The Applications of Digital Twinning for Climate and Resilience Planning

Stephen Deal

In order to address environmental problems, city governments are increasingly turning to a new tool: digital twinning. A digital twin is a living digital replica of a city that is continuously updated with real-time data and analytics on the physical, social and human interactions that occur in a city. One might liken the system to a video game in which players make planning decisions, such as what ordinances and land use patterns to implement, and watch their decisions play out in real time as their city simulation grows or declines based upon player inputs. A digital twin is not a substitute for traditional planning, but its ability to gauge multiple impacts in a simulation makes it a powerful tool for cities in the 21st century.

Digital Twinning in Practice

Digital twins can be defined as "intelligent adaptive systems that pair virtual and physical worlds."[1] A digital twin is more than just a virtual model of a city though; it is a model that cities can use to run simulations on everything from new policies to proposed infrastructure projects. Though many cities are in the early stages of building their own digital twins, the firm ABI Research estimates that by 2025 more than 500 city digital twins will be up and running across the world.[2]

To properly maintain a digital twin, a city must be able to combine multiple layers of data.[3] As described by Hurtado and Gomez in their article, *Mirror Mirror,* the base layer will consist of terrain information, while the layer above that will be building information modeling data that includes all city buildings. The middle portion of the model will consist of two additional layers: one to capture the infrastructure system of the city and another layer for mobility, which includes the physical transportation elements (roads, sidewalks). The final two layers are critical as they are the key drivers in the data collection and analysis process. By employing sensors across the city, local governments are able to gather real-time data on the layers below and they have an effective method for continually monitoring city systems and services. This sensor data constitutes its own layer, and because it is continually updated and monitored it helps drive the simulation work done at the highest layer. The top layer is the digital twin layer, the culmination of all the previous data compilations.

Arguably the most prominent example of twinning at this time is Virtual Singapore. The model employs 14 core datasets ranging from land use to underground utilities grabbed from "more than 3 million street-level images captured at street level and 160,000 images taken from the air."[4] What distinguishes this twin from past urban modeling efforts, is the intricate level of detail at the user's fingertips. The model distinguishes buildings from trees and minute urban details such as windows, rooftops and building facades are treated as unique assets within the model. The full level of data available through Virtual Singapore is not only significant for planners though, it is also significant to research and development.[5] The model can serve as a common digital platform for analysis and research. Previous collaborative efforts between cities and academia would often require significant time to simplify modeling and data processes used and translate that work into something practitioners could easily grasp and make use of. By employing a digital twin, the experimentation and testing within a project can be easily visualized and validated as stakeholders can better grasp how data variables flow and interact within the twin.

Environmental Applications of Twinning

One of the biggest positives of twinning is that it allows planners to view the city as a kind of dynamic organism, one that evolves in response to a wide variety of inputs, both seen and unseen. By utilizing digital twinning, planners have a valuable tool as they can measure a city's capacity for change. The chief executive of the firm which developed

Virtual Singapore, noted that by using real-time data a more holistic perspective becomes possible:

> The problem is that when we decide about the evolution of the city we are in some way blind. You have the urban view of it – a map – you decide to put a building here, but another agency has to think about transport....The creation of one thing changes so many other things – the flow and life of citizens.[6]

The problem is that when we decide about the evolution of the city we are in some way blind. You have the urban view of it – a map – you decide to put a building here, but another agency has to think about transport....The creation of one thing changes so many other things – the flow and life of citizens.

Though past planning endeavors have captured certain discrete facets of the urban experience for evaluation, the "flow of life" was something that remained elusive. Now through digital twinning, planners have a model which can roughly approximate that flow and can project it out into the future for policy analysis.

This type of analysis of city flow and movement has profound implications in the drive to builder greener cities. Environmental attributes are fickle and can change considerably over a short period of time. Different areas of a city may have better exposure to sunlight or be prone to higher wind speeds, which have profound implications for renewable energy development. Urban air quality is also highly variable, as warmer temperatures increase the production of ground-level ozone, which is a major factor in smog.[7]

Through digital twinning, cities can track these variable environmental factors and gain insight into how they interact with each other over a given period of time. Cities such as Los Angeles, Las Vegas, Phoenix, and New York are building digital twins to lower building emissions as part of the Clean Cities – Clean Future campaign from the software company Cityzenith. For example, in Las Vegas, street-level LIDAR (Light Detection and Ranging Sensors) data are being collected from sensors positioned across the city.[8] Using LIDAR sensors, the city can capture loads of data on street use and movement patterns, such as "whether a moving object is a pedestrian, vehicle, or bicyclist." This data can then be aggregated into a digital twin, which would gauge air and noise pollution. This can be accomplished by tracking sound levels and electricity usage. Since EV vehicles generally generate less noise than the average car that data can be captured and tracked across the city. A twin can also track important energy variables such as electrical grid load distribution and water management.

The applications of digital twinning are not simply limited to large metropolises though, smaller cities are getting in on the practice as well. In Ithaca, New York, town leaders are partnering with Cornell researchers to develop a digital twin to help manage local decarbonization efforts.[9] In total, Ithaca is home to around 8,000 buildings, ranging from new research buildings to 19th century residences. City energy use data from Ithaca will be paired with a dataset from the US Department of Energy that contains building profiles data. This profile data will help in capturing occupant behavior and energy uses within spaces. The twin will also capture critical data on the city's energy grid, such as the grid's existing capacity and what type of green energy sources the grid is utilizing. Cornell researchers are also obtaining building permit data from the city to determine how individual buildings are constructed. This will help building owners visualize the potential carbon savings associated with building retrofits and materials reuse.

Digital Twinning Comes to the Gulf

In the Gulf Coast region, a digital twin is being used for yet another important set of environmental issues: flooding and hazard mitigation. This two-year research project is made possible by funding from Texas Sea Grant, who will also be working with the project team to ensure that the data reaches critical coastal stakeholders. The proposed platform, known as AI-Based Roadway Flooding Digital Twinning or AIR-FLOOD for short, would assist coastal communities in Texas with storm evacuation procedures.[10] The project team, led by Dr. Kunhee Choi with Texas A&M University, will collect data across two broad categories, or pillars.

The first pillar will consist of flood mapping data. Relevant datasets in this category include: FEMA flood maps, a roadway inventory, high-resolution digital elevation data, and Hazus model data with detailed information on economic and structural damage associated with specific flood events.[11] The second pillar will be roadway assessment data. This pillar will include datasets such as: roadway inventory data from Texas DOT, pavement performance data for communities in the study area, and traffic volume data. Using datasets from these two pillars, the team will then work on building a web-based digital twinning platform.

By utilizing twinning, the project will be able to combine flood modeling and roadway damage prognostics in a way that will help coastal communities respond more quickly and dynamically to flood events. When completed in 2024, the platform will provide first responders with critical data on the best possible evacuation routes in the event of an extreme flooding event. The twin could also help local and state transportation agencies prioritize emergency roadway repair projects.

Conclusion

The potential planning applications for digital twins are considerable. The extraction process for high-quality digital data, which used to be static and on an as-need basis, now has the potential to be constant and ongoing through the use of a digital twin. More importantly the flow of data in a twin can adapt to assess different policy approaches or if a shift in modeling becomes necessary because of new growth. By utilizing twinning, planners no longer have to be satisfied with isolated statistical snapshots to capture urban change over time, they can make use of a model that approximates the flow and life of the urban realm.

Stephen Deal is the Extension Specialist in Land Use Planning for the Mississippi-Alabama Sea Grant Legal Program.

Endnotes

1. American Planning Association, *PAS QuickNotes No. 89* (2020).
2. Sarah Wray, *City Digital Twin Adoption Growing Fast But Challenges Remain*, Cities Today (March 2022).
3. Peter Hurtado & Alexsandra Gomez, *Mirror Mirror*, Planning Magazine (Spring 2021).
4. Linda Poon, *How Cities Are Using Digital Twins Like a SimCity for Policymakers*, CityLab (Apr. 5, 2022).
5. National Research Foundation, Singapore, *Virtual Singapore* (Feb. 20, 2021).
6. Matthew Wall, *Virtual Cities: Designing the Metropolises of the Future*, BBC News (Jan. 18, 2019)(quoting Bernard Charlès of Dassault Systèmes).
7. Minnesota Climate Adaptation Partnership, *Air Quality*, University of Minnesota.
8. Bryan Horwath, *Local Tech Company, City to Unveil Las Vegas 'Digital Twin' at CES Gadget Show*, Las Vegas Sun (Nov. 14, 2021).
9. Mike De Socio, *To Get to Net Zero, This City Is Making a Map*, CityLab (Jun. 10, 2022).
10. Dr. Kunhee Choi, *Project Summary Form, Texas Sea Grant: AI-Based Roadway Flooding Digital Twinning (AIR-FLOOD)* (available from the author).
11. Federal Emergency Management Agency, *Hazus* (Jun. 10, 2022).

In Sum.

A Summation of the Facts and Figures of Interest in this Edition

★ *Percentage of all greenhouse gases that are CO_2, by weight:*	79
★ *Cost of CO_2 on human health and the economy per metric ton:*	$51
★ *High bid total for Gulf of Mexico Lease Sale No. 257:*	$191,688,984
★ *Rank of Gulf of Mexico Lease Sale No. 257, historically:*	1
★ *Estimated number of cities that will have digital twins in 2025:*	500