Urban planning tools synthesize and collect data to improve the quality of city life

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Imagine your city as it might be in the not-so-distant future.

Transportation in this city is various, pleasant, and low-impact. There are safe and efficient bike lanes, and anyone can order a cheap ride from an autonomous, minimal-emissions vehicle. Because fewer people drive, and almost no one idles in traffic, air quality is high. There are plenty of parks and open spaces because cars are less prevalent. Life in your city is happy, healthy, and sustainable. Your city is, above all, a smart city.

The smart city, like the smart home, is built on and around the "Internet of things," in which networked products gather, store, and share user data while communicating with one another in order to create improved and highly-efficient living environments. In a smart city, the Internet of things expands outward from the home into a plethora of automated and interconnected urban devices. The communication between and among these devices allows for vast amounts of municipal data to be gathered and eventually analyzed. A smart city leverages its collection of massive data to learn about its residents, showcasing the ways in which smart cities are beginning to transcend the Internet of things, by gathering massive data sets that are gradually helping researchers understand vast and complex networks.

However differently smart cities may be defined or described, underlying them all is an array of interconnected social networks and systems, an understanding of which allows for data-driven urban planning that stands to vastly improve the quality of urban life. Sarah Williams, an Institute for Data, Systems, and Society (IDSS) affiliate and assistant professor of urban design who directs MIT's Civic Data Design Lab—an urban studies center that uses both data visualization and data collection to identify and understand various urban phenomena—is an example of an urban planner using this data to communicate the complexities of urban life in order to drive decisions. "When data is made comprehensible to a large number of people," Williams remarks, "it is well-positioned to drive social change. Creating tools that synthesize and collect data transforms how we see the world, at one time showing us the effects of policies while also providing essential information to develop new urban strategies."

William's research shows the kind of impact IDSS researchers are having by developing and communicating an understanding of vast and complex urban social networks. At the same time, other IDSS researchers are helping to develop smart technologies that will power future cities, such as autonomous vehicles and smart energy meters, using a systems approach to build effective solutions for the improvement of urban life and the solution of societal problems.

Transportation systems in smart cities

Transportation is one of the greatest of those problems, and one of the most essential areas for innovation within the smart city—particularly the promise of autonomous vehicles. Emilio Frazzoli, an IDSS faculty affiliate based in the Department of Aeronautics and Astronautics, has made significant inroads in the area of autonomous vehicle innovation. Frazzoli joined project leader and senior paper author Daniela Rus, the Andrew and Erna Viterbi Professor in Electrical Engineering and Computer Science—as well as other colleagues—in testing an autonomous vehicle pilot scheme last fall in Singapore, where the Singapore-MIT Alliance for Research and Technology (SMART) is based. Over six days, autonomous golf carts were made available to visitors in a large, public garden in Singapore, where passengers could summon them through an online booking station and book rides to and from predetermined points. The small carts, a minimalist version of an autonomous vehicle with a maximum speed of 15 miles per hour, adroitly navigated paths in the garden, making sure to avoid pedestrians and cyclists.

Frazzoli is now working to create street-ready autonomous vehicle technology that could transform urban travel in the near future. "If deployed more broadly," Frazzoli remarks, "autonomous cars have the potential to change how we think of personal mobility, especially in urban settings. Cars that are able to drive autonomously to pick up customers, take them to their destination, and then park themselves (or serve the next customer) can provide a mobility service that is almost as convenient as privately owned cars, with the sustainability of public transportation."

Another contribution from Frazzoli to autonomous vehicle technology is a mathematical model he developed with Carlo Ratti, a professor of the practice and director of the SENSEable City Lab in MIT's Department of Urban Studies and Planning. The model plans for an autonomous, or "slot-based," intersection" (Sl). These intersections remove the need for traffic lights by allowing autonomous vehicles, acting in concert as part of the Internet of things, to communicate with one another to ensure that each arrives at an intersection precisely when a "slot" required to pass through safely becomes available. This process speeds up traffic flow by eliminating unnecessary stoppage, decreasing emissions and increasing efficiency. Frazzoli's model demonstrates that it is possible to create a city without traffic lights, though such an achievement would require new innovation in other areas, for instance in developing ways for pedestrians and cyclists to move safely along with vehicles through Sl intersections.

Smart incentives

The smartest of smart cities go even further than mechanical and systematic improvements, however, by helping their residents learn how to best conserve resources, including their own money. The large amounts of data gathered on transportation patterns in cities is helping researchers understand and develop incentives that encourage people to adapt their behaviors to a more efficient model, and to make more optimal choices, such as traveling during off peak hours.

MIT assistant professor and IDSS faculty member Jessika Trancik, in collaboration with Moshe Ben-Akiva, professor of civil and environmental engineering, is leading a large project that explores possibilities for helping people adapt their transportation behavior. The pair, along with several other MIT departments and a team at the University of Massachusetts at Amherst, are developing the Mobility Electronic Market for Optimized Travel, or MeMOT, a system in which consumers are rewarded—as they are in other areas of the marketplace—for optimal behavior. As Trancik remarks, "People make transportation choices based on their preferences and the information that they have. There is no question that access to information … affects personal transportation choices on a daily basis."

By being given accurate, real-time information and feedback, consumers and residents are encouraged to exchange less efficient patterns of behavior for more efficient ones. In a smart city, where behaviors can be measured, data revealing actual behaviors and choices can also be more readily gathered, allowing for urban architects and engineers to learn which individual choices could be changed to improve overall quality of life and efficiency. Trancik remarks that's "why models are important. Through modeling we can combine the most useful pieces of information in diverse data sets to provide a picture of the daily choices available to consumers of vehicles, drivers and travelers more generally."

This sort of rapid responsiveness to readily available data, applied to individual choices about transport, energy, and other resources, could, in fact, be the very thing that finally closes the "open loop" of the energy markets, creating more efficient, reliable grids, something particularly necessary in the present and future age of "mega-cities."

Smart energy systems

Energy is one of the markets in which it is simultaneously difficult and crucial for consumers to make good, informed choices. This is because typical energy markets are "closed," as demand doesn't vary according to price (although price fluctuates with demand). Energy market prices fluctuate with extreme frequency, and, since most customers have no access to this data in real-time, they are unprepared and unable to respond to these sorts of pricing markets. Customers instead tend to base energy choices on convenience rather than price, creating an open loop that allows energy companies to set price according to demand, but which doesn't allow customers to respond to price. The normal feedback loop in these markets, however, is complicated by rapid price fluctuations.

When customers are given real-time pricing information in energy markets, as with "smart meters," the consequences of good responses can, surprisingly, be devastating, according to research conducted by IDSS Director Munther Dahleh and others. If demand changes according to price fluctuation, which is the goal of most "smart technologies" that provide consumers with real-time data, rapid and erratic fluctuations in demand could result. Such fluctuations could cause a particularly dangerous situation in energy markets, which have "ramp constraints," meaning that supply cannot easily keep up with rapidly fluctuating demand.

Dahleh and his collaborators, MIT research scientist Mardavij Roozbehani and Professor Sanjoy Mitter, are exploring just this nexus by using control theory (a branch of engineering and mathematics that studies how dynamic systems can be modified by feedback) to create a feedback loop for energy pricing that would allow for consumer pricing response, while mitigating excessive fluctuations in demand. Solving this problem could make for significantly better energy policy, contributing to more efficient and smarter cities that create less systemic risk to the grid, and make the grid considerably smarter. Dahleh remarks that "the smart grid, through smart metering, will enable real-time demand shifting to cope with the uncertainty of renewable generation and to reduce the stress on the power grid. To realize this value, we are developing models and strategies to design incentive mechanisms, through pricing or availability of information, that will shape the consumer's behavior in a fair and efficient manner."

Future promises

The smart cities of the not-too-distant future will themselves be feedback loops and smart grids comprised of interconnected, networked technologies that help people make informed choices based on efficiency, quality of life, and convenience. A sophisticated understanding of the data behind these complex networks will allow researchers to create continually improved systems that help people lead better, more efficient lives.

Although the prospect, and the reality, of smart cities does raise serious questions about cybersecurity, trust, and digital privacy, smart cities promise a great deal of improvement in the quality of life for their residents. The advances made by IDSS researchers, working across disciplines and domains, may even mean that tomorrow's "mega cities"—which once threatened to drain natural resources, and cause massive congestion across systems—will instead be "mega smart cities," fitted with highly-efficient interconnected systems that work together to offer residents a good, sustainable quality of life, and far more promising futures.

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