Green Gadgets?

The Smart-Cities Movement and Urban Environmental Policy

ANTHONY TOWNSEND

NEW YORK UNIVERSITY

Most of the world's population are now city dwellers, and mobile, wireless computers outnumber desktops. In an age of urbanization and technological ubiquity, how is the social compact around environmental degradation, science, and policy and planning shifting? What new challenges and what new tools are emerging? This chapter examines three interrelated developments in the smart-cities movement through an environmental policy lens. First, it considers the rapid growth in investment in smart infrastructure designed to improve efficiency, and the impetus provided by global carbon emission reduction efforts. It then looks at shifts in transportation and mobility and potential structural changes in metropolitan land use patterns that may have significant impacts on regional ecosystems. Finally, it examines the implications of distributed sensing for citizen science and debates around urban environmental justice.

URBANIZATION AND UBIQUITY

Planet of Cities

It is well understood that we are in the greatest period of city building that humanity may ever know. "The world population will reach a landmark in 2008," United Nations demographers declared in 2007, "for the first time in history the urban population will equal the rural population of the world."[1] Since then every conference—perhaps every single paper—on the future of urbanization begins with this rote observation. Truth be told, the UN was a little overzealous: there's some evidence that the pace of urbanization has slowed, particularly in sub-Saharan Africa, and the 50 percent threshold was not actually crossed until early 2009.[2] Still, economist Paul Romer's observation hits the mark: "In the lifetimes of our children, the urbanization project will be competed. We will have built the system of cities that their descendants will live with forever."[3] And we are well on our way to complete urbanization of the world's population. By 2050, nearly 70 percent of humanity will live in cities.[4] A speculative estimate suggests as many as 90 percent of the world's projected future population of 11 billion will be city dwellers in 2100.[5] The network of built-up areas and connecting infrastructure that supports them will shape the next several centuries of development, if not longer—much as we still live with the geopolitical consequences of the Silk Road, the ports of the Age of Exploration, the railroads of the British Empire, and the U.S. Interstate Highway System.

Yet, even as we make sweeping generalizations about the urban destiny of our civilization, we must recognize the great diversity in the nature of city development across the globe. In the United States—which alone among wealthy countries will add an estimated 90 million new metropolitan inhabitants by 2050—existing metropolitan populations continue to disperse, despite countercurrents of urban revitalization (which is happening at vastly lower densities than historically).[6] Already largely urbanized, Brazil will spend the twenty-first century rebuilding its vast squatter cities, the favelas. In sub-Saharan Africa, where 62 percent of city dwellers live in slums, the urban population is projected to double in population by 2025 (though as noted above, this rate is increasingly the subject of debate). Asian cities, reflecting the tremendous diversity of the largest and most populous continent, are charting a vast range of new forms—from the *desakota* urban-rural sprawl of Indonesia, to Singapore's hyper-managed artificial paradise, to India and China's tandem campaigns to build a hundred "smart cities."

Connected People and Things

At the precise moment the world became mostly urban, the spread of information and communications technologies (ICTs) passed its own crucial threshold: in 2008, also for the first time, the number of mobile broadband internet subscribers surpassed the number of fixed subscribers. The internet became mostly "untethered"—to borrow a term employed by the U.S. Army in the 1990s as it contemplated the dawning era of telecommunications-enabled mobile urban warfare (and reflecting the reality that "mobile" isn't accurate, since most of us are stationary most of the time when we use our portable devices).[7]

Mobile networks challenge urban planners' intuition about how telecommunications influences travel behavior and land uses. Often, we simplistically assume that by freeing us from wired terminals, mobile phones will allow firms and workers to permanently relocate to rural areas en masse. Yet most evidence points to the opposite. In developing countries, mobile phones have been a powerful enabler of seasonal rural-urban migration (which, not surprisingly, can best be tracked through mobile phone movements recorded by mobile phone companies).[8] Mobiles also reinforce the value of large gathering sites—the essential purpose of cities, after all. For instance, the most robust cellular networks are those that blanket meeting spaces like stadiums and conference centers. Refugees from the Syrian conflict have spread out across Europe with little more than their smartphones in hand.[9] In that sense, mobiles can be seen as a catalyst for density: they get you to the meeting and help you find your friends when you get there.

But there are countercurrents, of course. Mobile networks are also a substrate for sprawl, eliminating the social isolation and opportunity cost of travel by automobile. Not surprisingly, the capital invested in the 285,000 towers that constitute the U.S. cellular grid (about $500 billion, growing at $30–40 billion annually) now rivals that in the U.S. interstate highway system (about $500 billion).[10]

Talking on the go is hardly a new idea—the first mobile phone call was placed in the United States in the 1920s, from the back seat of a specially outfitted automobile in the Philadelphia suburb of Elkins Park. But also in 2008, even as we untethered ourselves from the grid, people become a minority on the internet. Today, there are at least two additional things connected to the internet for every personal device. But forecasts are that by 2020, some 50 billion networked objects will outnumber humans ten to one.

Today, the "internet of things," as these connected objects are collectively known, encompasses a growing range of wearable and portable devices designed for health and fitness applications, home appliances, as well as a growing array of networked automotive systems. As new and retrofitted buildings and urban infrastructure come online, they too will be fitted with embedded sensors and controls. These systems will have tremendous impacts for how cities are managed and planned as businesses, governments, and even citizens tap the pool of observations they create to understand the world, react, and even predict. These "big data" will be an immanent force that pervades and sustains our urban world, and their volume and velocity of production will drown out the entire human web. Consider that one proposed smart city for 200,000 people would produce over 150 times the amount of data contained in all of the 10 billion photos archived on Facebook as of 2013 (about 300 petabytes per year versus Facebook's 1.5 petabyte photo archive).[11] This middling smart city would even put the world's most prolific scientific instrument, the Large Hadron Collider, to shame—that atom-smasher only musters a data flow of about 20 petabytes annually.[12]

A New Symbiosis

Throughout urban history, the capabilities of ICTs and the size and complexity of cities have advanced hand in hand. City growth drives innovation in information processing tools, and the resulting governance innovations unlock further rounds of urban expansion. In the ancient world, writing supported cities' role as specialized hubs for government, commerce, and religion. In the industrial cities of the nineteenth century, the telegraph, telephone, and mechanical tabulators powered a "control revolution" that coordinated human activity on a previously unimaginable scale.[13] Today, the internet and cellular networks make both urban sprawl and global cities of previously unthinkable size possible—5, 10, or even 20 million people. Without these key technologies, cities would have collapsed under the weight of their own expansion.

As we confront unprecedented urbanization then, in the context of a new revolution in information processing technology, this is the fundamental question: can we employ these tools to manage another round of urban scaling—to megaregions of 40, 50, 75, or 100 million people—while simultaneously delivering a higher standard of living in a more environmentally sustainable and resilient manner?

This is, at its core, what the smart-cities movement is all about.

From Market to Movement

The term *smart* has entered the global urbanization discourse in the last few years, with little consensus about what it means, what it can contribute to a broader discussion about strategies for improving the urban condition, and its rhetorical limitations. Take, for example, these two statements:

> This is the final phase of industrialization. Everything in your society has to be modernized. Everything has to be smart.[14]

> "Smart city" pilot projects are proliferating around the world, bringing together technology companies and cities and towns in public-private partnerships to promote sustainability, conserve energy, reduce costs and meet the needs of citizens who are demanding a reasonable price.[15]

As seen in these quotations, the term *smart* is widely employed by bombastic proponents of corporate-engineered "solutions" to complex urban problems—with a sense of inevitability borrowed from the ICT industry's own mythology.

How "smart" won out over other terms is unclear—it is merely the latest in a lineage dating to the 1970s coined to describe the convergence of cities and ICTs—"wired city," "intelligent city," and "information city" and so on. In 2003, William Mitchell, former dean of the MIT School of Architecture and Planning and an prolific author on the topic, set up at the MIT Media Lab a research group what he named Smart Cities. Adapted by IBM for a multimillion-dollar marketing initiative in 2008 as Smarter Cities, the term seems to have stuck.

Nailing down a definition has been trickier, and scholars have proposed several. A useful one put forth by a major EU-funded effort (the oddly named Fireball Project) weaves technological transformation together with broader goals of citizen empowerment: "A useful definition to start with is to call a city 'smart' when 'investments in human and social capital and traditional (transportation) and modern (ICT-based) infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory government.' . . . To this, the notion of empowerment of citizens and 'democratizing innovation' should be added."[16] Furthermore, the authors tack on to this definition a place-making element, arguing that "the smart city provides the conditions and resources for change. In this sense, the smart city is an urban laboratory, an urban innovation ecosystem, a living lab, an agent of change."[17] In this view, a smart city is defined by the convergence of four elements: human capital development, digital enhancement of infrastructure, citizen engagement through open innovation processes, and a distinct and critical place-based element.

Smart cities, then, are seen as a pragmatic framework for urban management and planning and as highly focused on problem solving. Their broad historic context comes from urbanization and ubiquity. But their immediate context is an economic crisis and the breakdown of global governance. Where old institutions are seen as failing in the face of global challenges, new technologies and insurgent local efforts are seen as viable progressive alternatives. As the Fireball authors put it, the smart city is the engine of transformation, a generator of solutions for wicked problems."[18]

The Financial Crisis and the Maturing Market

"Black swans" matter.[19] By accident, the 2008 financial crisis was a crucial catalyst for the smart-cities movement, fusing together three trends that came to a boil that year—global urbanization, the mobile internet, and connected things.

While the market was moving in the general direction of smart cities, the financial crisis provoked a sharp and severe cutback in ICT spending by Fortune 500 and multinational corporations—the bread-and-butter customers of technology vendors such as IBM, Cisco, and Oracle. Aside from travel, ICT capital spending was one of the easiest places to trim and stockpile cash for what looked at the time to be a very volatile and extended, and potentially catastrophic, period of economic and financial uncertainty.

At the same time, however, government stimulus spending began to ramp up in the United States, Europe, and East Asia. Urban infrastructure represented the most promising opportunity for technology vendors to capture post-crisis stimulus spending. One widely circulated forecast, published in 2007 by consultancy Booz Allen Hamilton, claimed that global infrastructure needs would top $1.5 trillion annually for the next twenty-five years—just shy of 3 percent of global GDP. According to the Urban Land Institute, a real estate industry think tank, the United States alone needed to spend $2 trillion to repair and rebuild its decaying infrastructure.[20]

The bulk of infrastructure spending—97 percent—will be on conventional materials like asphalt and steel. But as much as 3 percent could go to ICT, which sets an upped bound for spending on the digital aspects of smart-city solutions. This figure is remarkably constant; either looking at the global scale (e.g., by comparing market forecasts for smart infrastructure to total infrastructure) or a large development project (e.g., Songdo City in South Korea, whose ICT business strategist reports 2.9 percent), or a single building (which can be gleaned from a variety of trade publications).

Smart-city ICT comes in three layers, according to engineering consultancy Arup: instrumentation that collects data throughout the city; urban informatics systems that process the signals; and an urban information architecture, or set of management practices and business processes, to put the results to use. Andrew Comer, a partner at construction engineering firm Buro Happold explains the cocktail-party math: "If you project that figure into the future, multiply it by a fairly conservative estimate of the construction costs involved, and take a relatively small percentage of that for high-technology infrastructure, it's trillions of dollars. If these hi-tech companies can capture parts of this market, they have a twenty to thirty year period of insatiable growth." Thus, smart cities promise to be a cash cow for the technology industry, chalking up some $100 billion in potential revenues over the next decade. And that's even before the management consulting fees—for, as Arup argued in 2010, "the smart city is so different in essence to the 20th century city that the governance models and organisational frameworks themselves must evolve."[21]

By 2011, even conglomerates like Siemens and GE had turned their attention to the smart-cities market, sensing even greater potential than the ICT niche that IBM and Cisco had unearthed. As Peter Löscher, CEO of Siemens put it, "this is a huge, huge opportunity." Yet, in the years since 2008, despite thousands of conferences, pilot projects, and other campaigns, the ambitions of these firms have largely been unrealized. As the *Economist* reported in 2013, "many cities lack the necessary resources for the more ambitious dreams of city planners. Companies such as Cisco, IBM and Siemens are all eager to sell them systems. 'None has met its revenue targets,' says a smart-city expert at a big consultancy. A new 'infrastructure and cities' division at Siemens has the lowest profit margin of all of Siemens's big businesses."[22] The reasons for inflated expectations are many but largely have to do with misperceptions about the decision-making processes of local governments, a lack of easily repurposable business models, and a poor job selling the value of investments to actual end users—the citizens themselves. But despite the setbacks of these old-line tech giants, the smart-cities market has continued to expand, mature, and evolve in a number of ways that suggest its long-term viability.

This is most clearly seen in the exponentially expanding size and scope of the smart-cities market forecasts. One widely noted study, published in 2011 by Colorado-based Pike Research (now part of Navigant) pegged the total market at $100 billion in annual sales globally by 2020.[23] But soon after, at the behest of the U.K. government, Arup produced a new forecast, which expanded the range of services, more than quadrupling the market to $408 billion per year by 2020.[24] Just over twelve months later, consultancy Frost & Sullivan in its own estimate again quadrupled the pie to $1.56 trillion.[25]

What is the significance of these ballooning forecasts? Partly it reflects the growing expectations among an expanding array of stakeholders—banking on the smart-city market to expand is not just IBM, but the U.K. government as well, as part of its export-led economic growth policy. Also, definitions of the sector are expanding (notably from the Pike to the Arup forecast) to include a larger range of value-added services riding on top of smart infrastructure, recognizing where the true nexus of innovation lies. Finally, there is a growing sense of the massive "dark-matter" cloud of start-ups and SMEs moving into the market and developing new niches with considerable potential—as seen in networks like Urban.Us and CityMart, which are trying to challenge traditional geographic obstacles to city-vendor procurement and startup-investor relationships and to help fledging firms expand globally beyond their initial launch cities.

But perhaps far more significantly, these forecasts are beginning to reflect the arrival of the big consumer-facing ICT companies in the smart-city market—Google, Apple, Intel, and Microsoft—all of which are now forming groups, developing strategies, making acquisitions, and launching initiatives in this space. (Full disclosure: I am a consultant to Sidewalk Labs, of which Google is a major investor, and I have previously consulted for Intel). Given that IBM and Cisco may have failed to capture citizens' imagination because they lacked experience with consumers, this could signal a crucial development.

The Political Economy of Smart Cities

So far, we have largely looked at the corporate agenda for smart cities, yet as Plato reminds us in *The Republic*, the city is and has always been a contested social and economic space: "For indeed any city, however small, is in fact divided into two, one the city of the poor, the other of the rich; these are at war with one another."[26] For every potential productivity or efficiency gain, smart technologies present a redistributive risk. Considerable serious debate is now underway, for instance, about the possibility of mass unemployment as intelligent systems are widely deployed in the coming decades, and the potential for catastrophic impacts on income and wealth distribution.[27] Several efforts to map the political economy of smart cities have been widely circulated, including the author's.[28] These seek to shift the locus of attention from the "what" of smart systems—the technologies and their applications—to the "why" and "how." The more successful ones, such as Elie Cosgrave's doctoral thesis on Bristol's smart-city policy framework in England, succeed by dissecting competing interests around specific projects in communities.

But even as global technology companies have dominated discussions about smart cities over the last decade, a parallel grassroots movement has coalesced. To use a computing metaphor: if industry has produced a mainframe vision of a smart city, the alternative is something akin to the personal computer: inexpensive and decentralized. Three big shifts in technology are enabling this shift. First, as already mentioned, computing has moved off the desktop. By 2011, sales of personal computers were flat, while smartphones and tablets sold in record numbers. These devices not only decentralize computing power from large organizations into the hands of everyday people, they also embed it in everyday urban spaces, spurring new ideas about potential uses. Second, the shift from fixed to untethered communications is pushing information technology into every crevice of the city. Third, cloud computing has decoupled information processing from place, enabling supercomputing power to be accessed from any device, anytime, anywhere—including our pockets. These raw materials provide a vastly expanded array of basic components for entrepreneurs, tinkerers, and media artists to develop novel responses to urban challenges—giving rise to services as varied as Uber (for e-hailing rides), SeeClickFix (for local information), and HandUp (for donating to homeless individuals). Hal Varian, Google's chief economist, has likened the situation to the early industrial era, when standardized machine parts spurred a global frenzy of "combinatorial innovation."[29] Where the corporate smart city primarily seeks to control, optimize, and make efficient, the bottom-up version also aspires to enhance access, sociability, transparency, and entertainment.

What of city government then? What is its role in this? As I wrote in 2013, it seemed a battle was brewing over the soul of the smart city: "Everywhere that industry attempts to impose its vision of clean, computed, centrally managed order, [civic hackers] propose messy, decentralized, and democratic alternatives. It's only a matter of time before they come to blows."[30] While they have rebuffed the most audacious visions of industry, city governments have not yet really embraced a fully citizen-powered vision of the smart city either. For now, they seem to be trying to balance interests, and identify sustainable strategies for innovation over the long term.

They are doing this through two primary means: creating new leadership positions and developing digital master plans. New leadership positions such as chief innovation officers, chief technology officers, chief data officers, and chief digital officers, have given cities the ability to coordinate and elevate technology policy and planning within city government, and leverage external resources in the private sector, universities, and the philanthropic community. Digital master plans represent a new comprehensive, long-range urban planning activity, seeking to develop a vision and road map for investments in ICTs that align with citywide policy.[31]

The political economy of the smart city is still in flux, and alliances and alignments of course vary from place to place—the relationship between industry and city government runs from hot to cold, and the same for civic hacker groups, as well. Meanwhile, universities are moving en masse to position themselves as key players through the establishment of urban science and urban informatics centers and so-called living labs for smart-city engineering.[32]

SMART CITIES AND THE ENVIRONMENT

During the Progressive Era, widespread recognition of the threats to public health presented by overcrowding and poor sanitation in U.S. cities led to the launch of numerous reform programs. These efforts improved sanitary conditions through improvements in water and sewer infrastructure and housing stocks. At the same time, conservationists achieved a consensus around the need to prevent further damage and depletion of natural resources from human settlement and industrial activity.

As the environmental movement matured in the postwar period, new scientific evidence gave rise to a loose compact of interests, which played an increasing role in spurring nations and regions to address the effects and roots causes of environmental degradation. Previously, externalities from industrial production could be ignored, as those costs could be off-loaded to surrounding neighborhoods, downstream residents, or downwind lakes. But as suburban sprawl brought city and countryside into more direct contact, these distinctions began to break down.

Increasingly, this compact (especially at its scientific roots in the case of climate change) is being attacked, but is it unraveling? As they provide new tools for monitoring, regulating, and managing urban environments, to what extent does the smart-cities movement reinvigorate the public debate over the social compact on environmental sustainability and the protection of the larger society?

We turn now to three themes where the smart-cities movement is directly engaging structural underpinnings of the urban environmental compact, also posing a number of questions for further discussion and research. These themes are infrastructural complexity and efficiency, transportation innovation, and citizen science.

Infrastructural Complexity and Efficiency

One of the key engineering challenges of future cities is infrastructural complexity. Delivering responsive, high-quality urban services requires careful integration of many different networked resources in a carefully synchronized fashion. For instance, mass deployment of electric vehicles will require new approaches to balancing the flow of vehicles on road networks as well as the flow of energy on power grids, and the interactions between the two dynamic systems. As social demands for reliability and resilience increase, increasingly distributed points of generation and distribution will further complicate matters. Meanwhile, the liberating impacts of ICTs on individuals and organizations—breaking down traditional schedules and travel routes—are creating more differentiated infrastructure usage patterns, further complicating the picture.

Coping with the complexity of infrastructure itself, and the rapidly changing and increasingly dynamic patterns of use, will require new approaches from operators. Three possibilities present themselves.

First, even as complexity is a challenge, it can also be a tool. By engineering entire systems, we can exploit new synergies, such as cogeneration, which uses waste heat from industrial processes to produce electricity. This well-established approach is being developed in many efforts, but it is largely incremental in the gains it presents.

Second, new sensory capabilities of smart cities, when linked to predictive computer models, can allow for infrastructure to be managed in a far more optimized fashion than before. For instance, renewable energy sources such as solar present a particularly difficult problem given the unpredictability of the weather and the high cost of building storage for cloudy days. But, as researchers at the National Center for Atmospheric Research and Xcel Energy in Boulder, Colorado, have shown, highly accurate solar forecasts can be used to balance supply and demand in real time over a wide area. In one experiment, the group briefly supplied 60 percent of the state's power needs exclusively from solar.[33] This is an example of what we might call a super-intelligent city, where machine intelligence performs analytical and allocation functions largely beyond the scope of possible human understanding (but with human oversight, at least for now). It is, essentially, a fly-by-wire city. Take away the computers and it falls apart. For a sneak preview of this in practice, we need only look at some of the more recent innovations in active structural control, which operate in much the same way.

An alternative approach, which addresses the lack of transparency inherent in the previous example (assuming that the model uses machine learning, it is probably illegible) is what is called human task routing. Here the idea is to assemble a large group of human beings online to disaggregate portions of a large, complex task into smaller, discrete tasks that can be more easily completed and then to reassemble the completed work into a finished product. We might imagine this being used to analyze data about energy flows in a city, analyze signals intelligence for counterterrorism efforts, or look for signs of socioeconomic distress in data collected at city schools. Such approaches are currently employed in a number of crowdsourced online work platforms such as ODesk, Mobileworks, and Amara for tasks like market research, writing documents, transcription, and translation.[34]

A third approach to infrastructural complexity and efficiency is simply behavior change—trying to “nudge” people (to use Thaler and Sunstein’s 2008 term) to reduce burdens on infrastructure. This raises some of the most intriguing possibilities because we start to enter a world where the market-based innovations that we have seen in telecommunications are unleashed on the consumer energy sector. In the 1980s, when digitization of the phone system allowed more calls to be squeezed onto the same trunk lines, it also put intelligence in the network. Creating new services like call waiting, voice mail, and caller ID was then simply a matter of writing new switching software.[35] Proponents of smart power grids expect a similar wave of innovation in energy services. Start-up firms could audit and manage home electricity use in return for a small cut of the energy bill reduction. Automating that process would be advantageous in a world where Siemens forecasts that electricity prices could change as often as every fifteen minutes.[36] Smart grids could also map our social networks to the production, distribution, and consumption of electricity. Eric Paulos of the University of California, Berkeley, proposes using sensors to document how, where, and by whom energy is generated and making this information available during transactions. Such metadata could enable markets for power around any number of causes, interests, or goals. Today, power suppliers largely compete on price and on carbon footprint. A smart grid could allow the data about electricity to become as valuable as the power itself, and such data could enable better decisions about how we use electricity.[37]

Smart-city innovations in efficiency, and the infrastructure complexity they will manage and require be put in place to achieve them, raise many questions about environmental compact.

- How will the public perceive the complex cause-and-effect relationships within these systems and the environmental outcomes they produce?
- How will the roles of software and algorithms be made more transparent? How can the assumptions of model builders be scrutinized and their implications examined?
- What is the role of human oversight in the automation of urban infrastructure systems?

- What ethical issues are involved in choosing between automating efficient behaviors and seeking to induce behavior change?

Transportation Innovation

The smart-cities movement is also having a more direct impact on the public debate around the social compact on environmental sustainability in transportation innovation.

While enormous changes have occurred in urban U.S. businesses, governments, and society in the last 25 years, little has changed in transportation. One could make the case that the way we get around—from the technology, to the business models, to the regulatory schemes—has not changed in 75 years (for surface transportation) to 125 years or more (for rail and ferry transit).

Yet in the last several years we have seen the introduction of a string of innovations, almost exclusively privately initiated, that are dramatically changing transportation business models, challenging existing regulatory schemes head-on, and most importantly, portending substantial long-term shifts in travel patterns and land use in our inner cities and larger metropolitan areas in coming years—shifts that could have both profound positive and negative impacts on regional ecosystems. Thousands of new digital technologies and services have come to market in recent years that are turning transportation from a bricks-and-mortar business into an information-based and informatics-based activity.

Disruption is happening throughout the value chain, as in the following examples.

- Infrastructure networks: adaptive traffic signaling, electronic road pricing
- Vehicles: autonomous vehicles, programmable vehicle performance
- Business models: car sharing, ride sharing
- Interfaces: crowdsourced traffic reporting, multi-model integration

The result of all this investment and innovation is that city dwellers are increasingly dependent on an array of digital services and technologies to make and manage travel choices, and often also dependent on them to actually take the trip. These services are having real impacts on travel behavior, changing why, when, where, and how people take journeys to work, home, and other locations and activities. They are changing both the supply and the demand sides of the travel equation.

Ironically, while transportation planners are mostly unaware of the interactions between new ICTs and travel behavior, and their implications for future land use needs, some start-ups are tackling this head-on. For instance, the carpooling service Zimride, launched at the University of California, Berkeley, but later deployed for two large music festivals (Coachella and Bonaroo), is a platform for large venue and facility operators to coordinate and incentivize carpooling. Over the long run, services like Zimride could allow large amounts of land now tied up for parking to be freed for development, potentially creating a virtuous circle of densification that could create greater demand for transit.

Transportation planning is only slowly waking up to these developments. Internal debates in the field remain focused on infrastructure and urban form rather than on the direct behavioral impacts of these new technologies. As a result, these high-value, high-impact innovations in transportation are coming from the private sector with little coordination or planning. And their collective impact and potential unintended consequences are not being adequately explored.

Take, for instance, the conflicts between Uber and local regulators. It is clear that the conflicts between innovators and regulators that we are seeing now are merely suggestive of much larger challenges to come. These are just the initial skirmishes in much bigger conflicts that will arise over how transportation systems will work in twenty-first-century cities, and over the roles and relationships between public- and private-sector providers. The rapid private-sector innovation-driven shift in transportation—which I call reprogramming mobility—has profound consequences for the environmental compact in the United States, as it ties together the two most significant environmental choices most U.S. households make: their choice of residence and their mode of commuting. Some questions include the following.

- How can transportation planners understand, forecast, and explain alternative transportation futures to communities?
- What kinds of narratives can create compelling linkages between individual transportation choice architectures on the one hand and community goals and visions and global environmental impacts on the other?
- What are the actual trade-offs among the three assets of land use, transportation, and ICTs? What substitutes and what complements? What kinds of new, more sustainable designs and forms are possible (e.g., televillages, or whatever is the next version of them—such as the

Washington, D.C., developer who secured a zoning change to eliminate a required parking deck by giving every resident a bike share membership)?

Citizen Science

In 1976, when Steve Jobs and Steve Wozniak demonstrated the Apple-1 prototype at the Homebrew Computer Club in Palo Alto, California, just down the road from Menlo Park (where the more radical People's Computer Company, another user group, gathered), the electronics community in Northern California was abuzz with the potential of democratized computing power. Today, the same urges that set off that revolution can be felt within the networks of inventors, entrepreneurs, tinkerers, and researchers exploring the potential of connected objects, environments, buildings, and cities. And as the ability to cheaply and quickly deploy sensors in the city meets up with the long-established traditions of citizen science developed in fields as varied as astronomy and ornithology, the smart-cities movement is poised to breathe new energy into the urban environmental justice movement.

In recent years, the internet has allowed scientists to engage ever-larger groups of amateurs in collecting and analyzing data, in much the same way that meteorologists have long collected weather and climate data from a distributed network of volunteer-maintained instruments and stations. Amateurs have made important discoveries in many areas of science, such as astronomy, by analyzing large sets of data. They have also played a major role in formulating research questions as well, such as the growing interest in rare diseases, which were largely ignored until victims could find each other, share information, and organize online.

But citizens aren't waiting for universities to launch their own research. Urban environmental sensing is a particularly intense area of citizen-driven scientific data collection. In Paris, for instance, the internet think tank Fing (Foundation Internet Nouvelle Génération) developed a wristwatch for measuring street-level ozone. In a demonstration involving a hundred bicyclists riding in a single neighborhood, volunteers were able to create a finely detailed air pollution map that dramatically surpassed the government's sparse network of just ten stations across the entire city. At MIT's SENSEable City Laboratory, researchers took some rudimentary GPS-enabled phones, glued them to various pieces of rubbish and threw them away. Within days, they had generated a map of the removal chain, illuminating the secret journeys of our waste. In New York, a group calling itself Public Laboratory builds inexpensive sensors that alert citizens to situations during thunderstorms when the city's storm-water drains overflow into its sewage system, causing coastal discharge of human waste. The intent is that ambient displays in homes would spur people to refrain from flushing toilets during these events, thus reducing the flow of raw sewage into waterways.

As mentioned previously, universities are seizing the chance to stake out new territory in smart cities. Just since about 2010, a vast array of new academic and nonprofit institutions have been established to develop and exploit these new data streams to advance human understanding and improve the management of cities. From New York University's Center for Urban Science and Progress to the University of Chicago's Urban Center for Computation and Data to the Intel Collaborative Research Institute for Sustainable and Connected Cities in London, it has become clear that this is going to be a major global research theme, one with considerable potential impact across a huge range of policy arenas.

Not surprisingly, many of the new urban science labs—including MIT's SENSEable City Lab and NYU's Center for Urban Science and Progress—are directly engaging with these kinds of citizen urban science efforts. This makes sense, since the nature and scale of the subject of interest (cities) almost demand a strategy of leveraging citizens as extensions of the university's capacities.

More important, however, is that including citizens in research makes it potentially more likely that they will welcome the results of the research as valid and accept their use in the design of new interventions. Engaging citizen science may represent a strategy for making this wave of urban science, and its application in the public sector, significantly less technocratic than what we have seen in the past, and make the research itself into an act of civic engagement. Open data will play a crucial catalyzing role in those collaborations.

Citizen urban science raises a bewildering number of questions about the environmental compact, including these two:

- Will citizen urban science focus mostly on augmenting professional data gathering, filling in gaps, or creating alternative narratives that challenge official data?
- What is the role of open data platforms in facilitating collaborations between citizens, universities, and city governments in urban research?

IMPLICATIONS FOR PLANNING RESEARCH

We have looked at the rise of the smart-cities movement and its emerging intersections with urban environmental policy in three areas: infrastructural complexity, transportation innovation, and citizen science. Further elaboration on the potential for citizen science to inform planning research is warranted, and a cautionary tale about the overall prospects of the smart-cities movement to achieve meaningful long-term environmental results.

Citizen Urban Science and Future Collaboration

The nature of urban research appears to be changing rapidly. Universities around the world are bringing online a massive new infrastructure for data-driven urban research in the coming decades—an investment that could surpass $2.5 billion by 2030. But the new urban science, as many are calling this movement, has not yet defined how it intends to engage or empower non-professionals in the research process—a glaring omission in an age in which new digital platforms are unleashing the power of mass participation in so many other areas of the economy, governance, and intellectual and political life.[38] While there is much talk of the importance of citizens in these efforts as beneficiaries of research effort, their envisioned role in the research process is far less clear. Predominantly, these efforts envision future urban research as a tripartite collaboration of university, city government, and private sector firms. But will this new intellectual venture be an inclusive endeavor? What role is there for the growing ranks of increasingly well-equipped and well-informed citizen volunteers and amateur investigators to work alongside professional scientists? How are researchers, activists, and city governments exploring that potential today? Finally, what can be done to encourage and accelerate experimentation?[39]

Citizen science has thrived in recent years as these changes have unfolded. While amateurs have long played important roles in many fields, from astronomy to meteorology, the Web has lowered the cost and expanded the range of collaborative activities with professional scientists. For instance, amateurs now routinely participate not only in the analysis of large data sets, but in so doing help train computer software to perform the same tasks. There is so much citizen science happening now that the practice itself is becoming a field of academic inquiry itself—in early 2015 the prestigious journal *Bioscience* called for the recognition of "research on citizen science as a distinct discipline."[40]

Urban research is changing quickly, but its relationship with citizen science will inevitably become deeply complex and multifaceted, and controversial. That's because not only is citizen science a necessary key to improving the science of cities, it is a tool for making the case that the results of such research are to be trusted when applied in urban governance. Citizen science can provide the ground truth necessary to trust the synoptic urban sensing tools being used in urban science. Our operating hypothesis is threefold. First, we expect that citizen urban science will become an increasingly important strategy within the urban science movement—for doing better science, by creating larger and more detailed data sets. Second, it will be used to render the pursuit of science less technocratic, by giving citizens a stake in data gathering, analysis, application of results, and even setting parts of the research agenda. Third, it will create legitimacy to apply new knowledge in the real world, by creating sustained engagement between researchers and partners in local governments for tech transfer.

The way that citizen urban science evolves will both shape and be shaped by the legacy of the environmental justice movement over the last half-century, which demonstrated how citizen urban science can have major lasting impacts on urban policy and planning, and the lives of people and groups in urban communities. Environmental justice itself grew directly out of the civil-rights struggle—in 1968 Martin Luther King Jr. fought on behalf of black sanitation workers in Memphis.[41] The environmental justice movement coalesced in the 1970s and 1980s through activist efforts, which focused attention on the systematic biases and shortcomings of environmental risk assessment practices in the United States—especially around urban air pollution impacts of siting decisions for highly noxious public facilities such as incinerators, trash transfer stations, and waste treatment plants.

In the 1990s, the movement began to trigger reforms on urban environmental policy at the federal level. Robert Bullard's landmark report *Dumping in Dixie: Race, Class, and Environmental Quality* (1990) led directly to the Clinton administration's 1994 executive order mandating environmental justice reviews in the conduct of federal government operations.[42] But despite its origins in a movement based on its appeal to human rights, ethics, and fairness, data and quantitative evidence have been critical to building support and a record of victories for the movement. Citizen- and activist-collected data have been used to win cases on the behalf of communities unfairly targeted as hosts for threats to public health, such as nuclear-waste disposal and industrial facilities.[43] Such data were used to contest the federal government's own assessment tools, which had become so institutionalized that their weaknesses were called an open secret.[44]

Although environmental justice had a contentious relationship in the past with professional science—the movement generally viewed traditional science as cold and detached, and unwilling or unable to incorporate social factors into environmental hazard assessment, whereas the scientists saw environmental justice advocates as unorganized and emotional—the movement still wielded scientific data and methods to serve its own ends with great prowess and effectiveness. Evidence-based campaigns have been effective in policy circles at the federal level, bringing change to the ways the EPA conducts environmental assessments as well as leading to the creation of the Office of Environmental Justice, but these efforts still face challenges. Despite the massive amount of citizen-collected data the movement has produced, very little of it has been utilized in formal scientific research, where it is still often viewed with extreme skepticism.[45]

Today's efforts to link environmental concerns with citizen cover a broad spectrum of models for bringing together citizens, academic researchers, and government agencies to do urban research. A recent paper looks at three case studies:

- Chicago's Array of Things: a large-scale urban environmental sensor network blanketing the downtown Loop, established to provide a test bed for university research and citizen engagement.
- Amsterdam's Smart-Citizens Lab: a training and prototyping facility in Amsterdam that seeks to develop a corps of citizen scientists to deploy and maintain sensors throughout the city.
- New York City's Trees Count!: a crowdsourced effort to conduct a decennial census of street trees to support ongoing planning and operations, and potential future research.[46]

These early efforts to mobilize citizens to advance the collection, analysis and application of urban data in cities highlight both the promise and the nascent nature of citizen urban science today. Although citizen science has spread broadly around the globe and garnered attention from national policy makers, this movement is only slowly gaining traction at the city level.[47] As these projects and others like them progress, the utility of citizen generated data is substantial. Yet further efforts are necessary to organize and direct the trajectory of citizen urban science for it to have the transformative impact demonstrated by the environmental justice movement.

Three emerging nodes of collaboration that should be targeted for further research and support in the immediate future—shared sensing infrastructure, open data, and networked social capital.

SHARED SENSING INFRASTRUCTURE: Each of these efforts began with research and development of a new instrument for data collection—the Array of Things sensor pod, the Smart Citizen Kit, and the tablet app used by Trees Count! This is counterintuitive, because advocates of participatory digital urbanism routinely point to mass ownership of smartphones as a fundamental enabler of citizen urban science—yet each of the projects saw the need to invest considerable resources and time in deploying a new, customized data collection platform. A key question going forward is whether increasing fragmentation of infrastructure is expected or desirable, or if, as Array of Things and Smart Citizen Kit implicitly aspire, there is an opportunity to colocate most of the required sensors for a portfolio of efforts, organizations, and projects on a single physical infrastructure. If this is technically feasible, how can it be made financially and institutionally feasible? (For instance, what happens when conflicts over sensor requirements occur?)

OPEN DATA: The open-data movement has demonstrated how sharing of information without restrictions can, as Code for America founder Jennifer Pahlka describes it, "allow us to collaborate without talking about it."[48] However, significant obstacles inhibit realizing the full potential of open data to catalyze and accelerate citizen urban science. As we saw in environmental justice, government officials and even academic researchers are often skeptical of the quality and bias of citizen-generated data. Even where they are collected, and pressing policy issues exist, they are likely to be ignored. Citizen advocacy groups may balk at sharing data that could be used to frame a case against their preferred course of action. Researchers, while increasingly being pressured to open research data for review and subsequent use, have powerful incentives to hoard valuable research data. Future research should probe further into the value chains that develop and can be developed around urban sensor data, and the way open sharing can help accumulate and distribute that value in equitable and productive flows. We expect that this will require deep ethnographic and managerial types of studies.

NETWORKED SOCIAL CAPITAL: The key to understanding and enabling these value chains will be focused effort on catalyzing and cultivating the networked social capital that gives rise to and sustains citizen urban science undertakings. Each of these cases addresses this node of collaboration in a substantial way—the Array of Things has created a dense network of institutional partnerships, the Smart Citizens Lab is focused on recruiting and training a grassroots cadre of citizen-scientists, and Trees Count! seeks to build an army of volunteers who can be mobilized in times of need by government to provide a public service. Yet important questions remain: How can these models be made replicable? How do they complement or compete with each other? What models are best suited to which aspirations of citizen urban science—for example, collection of scientific data, issue advocacy and policy change, community and economic development?

Thinking about the Unthinkable

There is no doubt that smart cities are a key area of concern for urban planning and that urban environmental monitoring is a key application area at the highest levels of federal policymaking—statements to this effect by key Obama administration officials at smart-city events in 2015 make this clear.[49] And there are competing visions for how to accomplish this—through coordinated, centralized, city-led, and corporate-enabled deployment of comprehensive sensing grids, or through more citizen-driven, distributed frameworks. There is every reason to believe that at least one of these approaches might work, both could work independently, or they might even complement each other in a new beautiful synergy—in fact, that wouldn't be all that different from how the internet and the World Wide Web has worked out (with a few caveats).

But I would be remiss as a forecaster if I didn't paint a somewhat darker picture of what might lie ahead. For we need to approach smart cities with skepticism, to think about the worst that could happen, and how we might face it. For the implicit assumption in nearly all framings of the smart-cities concept is that they will be more efficient and better for the environment than contemporary urbanization frameworks. But there are many scenarios, eminently plausible, where this is a false assumption. Let us close by considering a few.

First, smart technology might not deliver enough efficiency. The improvement needed to stabilize carbon dioxide emissions are "neither trivial nor impossible," according to a 2007 United Nations Foundation report. But they are certainly not a sure thing. In the worst case, more efficient smart infrastructure will actually work to hold down the price of energy and stimulate even more consumption—what economists call the "rebound effect."[50]

Second, smart technology might turn out to be less effective in curbing energy use, yet highly effective for reducing traffic congestion and fighting crime. Although cities in developed nations would become more appealing places to live as the quality of life improved, also indirectly reducing energy consumption by drawing people back from the suburbs to denser communities, in the developing world it could accelerate the growth of megacities powered by today's dirty energy technologies. That would be an economic success story of epic proportion but a global ecological disaster. Imagine a smart Johannesburg suddenly free of crime and booming, absorbing millions of migrants from sub-Saharan Africa into a ramshackle infrastructure of dirty minibuses and smoky coal- and dung-fueled stoves.

A third doomsday story goes like this: we do crack the code of sustainable design and bring the needed technologies to market—but not in time. Even in Singapore, with its long and proven tradition of technocratic planning, smart-infrastructure projects move at a snail's pace; digitization of the nation-state's congestion toll system was twelve years in the making, finally implemented in 1998.

A fourth possibility is economic stagnation. If the malaise of the developing world is too much growth, for the rich cities of the global north it may be too little. If, as many economists now suspect, smart technology cannot improve our productivity, we might not be able to pay for further improvements in energy efficiency.

In a final unthinkable future, the wealthy fall back on smart technology to retreat to gated enclaves, sustained by captured resources managed solely for their own benefit. This is already the norm across much of the developing world, where the poor have less access to clean water, healthy food, and basic sanitation, and pay vastly higher prices for them when they do. As competition for natural resources heats up over the next century, and the impacts of climate change disrupt supplies, the rich may be able to wall themselves off from the consequences of their own overconsumption. Instead of making cities more resilient to the challenges of rapid growth and climate change, smart technology could limit the ability of poor and vulnerable communities to adapt.

Notes

1. "World Urbanization Prospects: The 2007 Revision," United Nations, Department of Economic and Social Affairs, Population Division—Population Estimates and Projections Section, New York, February 26, 2008, 1.

2. "World Urbanization Prospects: The 2009 Revision," (New York: United Nations, Department of Economic and Social Affairs, Population Division—Population Estimates and Projections Section, New York, March 2010, 1.

3. Paul Romer, "Charter Cities." Accessed April 11, 2016. http://econ.as.nyu.edu/docs/IO/22933/Romer1_02132012.pdf

4. "World Urbanization Prospects: The 2011 Revision," United Nations, Department of Economic and Social Affairs, Population Division—Population Estimates and Projections Section, New York, March 2012, 1.

5. Author's calculation based on global population forecast in *The 2010 Revision of World Population Prospects* and urbanization forecast of 70 to 80 percent in Shlomo Angel, *Planet of Cities* (Cambridge, Mass.: Lincoln Institute of Land Policy, 2012).

6. IHS Global Insight, "U.S. Metro Economies: Outlook—Gross Metropolitan Product, and Critical Role of Transportation Infrastructure," United States Conference of Mayors, 2012, accessed August 20, 2015, at http://usmayors.org/metroeconomies/0712/FullReport.pdf.

7. D. A. Hall, "Tactical Internet System Architecture for Task Force XXI," *IEEE*, 1996, 219–30, doi:10.1109/TCC.1996.561089.

8. Amy Wesolowski and Nathan Eagle, "Inferring Human Dynamics in Slums Using Mobile Phone Data," Working Paper, Santa Fe Institute, accessed August 20, 2015, at http://www.santafe.edu/media/cms_page_media/264/AmyWesolowskiREUFinalPaper.pdf.

9. Matthew Brunwasser, "A 21st-Century Migrant's Essentials: Food, Shelter, Smartphone," *New York Times*, August 25, 2015.

10. "U.S. Wireless Quick Facts," Cellular Telecommunications Industry Association, accessed February 3, 2013, at http://www.ctia.org/consumer_info/index.cfm/AI D/10323; Massoud Amin, "North American Electricity Infrastructure: System Security, Quality, Reliability, Availability, and Efficiency Challenges and their Societal Impacts," in *Continuing Crises in National Transmission Infrastructure: Impacts and Options for Modernization*, National Science Foundation (NSF), June 2004, 1; "CTIA Semi-Annual Wireless Industry Survey," Cellular Telecommunications Industry Association, Washington, D.C., 2012, accessed September 1, 2015, at http://www.ctia.org/your-wireless-life/how-wireless-works/annual-wireless-industry-survey.

11. Rich Miller, "Facebook Hosts 10 Billion Photos," Data Center Knowledge, accessed July 30, 2015, at http://www.datacenterknowledge.com/archives/2008/10/15/facebook-hosts-10-billion-photos/.

12. "Living PlanIT—PlanIT Valley—A Smart and Connected City for Portugal," accessed July 26, 2015, at http://www.living-planit.com

13. Charles Perrow, *Normal Accidents: Living with High-Risk Technologies*, rev. ed. (Princeton, N.J.: Princeton University Press, 1999 [1984]).

14. Steve Hamm, "Live Blogging from Smarter Cities Rio: Day 1," *Building a Smarter Planet: A Smarter Planet Blog*, November 9, 2011, accessed January 25, 2011, at http://asmarterplanet.com/blog/2011/11/live-blogging-from-smarter-cities-rio-day-1.html.

15. "World Economic Forum Annual Meeting 2012: The Great Transformation: Shaping New Models," World Economic Forum, Davos-Klosters, Switzerland, 2012, 25, accessed June 18, 2015, at http://www3.weforum.org/docs/AM12/WEF_AM12_Report.pdf.

16. Hans Schaffers, Nicos Komninos, Marc Pallot, et al., "Smart Cities as Innovation Systems Sustained by the Future Internet," technical report 2012, URENIO Research

Unit, Thessaloniki, Greece, 2012, 5, accessed at http://www.urenio.org/wp-content/uploads/2012/04/2012-FIREBALL-White-Paper-Final.pdf.

17. Ibid., 6.

18. Ibid., 57.

19. Nicholas Nassim Taleb, *The Black Swan: The Impact of the Highly Improbable* (New York: Random House, 2007).

20. Jonathan D. Miller, "Infrastructure 2011: A Strategic Priority," Urban Land Institute and Ernst & Young, 2011, accessed September 1, 2015, at http://www.uli.org/ResearchAndPublications/%7E/media/Documents/ResearchAndPublications/Reports/Infrastructure/Infrastructure2011.ashx.

21. Andrew Comer and Kerwin Datu, "Can You Have a Private City? The Political Implications of 'Smart City' Technology," *Global Urbanist*, last modified February 11, 2011, http:// globalurbanist.com/2011/02/17/can-you-have-a-private-city-the-political-implications-of- smart-city-technology; "Smart Cities: Transforming the 21st Century City via the Creative Use of Technology," Arup, last modified September 1, 2010, 10, accessed September 14, 2015, at http://www.arup.com/Publications/Smart_Cities.aspx.

22. "The Multiplexed Metropolis," *Economist*, September 7, 2013, accessed July 23, 2015 at http://www.economist.com/news/briefing/21585002-enthusiasts-think-data-services-can-change-cities-century-much-electricity.

23. "Smart Cities: Intelligent Information and Communications Technology Infrastructure in the Government, Buildings, Transport, and Utility Domains," Pike Research, online report, 2011, no longer available.

24. "The Smart City Market: Opportunities for the UK," research paper, Department for Business Innovation and Skills, and ARUP, London, 2013.

25. "Frost & Sullivan: Global Smart Cities Market to Reach US$1.56 Trillion by 2020," Frost & Sullivan, accessed Jannuary 25, 2011, at http://ww2.frost.com/news/press-releases/frost-sullivan-global-smart-cities-market-reach-us156-trillion-2020/.

26. Plato, *The Republic*, Internet Classics Archive, accessed April 11, 2016, at http://classics.mit.edu/Plato/republic.5.iv.html.

27. For instance, see Erik Brynjolfsson and Andrew McAfee, *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies* (New York: W. W. Norton, 2014).

28. See for instance Robert G. Hollands, "Will the Real Smart City Please Stand Up?," *City* 12, no. 3 (2008): 303–20, doi: 10.1080/13604810802479126; Adam Greenfield, *Against the Smart City* (New York: Amazon Digital Services, 2013); Anthony M. Townsend, *Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia* (New York: W. W. Norton, 2014).

29. Hal R. Varian, "Innovation, Components and Complements," 2003, accessed January 18, 2011, at http://www.almaden.ibm.com/coevolution/pdf/varian_paper.pdf.

30. Townsend, *Smart Cities*, 9.

31. For a overview of eight digital master plans, see Anthony Townsend and Stephen Lorimer, "Digital Master Planning: An Emerging Practice in Global Cities,"

NYU Marron Institute of Urban Management Working Paper No. 25, New York, 2015, accessed August 14, 2015, at http://marroninstitute.nyu.edu/uploads/content/Working_Paper_25_Digital_Master_Planning.pdf.

32. Anthony Townsend, *Making Sense of the New Urban Science*, New York University Wagner School, Rudin Center for Transportation Policy and Management, July 2015, accessed September 10, 2015, at www.citiesofdata.org/making-sense-of-the-science-of-cities/.

33. Kevin Bullis, "Smart Forecasts Lower the Power of Wind and Solar," *MIT Technology Review*, April 23, 2014, accessed September 2, 2015, at www.technologyreview.com/featuredstory/526541/smart-wind-and-solar-power/.

34. For further background on human task routing, see "The Future of Coordination: A Toolkit for Making the Future," Institute for the Future, accessed September 2, 2015, at www.iftf.org/coordination/.

35. Townsend, *Smart Cities*, 26.

36. Tim Schröder, "Automation's Ground Floor Opportunity," *Pictures of the Future*, spring 2011, 19, accessed June 5, 2015, at www.siemens.com/innovation/apps/pof_microsite/_pof-spring-2011/_pdf/pof_0111_strom_buildings_en.pdf.

37. Eric Paulos and James Pierce, "Citizen Energy: Towards Populist Interactive Micro-Energy Production," Hawaii International Conference on System Science (HICSS) Kauai, 2011.

38. Townsend, *Making Sense of the New Urban Science*.

39. Anthony Townsend and Alissa Chisholm, *Citizen Urban Science: New Partnerships for Advancing Knowledge*, Cities of Data Project, New York University Wagner School, Rudin Center for Transportation Policy and Management, August 2015, accessed September 2, 2015, at www.citiesofdata.org/report-citizen-urban-science/.

40. R. Jordan, A. Crall, S. Gray, T. Phillips, and D. Mellor, "Citizen Science as a Distinct Field of Inquiry," *BioScience* (2015), doi: 10.1093/biosci/biu217.

41. "Teaching with Documents: Court Documents Related to Martin Luther King, Jr., and Memphis Sanitation Workers," National Archives, accessed July 25, 2015, at www.archives.gov/education/lessons/memphis-v-mlk/.

42. U.S. Environmental Protection Agency, "Summary of Executive Order 12898—Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," overviews and factsheets, accessed July 26, 2015, at www2.epa.gov/laws-regulations/summary-executive-order-12898-federal-actions-address-environmental-justice.

43. Robert D. Bullard and Glenn S. Johnson, "Environmentalism and Public Policy: Environmental Justice: Grassroots Activism and Its Impact on Public Policy Decision Making," *Journal of Social Issues* 56, no. 3 (2000): 555–78, doi:10.1111/0022-4537.00184.

44. Jason Corburn, "Environmental Justice, Local Knowledge, and Risk: The Discourse of a Community-Based Cumulative Exposure Assessment," *Environmental Management* 29, no. 4 (2002): 451–66.

45. Cathy C. Conrad and Krista G. Hilchey, "A Review of Citizen Science and Community-Based Environmental Monitoring: Issues and Opportunities," *Environmental Monitoring and Assessment* 176, nos. 1–4 (2011): 273–91, doi:10.1007/s10661-010-1582-5.

46. Townsend and Chisholm, "Citizen Urban Science."

47. Nick Sinai and Gayle Smith, "The United States Releases Its Second Open Government National Action Plan," White House, December 6, 2013, accessed August 5, 2015, at www.whitehouse.gov/blog/2013/12/06/united-states-releases-its-second-open-government-national-action-plan.

48. Jennifer Pahlka quoted in Townsend, *Smart Cities*, 291.

49. Tom Kalil at VIP Keynote Plenary Session, Global City Teams Challenge Expo, June 1, 2015, Washington, D.C.

50. "World Urbanization Prospects: The 2007 Revision"; Blake Alcott, "Jevons' Paradox," *Ecological Economics* 45, no. 1 (2005): 9–21.

It Is Easier to Be Smart than to Be Green

DISCUSSANT: MOIRA ZELLNER
UNIVERSITY OF ILLINOIS AT CHICAGO

Our panel focused on the notion of the smart city and its potential to address difficult environmental issues through the use of various forms of digital technology, among them sensed, simulated, and communicated data; computational models, operations and management algorithms; and data mining techniques. Although human ingenuity has given rise to an incredible number of digital tools that are cheaper to access and use, this does not automatically translate into social and environmental improvements. Moreover, despite the advances in the areas of data science, big data, urban informatics, and urban analytics, humanity as a whole is still struggling to figure out how to shift gears and operationalize concepts such as sustainability and resilience. This is a much larger issue than the question of how to use our tools. It's about what we might want to use our tools for.

To start this conversation, we might want to distinguish among the following:

1. Data: facts or measurements collected for further analysis (note: further analysis should be the purpose of collecting data)