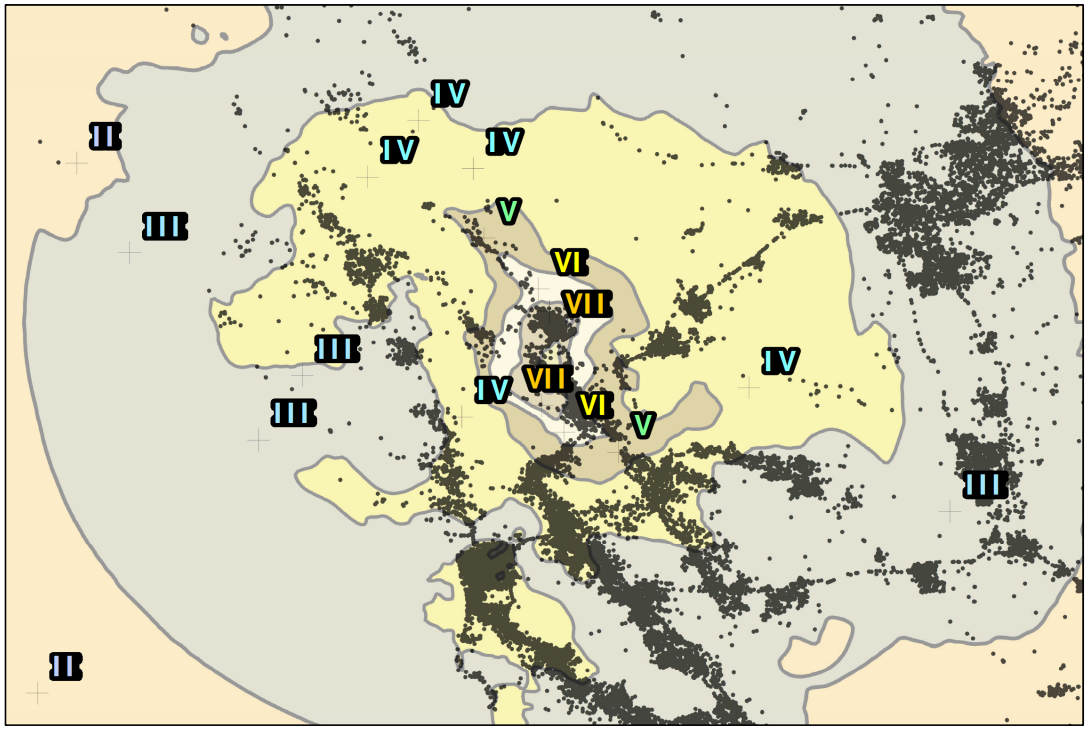
Representative Publication:

Wang, Y. and Taylor, J. (2019). "DUET: A Data-Driven Approach based on Latent Dirichlet Allocation Topic Modeling," *ASCE Journal of Computing in Civil Engineering*, 33(3): 04019023. DOI: 10.1061/(ASCE)CP.1943-5487.0000819.



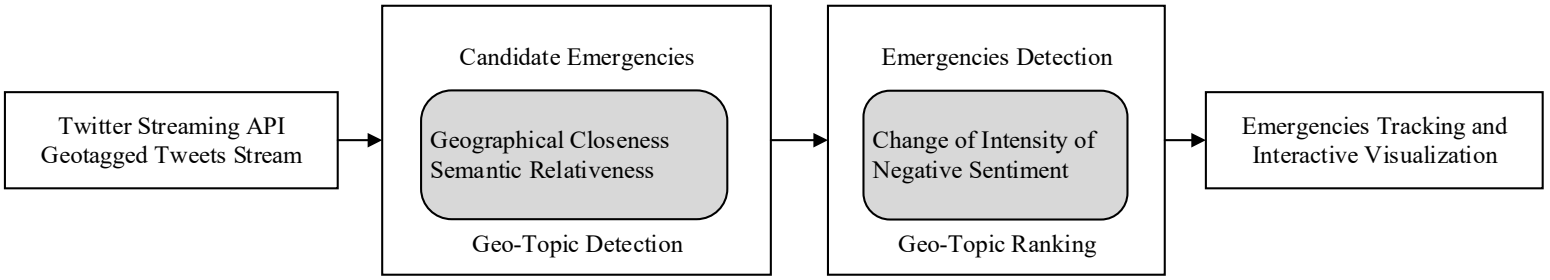
Representative Publication:

Pollyea, R., Mohammadi, N., Taylor, J. and Chapman, M. "Geospatial Analysis of Oklahoma Earthquakes (2011 - 2016): Quantifying the Limits of Regional-scale Earthquake Mitigation Measures," *Geology* (2018). doi: https://doi.org/10.1130/G39945.1.

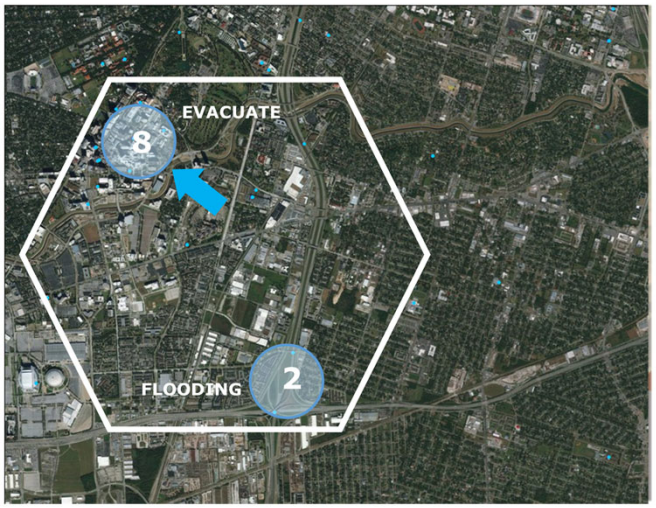


Representative Publication:

Wang, Y. and Taylor, J. "Coupling Sentiment and Human Mobility in Natural Disasters: A Twitter-Based Study of the 2014 South Napa Earthquake," *Natural Hazards* (2018).



PUBLIC SAFETY



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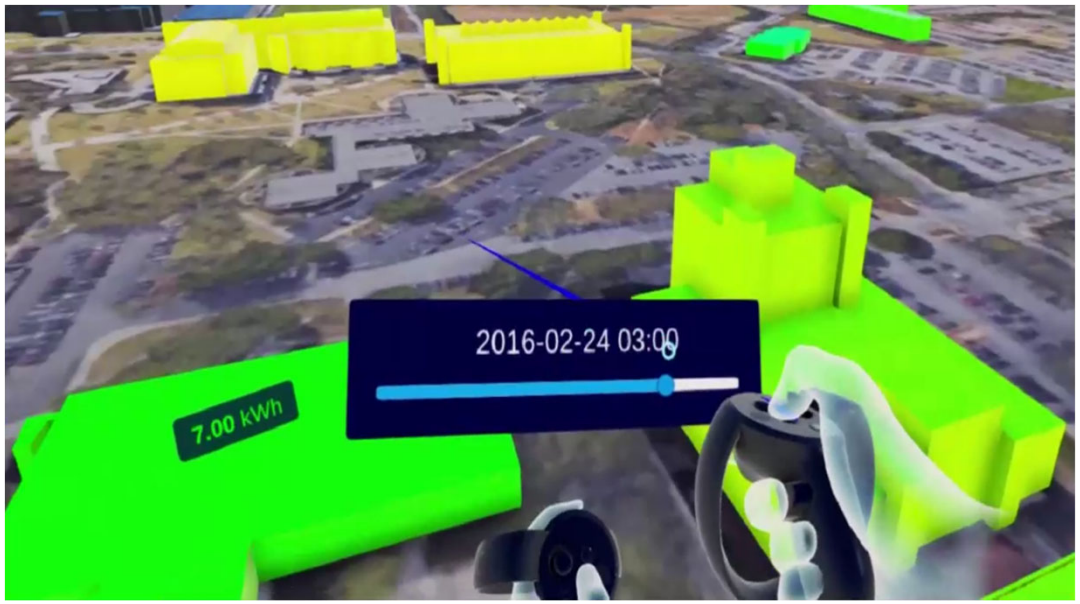
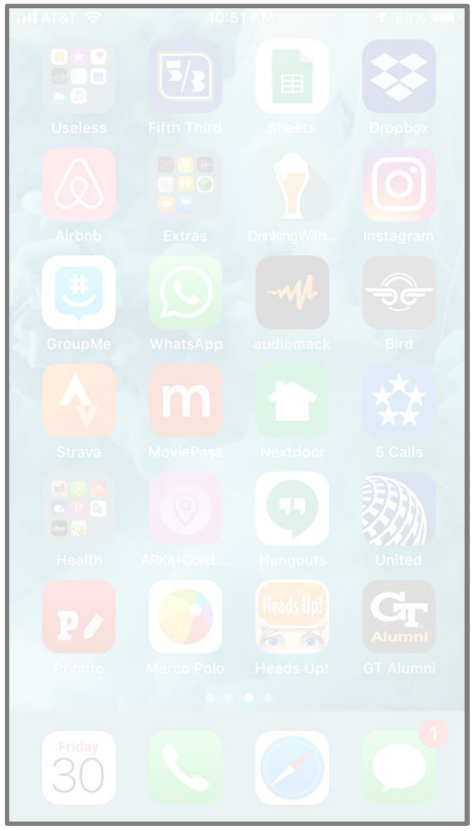


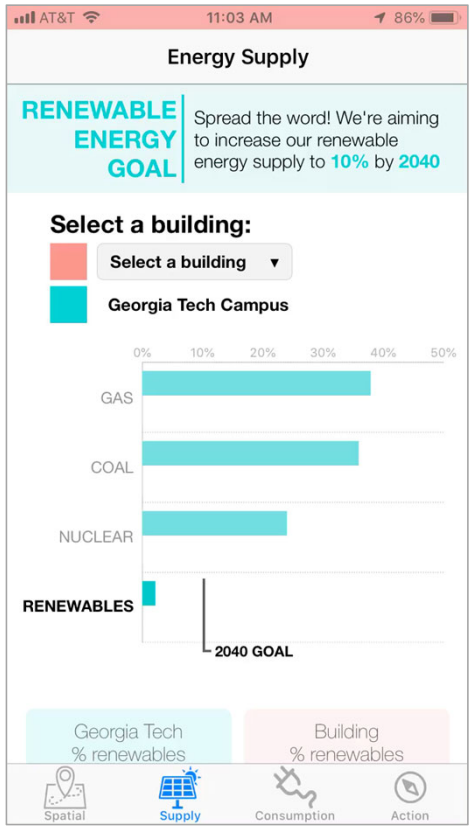
Representative Publication:

Xu, L., Francisco, A., Mohammadi, N., and Taylor, J. "Development of a Virtual Reality Integrated Community-scale Eco-Feedback System." In *Proceedings of the 2019 ASCE IC3E* (2019), Atlanta, GA.

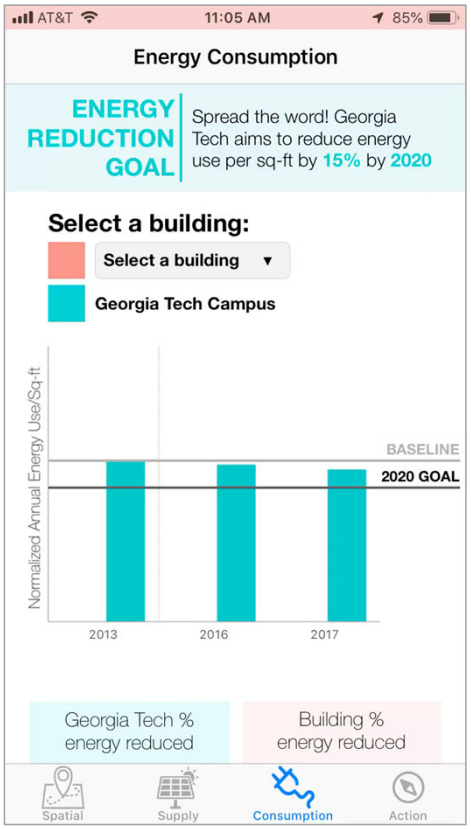
Spatial



Energy Supply

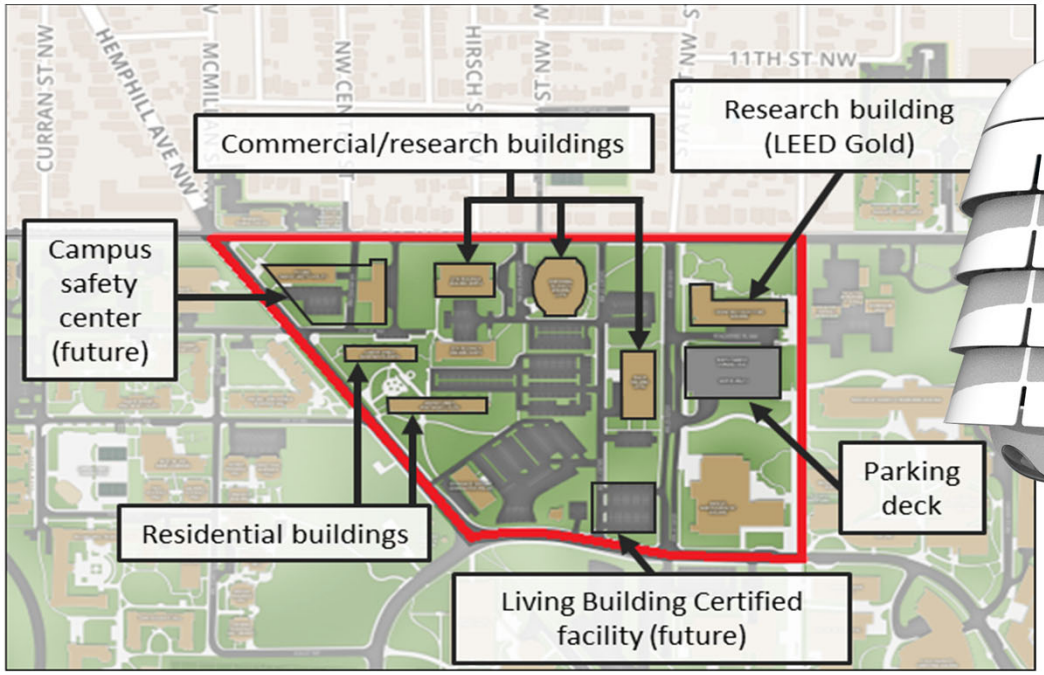


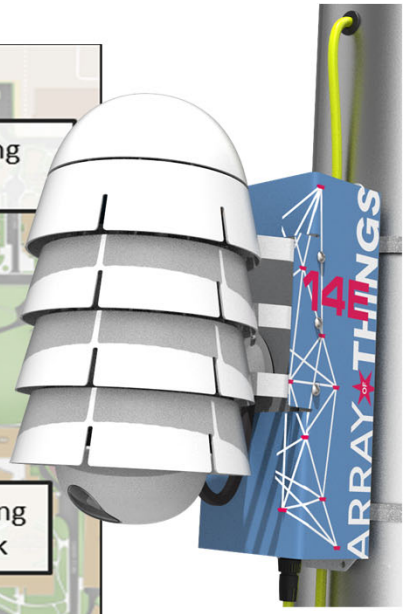
Energy Consumption



Representative Publication:

Francisco, A. and Taylor, J. (2019). "Understanding Citizen Perspectives on Open Urban Energy Data through the Development and Testing of a Community Energy Feedback System," *Applied Energy* (https://doi.org/10.1016/j.apenergy.2019.113804).





Courtesy: Argonne National Lab

Representative Publication:

Mohammadi, N. and Taylor, J. "Smart City Digital Twins." In *Proceedings of the 2017 IEEE Symposium Series on Computational Intelligence (IEEE SSCI) (2017)*, Honolulu, HI, November 27 – December 1. doi.org/10.1109/ssci.2017.8285439.

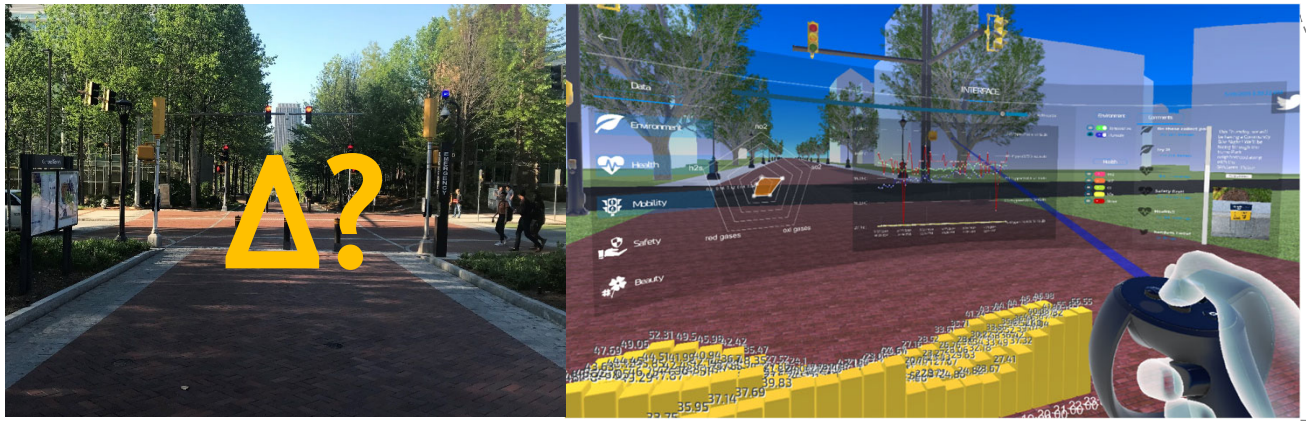
Smart City Digital Twin:
Smart Corridor at the Georgia Tech Campus

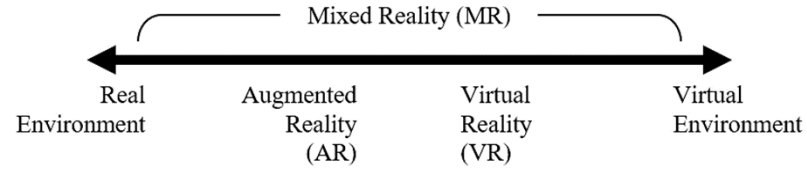
1 What Happens?

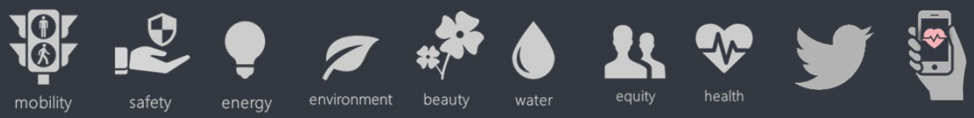
2 Why it Happens?

3 What if___ Happens?

4 Interventions

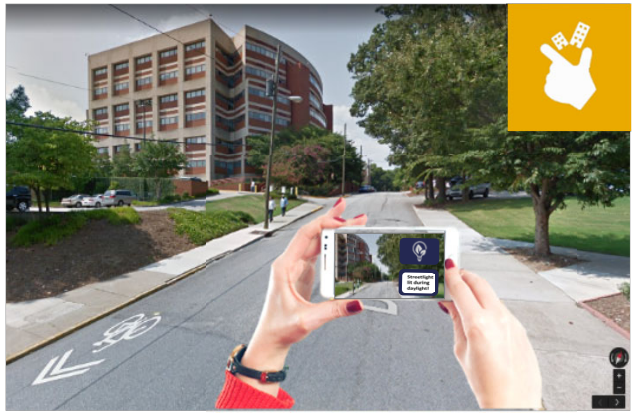


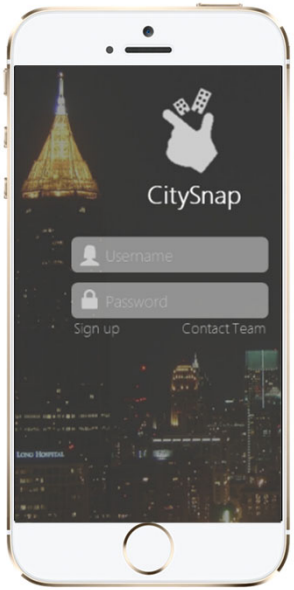




Smart City Digital Twin → Citizen Feedback:

CitySnap Augmented Reality (AR) Crowd-sensing App (Citizens)





mobility safety energy environment beauty water equity health

Smart City Digital Twin → Citizen Feedback:

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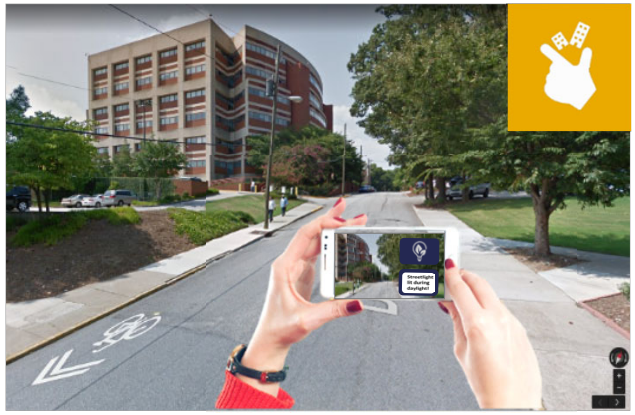
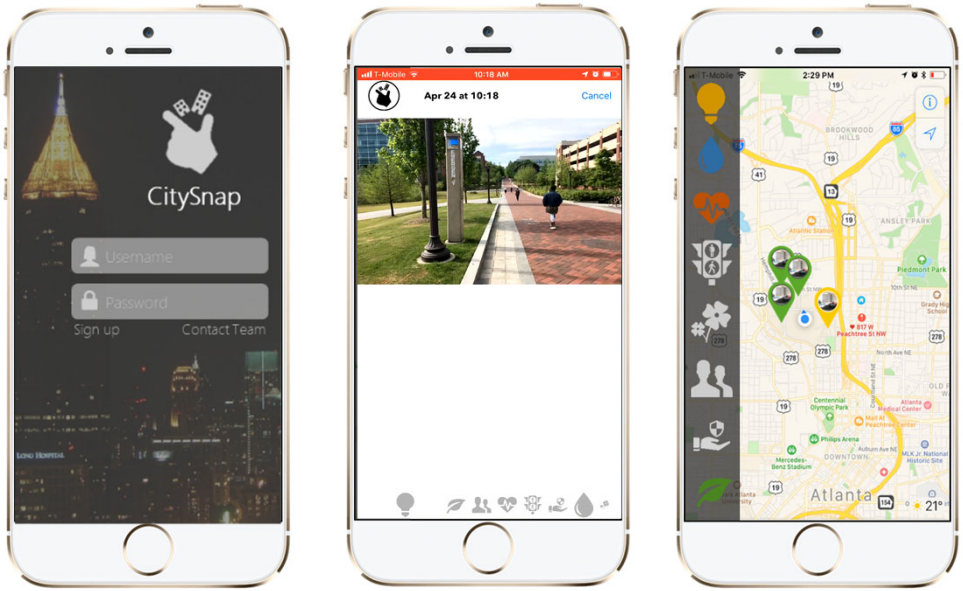




mobility safety energy environment beauty water equity health

Smart City Digital Twin → Multi-Sensor Integration:
Array of Things Multi-Sensor Node Enables *Smart Corridor*

energy water

Building-Level
Electricity (Elevators, Lighting, Café etc.)
Gas

Water Consumption
Water
Chilled Water
Steam
Rain Water

health

Ambient Air Quality
Carbon Monoxide
Hydrogen Sulphide
Nitrogen Dioxide
Ozone
Sulfur Dioxide
Air Particles

Sound intensity
RMS Sound Level

mobility safety

Street conditions, traffic flow, events
Camera

Detect heavy vehicles, shock to street pole
Magnetic Field
Acceleration and Orientation
Physical
Shock/Vibration

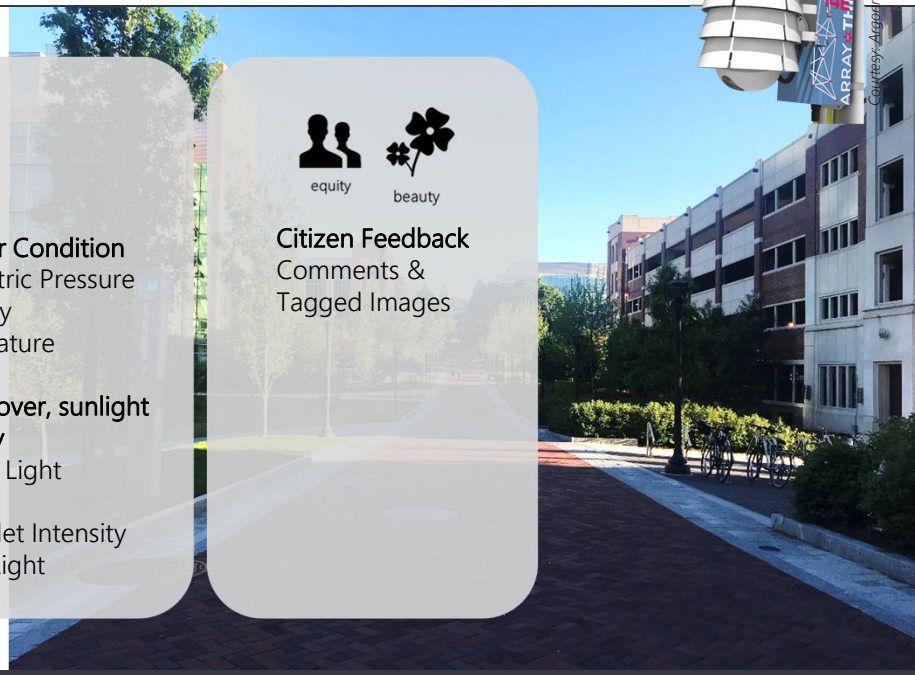
environment

Weather Condition
Barometric Pressure
Humidity
Temperature

Cloud cover, sunlight intensity
Infrared Light
Light
Ultraviolet Intensity
Visible Light

equity beauty

Citizen Feedback
Comments &
Tagged Images



Courtesy: Argonne National Lab

mobility safety energy environment beauty water equity health

Smart City Digital Twin:

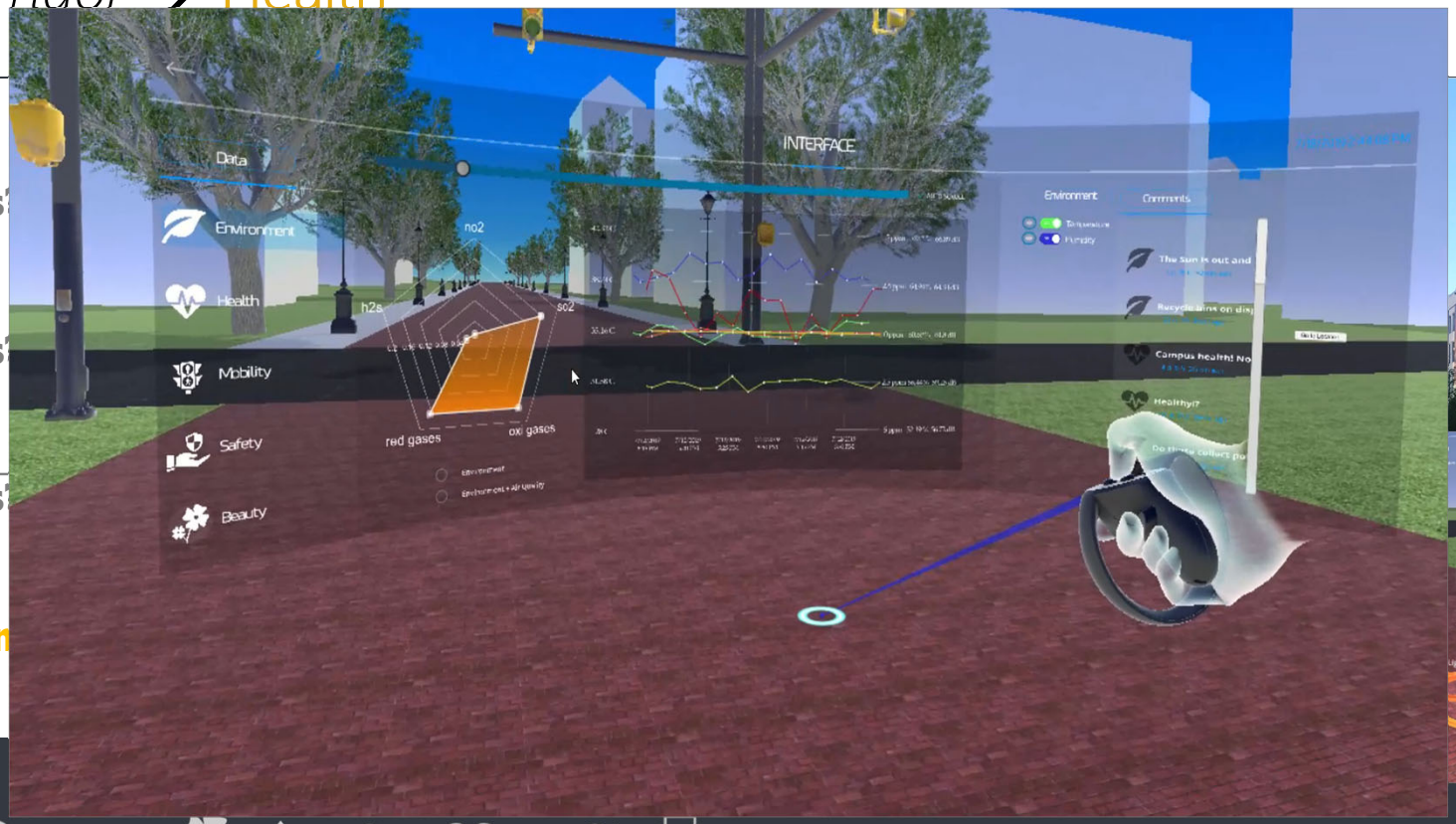
Smart Corridor → Health

1 **What Happens**

2 **Why it Happens**

3 **What if__ Happens**

4 **Interven**



Courtesy Argonne National Lab

mobility safety energy environment beauty water equity health

Monitoring violations of World Health Organization (WHO) thresholds for health-harmful pollution levels.

Smart City Digital Twins:

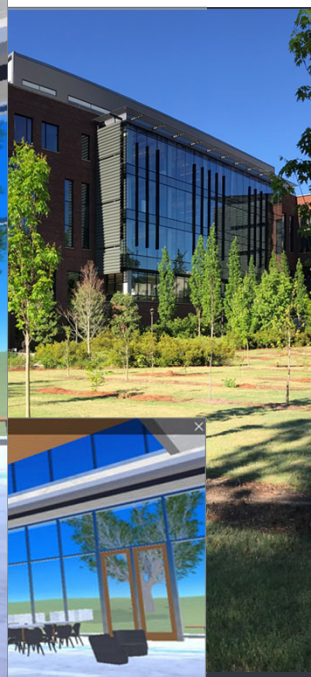
Smart Corridor → Energy/Water

1 **What Happens?**

2 **Why it Happens?**

3 **What if___ Happens?**

4 **Interventi**



mobility safety energy environment beauty water equity health

Monitoring variations in water/energy consumption levels correlated with human activities in buildings.

Smart City Digital Twins:
Empowering City Governments

1	**What Happens?**	***Monitor Sensor Data Against Thresholds***
2	**Why it Happens?**	***Correlations + Citizen Feedback***
3	**What if___ Happens?**	***Scenario-based Predictions***
4	**Interventions**	***Automate, Optimize, & Improve***

mobility safety energy environment beauty water equity health

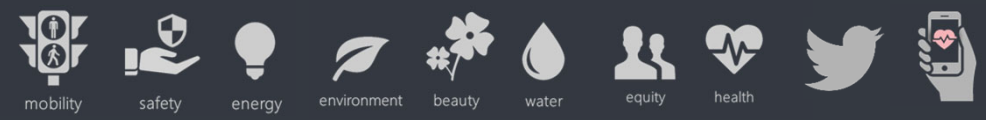
Smart City Digital Twins:
Benefits of Smart Sensing in Columbus

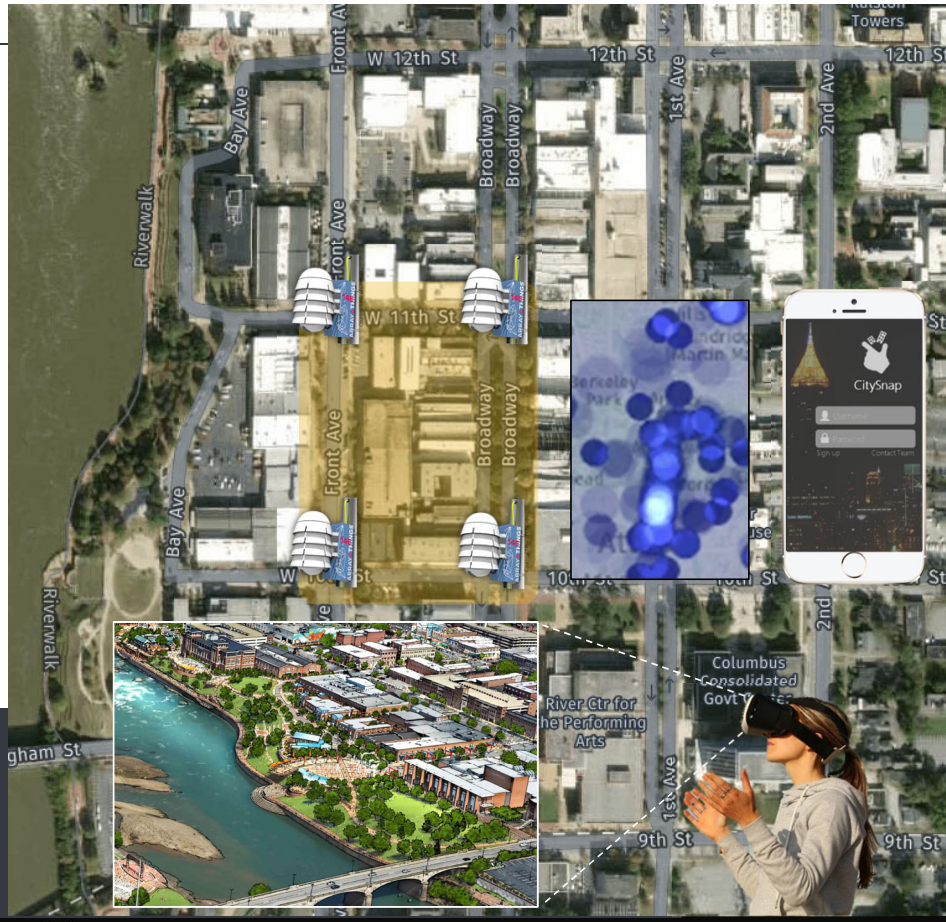
1 **What Happens?** — ***Monitor Sensor Data Against Thresholds***

2 **Why it Happens?** — ***Correlations + Citizen Feedback***

3 **What if___ Happens?** — ***Scenario-based Predictions***

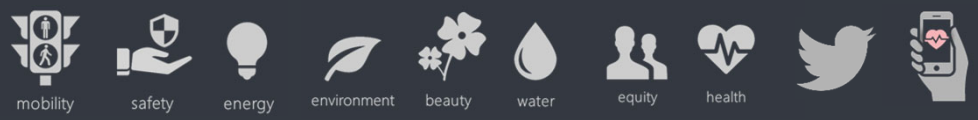
4 **Interventions** — ***Automate, Optimize, & Improve***

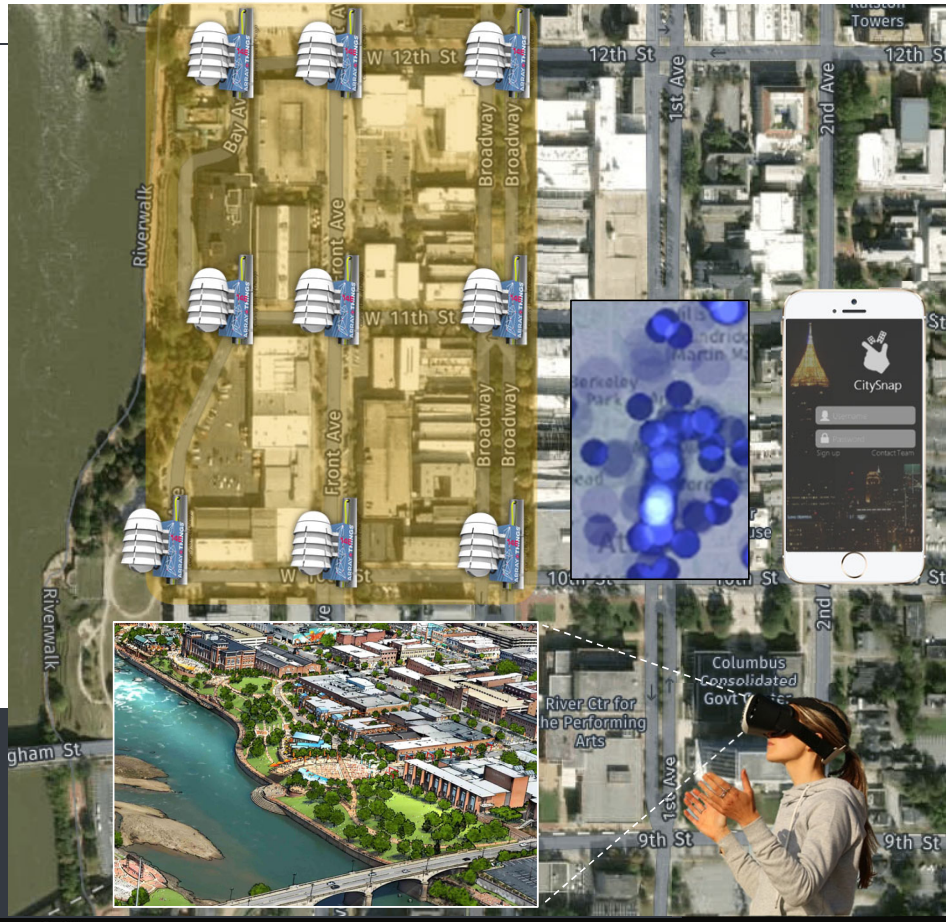


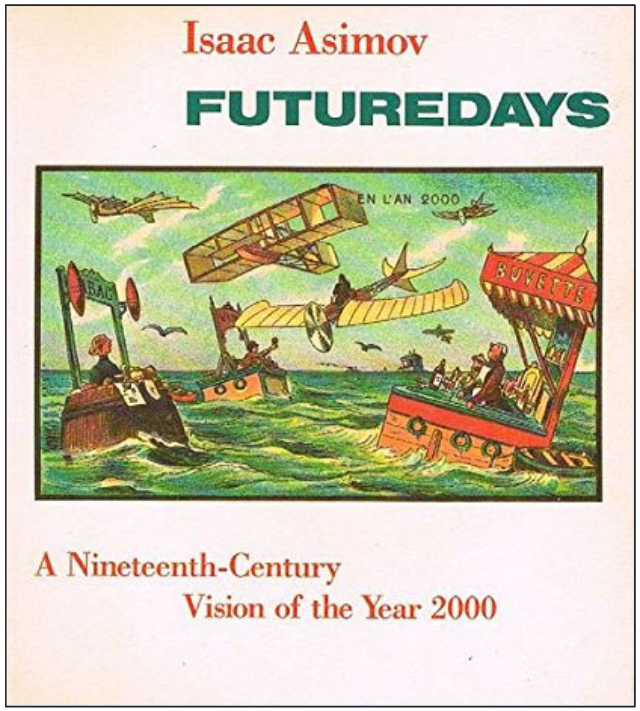


Smart City Digital Twins:
Benefits of Smart Sensing in Columbus

1. **Equip Columbus to better understand how people move through Uptown.**
2. **Improve understanding of the impact of climate, air quality, noise and other factors.**
3. **Create a "digital twin" of Uptown with tools and resources for businesses, gov't & the public.**
4. **Hyper-local data helps CCG anticipate and pro-actively address potential problems.**



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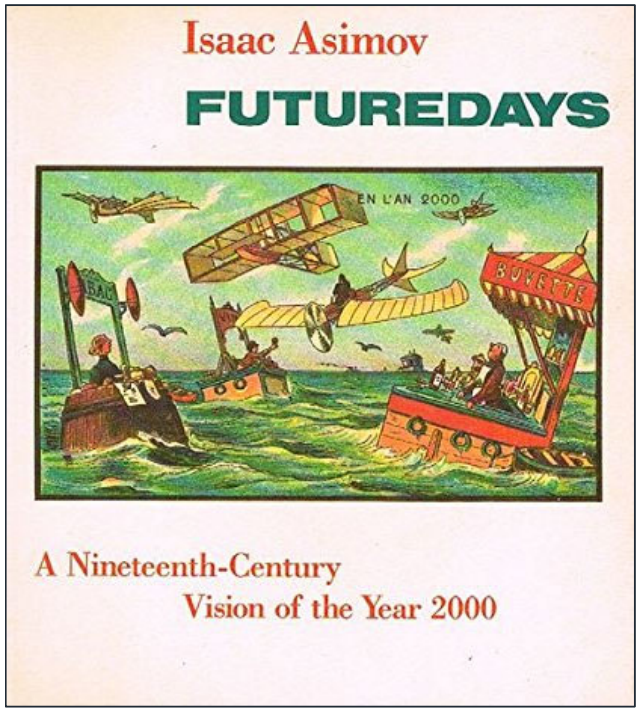
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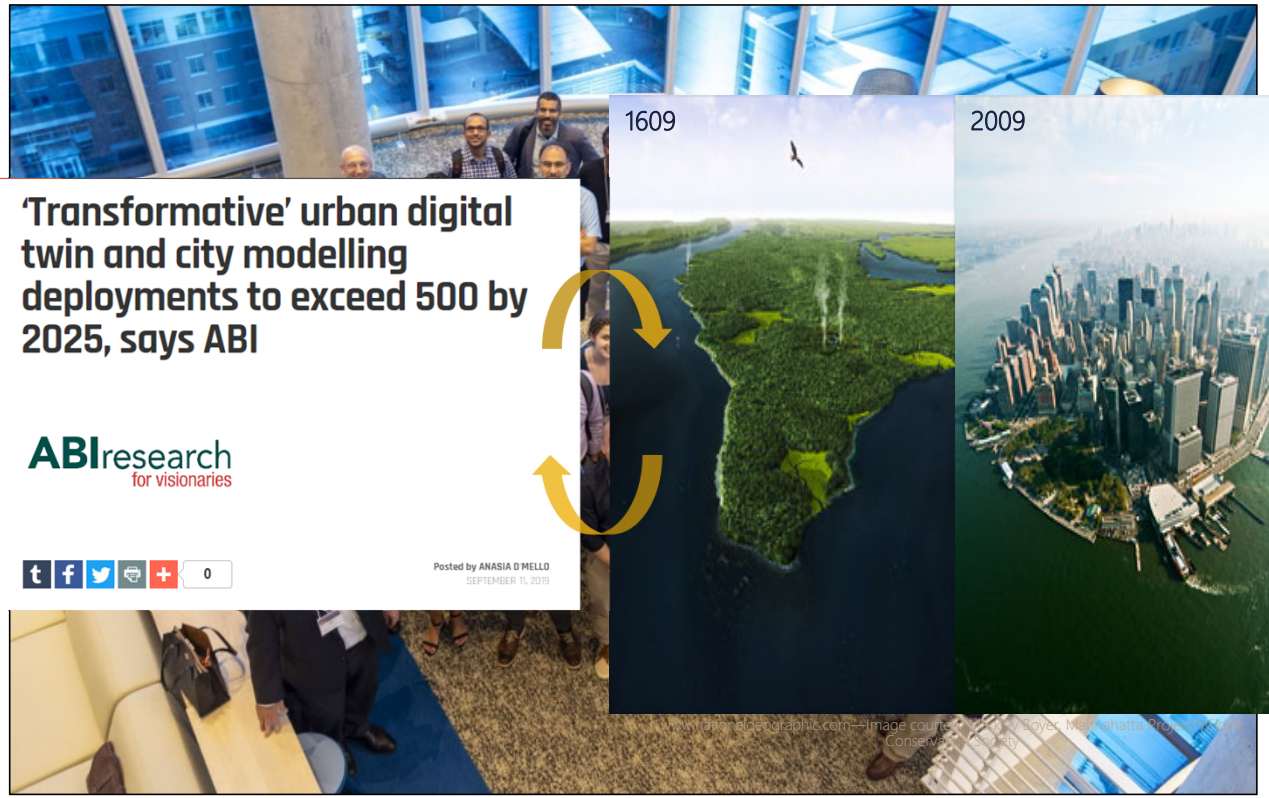
'Transformative' urban digital twin and city modelling deployments to exceed 500 by 2025, says ABI
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Posted by ANASIA D'MELLO
SEPTEMBER 11, 2019
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Georgia Tech

Thank you!

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