



senseable city lab:...

The Social Nexus

The best way to harness a city's potential for creativity and innovation is to jack people into the network and get out of the way

By Carlo Ratti and Anthony Townsend

ON JANUARY 25 THE STREETS OF CAIRO erupted in protest against then president Hosni Mubarak's repressive Egyptian regime. Over the next 72 hours the government shut down the country's Internet service and mobile-phone system in an attempt to squelch the rebellion—to no avail: a rich ecosystem of Facebook conversations, Twitter outbursts and chat-room plans had already unified millions of Cairo's people, who continued the relentless uprising. The government backed down and restored communications to keep the country's economy on life support, but the masses kept up the pressure until Mubarak resigned 14 days later.

Just weeks before, during Tunisia's "Jasmine Revolution," dissident blogger and protest organizer Slim Amamou used the mobile social app Foursquare to alert his friends of his January 6 arrest. By "checking in" to Foursquare's virtual depiction of the jail in Tunis where he was being held, Amamou revealed his location to a global web of supporters and immediately grabbed the international spotlight. The news stories sparked further uprisings, and longtime president Zine El Abidine Ben Ali was soon ousted.

Across the archipelago of places where the "Arab Spring" revolts played out, citizens used new Internet applications and ubiquitous mobile phones to wage a battle over the soul of their cities, shifting resources back and forth from cyberspace to "city-

space." Contrast those transformations with a handful of large urban development projects that have been vying to be crowned the model "smart city" of the future. Furthest along is Masdar in the United Arab Emirates, a walled community intended for 50,000 residents in the desert outside of Abu Dhabi, in which every building, streetlight and personal electric "pod" vehicle has been preplanned and preloaded with high-tech gear, largely to maximize energy efficiency. At Masdar, as well as New Songdo City in South Korea and PlanIT Valley in Portugal, real estate developers, global information-technology companies and governments are attempting to build urban centers from scratch that are filled with technologically enhanced infrastructure and services. The designers say their grand conceptions will determine how future cities will be built.

But as models, these top-down projects pale in comparison to the emergent form of intelligence that is bubbling up from millions of newly cyber-connected residents. Truly smart—and real—cities are not like an army regiment marching in lock-step to the commander's orders; they are more like a shifting flock of birds or school of fish, in which individuals respond to subtle social and behavioral cues from their neighbors about which way to move forward. Although the mobs in Cairo and Tunis appeared unruly, their actions resulted from digital coordination of human activity on an unprecedented scale. Hundreds of thousands of people appeared in Tahrir Square in Cairo because

IN BRIEF

Truly smart cities will emerge as inhabitants and their many electronic devices are recruited as real-time sensors of daily life.

Networking the ubiquitous sensors and linking them to government databases can enhance a city's inventiveness, efficiency and services.



CITIES



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36.7

MILLION

The number of people who live in the Tokyo-Yokohama urban area, the most populated in the world

SOURCE: Demographia

text messages and tweets summoned them—reflecting an immensely powerful, democratic and organic alternative vision of the smart city.

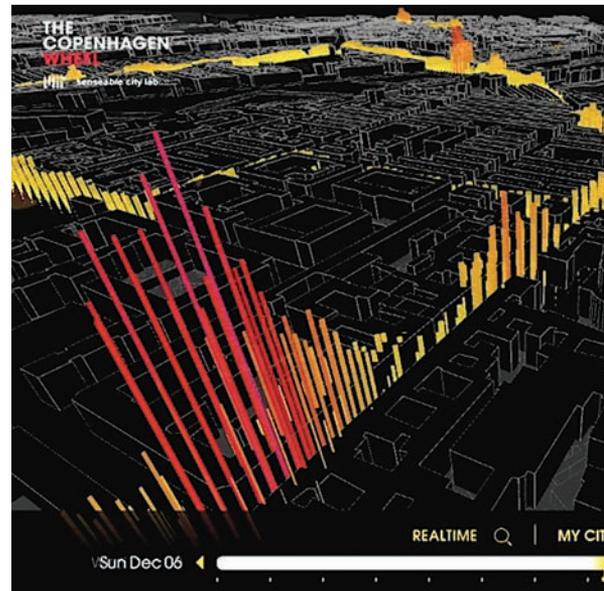
Rather than focusing on the installation and control of network hardware, city governments, technology companies and their urban-planning advisers can exploit a more ground-up approach to creating even smarter cities in which people become the agents of change. With proper technical-support structures, the populace can tackle problems such as energy use, traffic congestion, health care and education more effectively than centralized dictates. And residents of wired cities can use their distributed intelligence to fashion new community activities, as well as a new kind of citizen activism.

GOING BEYOND URBAN EFFICIENCY

WHY ARE COUNTRIES racing haphazardly to implement smart cities? Why is IBM forecasting a \$10 billion market in this arena by 2015? What is happening at an urban scale today is similar to what happened two decades ago in Formula One auto racing. Up to that point, success on the circuit was primarily credited to a car's mechanics and the driver's capabilities. But then telemetry technology blossomed. The car was transformed into a computer that was monitored in real time by thousands of sensors, becoming "intelligent" and better able to respond to the conditions of the race.

In a similar way, over the past decade digital technologies have begun to blanket our cities, forming the backbone of a large, intelligent infrastructure. Broadband fiber-optic and wireless telecommunications grids are supporting mobile phones, smartphones and tablets that are increasingly affordable. At the same time, open databases—especially from the government—that people can read and add to are revealing all kinds of information, and public kiosks and displays are helping literate and illiterate people access it. Add to this foundation a relentlessly growing network of sensors and digital-control technologies, all tied together by cheap, powerful computers, and our cities are quickly becoming like "computers in open air."

The vast amount of data that is emerging is the starting point for making efficient infrastructure programmable so that people can optimize a city's daily processes. Extracting information about real-time road conditions, for example, can reduce traffic and improve air quality. In Stockholm's road-pricing scheme, cameras automatically identify license plates of vehicles entering the city center and charge drivers' accounts up to 60 kronor (\$9.50) a day, depending on where the cars go. The system has reduced the waiting time for vehicles traversing the central district by up to 50 percent and has reduced pollutant emissions by up to 15 percent. Similar technologies can help lessen water use (one example is being used by the Sonoma County Water Agency in



California) and provide better services to citizens.

Two recent projects devised by the Senseable City Laboratory at the Massachusetts Institute of Technology illustrate the intelligence that is possible. Trash Track reveals how garbage flows through a city's waste-management system, indicating how to create a more efficient "removal chain" (as opposed to the supply chain). Electronic tags that transmit information over cellular networks are attached to pieces of trash to see where the items go. In one Seattle test the lab tracked more than 2,000 items, including recyclable materials such as glass, metal and plastic; household hazardous waste such as rechargeable batteries; and electronics such as monitors. Some items traveled across the U.S. (one printer cartridge went 6,152 kilometers!). Some ended up in legally compliant destinations, and some did not. The results reveal ways to minimize carbon dioxide emissions by transporting waste more efficiently. And Seattle could use the information to promote behavioral changes among its citizens, encouraging them to recycle more or to properly dispose of hazardous materials.

The second project, LIVE Singapore, uses real-time data recorded by the myriad communications devices, microcontrollers and sensors found in our urban environment to analyze the pulse of the city, moment to moment. The results suggest new ways to understand and optimize the city, ultimately to help people experience it like never before. LIVE Singapore's open-platform software allows people to develop different applications in a collaborative way. Work has begun on apps that tell commuters how they can reach their homes fastest, how residents can reduce their neighborhood's energy consumption and how inhabitants can get hold of a taxi when a rainstorm is crossing the island and the vehicles all seem to have disappeared.



The potential for developing more of this kind of efficient infrastructure is vast—and a good fraction can be unleashed through smart systems. It is thus no surprise that many large corporations, such as IBM, Cisco Systems, Siemens, Accenture, Ferrovial and ABB, are setting their sights on the urban space.

LESSONS FROM THE NETWORKED PAST

IT IS FITTING that Cairo has become a modern model of urban transformation because the ancient world holds the key to understanding what makes cities thrive. The invention of agriculture 10,000 years ago begot the first fixed settlements. As farming produced more food than was needed for survival, towns and villages developed specialized labor forces and institutions. Markets, temples and palaces created social networks organized for commerce, worship and government. Over time the interactions within these networks became more layered and complex. It turns out that sociability, not efficiency, is the true killer app for cities.

Furthermore, although landmark buildings shape our historical understanding of many metropolises, in reality most of the physical stuff in cities was built by everyday people. City building was highly democratized, decentralized, free-flowing and adaptive, just like its social and economic life—a rich tapestry of communal architecture whose design achievements were the result of collective effort rather than celebrity “starchitects.”

This organic growth of classical cities holds several lessons for future smart cities. First, by imposing a preordained design, centralized planners often fail to create a city that is tailored to inhabitants’ needs, that reflects their culture or that creates the rich mix of activities that distinguishes great places. Centralized plans also make many assumptions

about what people want, causing such plans to be brittle in the face of change. So many “smart home” projects have failed over the past few decades precisely because designers made the wrong assumptions about how people would want to integrate technologies into their daily lives and did not build in the capacity to adapt to unforeseen situations.

Second, top-down visions ignore the enormous innovative potential of grass-roots efforts. We have all witnessed how the decentralization of design transformed the World Wide Web into a fascinating milieu for social interaction. By providing finished solutions rather than new raw materials for building the physical and social fabric of smarter cities, top-down designs rob themselves of any capability to invent new ideas for how to make cities better. If we compare the bounty of ideas that have come from city-sponsored app contests such as New York City’s BigApps challenges with the vague promises for how high-definition videoconferencing will be used in New Songdo City, it is clear that the biggest innovations will come from the bottom.

Finally, a focus solely on efficiency ignores fundamental civic goals such as social cohesion, quality of life, democracy and the rule of law. Improving sociability through technology, however, does target these needs, while also unlocking new approaches to efficiency. For example, the app Dopplr allows users to calculate and share the carbon footprint of their travel, which may inspire more sustainable behavior.

BUILDING FROM THE BOTTOM-UP

IF WE FOCUS on sociability as the starting point for design and tapping citizens as the source of innovation, how do we go about crafting a smarter city?

An ideal beginning is to leverage the growing array of smart personal devices we all wield and re-

Roll out: Controlled by a smartphone, the Copenhagen Wheel (*red disk*) provides pedal assistance but also sends temperature, humidity, noise and pollution data to a real-time environmental database. Nitrogen oxide levels in Copenhagen are displayed at the left.

cruit people as the sensors of a city rather than relying only on formal systems embedded into infrastructure. The traffic function on Google Maps is a good example. Instead of building a costly network of dedicated vehicle sensors along roadways, Google constantly polls a large network of anonymous volunteers whose mobile devices report their up-to-the-minute status, which reveals where traffic is flowing, slowed or stopped. The information is delivered to drivers via mobile mapping applications in various ways—as colored overlays indicating traffic speeds, as estimated driving times that account for delays or as a factor in determining alternative routes. These handy data allow users to see the circulatory network of the city in real time and to understand the constantly changing cost in time of getting from point A to point B. Although Google is certainly not a grassroots platform, this example shows how peer-to-peer sharing of sensory data can have a huge impact in helping to manage urban infrastructure. This scenario also shows how smart cities can be both sociable and more efficient without imposing order from above; you choose the best route based on your peers' observations instead of being directed by traffic engineers.

Google's traffic app leverages a large base of existing consumer devices. But bottom-up approaches to sensing can also provide rapid, cheap deployment of new kinds of sensors that measure and record data about people's activities, movements,

surroundings and health. As recently as 2009, Paris had fewer than a dozen ozone-monitoring stations. To greatly expand this official data stream, the Green Watch project, overseen by Internet think tank Fing, distributed 200 smart devices to Parisians. The devices sensed ozone and noise levels as their wearers went about their daily lives, and the ongoing measurements were shared publicly through the Citypulse mapping engine. In the first trial more than 130,000 measurements were taken in a single city district. The experiment showed how a grassroots sensing network could be deployed almost in an instant—at dramatically lower cost than expanding the city's archaic fixed stations. The project also showed that citizens could become deeply engaged in environmental monitoring and regulation. Ultimately, sensors for grassroots networks will be built into everyday objects: phones, vehicles and clothing.

Bottom-up approaches are also leveraging the sociability of cities to change patterns of activity. As the booming popularity of local shopping networks such as Groupon and LivingSocial shows, connecting local businesses and city dwellers through mobile social networks is a powerful catalyst for action. These new ways of scripting the city can create more lasting kinds of social touch points, too. The Foursquare mobile social network that Amamou used in Tunis can also turn going out on the town into a kind of mobile game. It crowns the most frequent visitor to every café, bar and restaurant as the “mayor”—a reference to the “self-appointed public characters” described in 1961 by urbanist Jane Jacobs in *The Death and Life of Great American Cities*. Like the corner gossips that Jacobs argued were so critical to neighborhood cohesion and safe streets, Foursquare's mayors remind us that even the most intelligent of digital cities are vital because they are filled with interesting and accessible people.

Another way to put citizens in the driver's seat is to instrument buildings, plazas and even sculptures with embedded sensors and actuators. These devices will create capabilities for passersby to alter how the built city behaves. For example, the Digital Water Pavilion in Zaragoza, Spain, is a public sculpture whose walls are created by jets of water that can display patterns and react to people. As individuals walk through the space, the jets turn on and off, allowing pedestrians to proceed without getting wet.

This programmable world will extend beyond the physical city. Today many municipalities offer telephone hotlines reached by dialing 311 that give citizens rapid access to city government information and services, as well as the ability to file reports about everyday issues. These systems will evolve into wiki-like information repositories that allow citizens to team up and help themselves. For instance, one resident, using Boston's mobile 311 app

Dry passage:

Sensors and actuators in Zaragoza, Spain, turn off select water jets as a pedestrian approaches—one example of responsive architecture.



(dubbed Citizen's Connect), responded to a plea for help in removing an errant possum from another Bostonian's garbage can in less than half an hour—well before the city's own Animal Control unit could mobilize to respond. On successfully evicting the critter, the Good Samaritan left a comment on the 311 system that the matter was resolved. As government information systems that enable citizens to add and edit information become more widespread, they will support innovation in how services are delivered and funded in caregiving, education and other nonemergency functions. Successes in online social gaming can provide lessons in how to motivate and reward volunteers. Citizens will have to make sure, however, that city government does not view “crowdsourcing” work from the masses as a convenient way to offload its obligations.

More natural computer interfaces will let non-techies, disabled persons and the illiterate participate more fully in civic life, making it smarter still. Although gestural interfaces that recognize individual faces are new, the Institute for Creative Technologies at the University of Southern California has developed a gestural controller for Gmail that, if combined with speech synthesis and recognition, could allow the illiterate poor, the elderly and the disabled to use e-mail and explore the Web. As these technologies spread to cybercafés throughout poor urban communities, such as the national network of more than 600 *Pontos de Cultura* (culture hotspots) in Brazil's favelas, we will see an urban movement emerge for more inclusive smart services.

Part of what makes cities smart is a system of checks and balances, and networked cities are changing the way citizens monitor city hall. Hyperlocal news sites such as EveryBlock aggregate Web content and public data about individual streets, cover local issues and monitor local government more thoroughly than traditional newspapers or television. Web sites such as Oakland Crimespotting in California enable residents to analyze and create interactive maps of detailed crime data by using information mined from ubiquitous, real-time social media streams and government databases. Crime information systems akin to New York City's CompStat have long allowed police departments to create detailed maps of criminal activity, but better access to crime data will empower citizens to analyze policing and public safety, perhaps leading to different kinds of community policing.

A PLANET OF CIVIC LABORATORIES

IF THE RISK of visions like Masdar is their elitism and singular focus on efficiency, their advantage is clarity of purpose. The bottom-up smart city is a continual work in progress; its organic flexibility is also its biggest flaw. But as civic laboratories for urban innovation, these seemingly chaotic places are becoming part of a global movement. To make

rapid progress, we need to build mechanisms for scanning, evaluating and cross-fertilizing good ideas—ways to spread the best methods for crowdsourcing public services or using citizens as sensors, just as we have in the past spread the best ideas for bus rapid transit or bike sharing.

Here is where mayors, architects, planners and technologists might play their most effective role in shaping truly smart cities—by marshaling and integrating the great engineering resources of top-down approaches with the innovation of grassroots initiatives. Governments in cities as diverse as New York City, London, Singapore and Paris are taking tentative first steps by making formerly private government data warehouses public. These resources are empowering entrepreneurs to come up with mobile software applications that meet citizen needs. But it is not clear how the entrepreneurs will sustain these efforts. The grassroots developers bring engagement and creativity to the table, but corporations and politicians are needed to scale and sustain the large systems that the innovations run on. After all, the revolutions of Cairo and Tunis played out on a mobile infrastructure built by Vodafone and other global companies.

It is also up to civic leaders to listen to citizens and together frame their own smart city vision. Every community faces a unique set of circumstances, as well as resources to address them. Some local experiments will morph into “best practices,” data sets, computer models and visualizations that can be repurposed elsewhere, but many of the best smart city solutions will be like the best urban experiences: unique, local and unreplicable—as they should be!

SMART CITIES FOR ALL TIME

IS MASDAR REALLY a glimpse into how we will live tomorrow? Or will it suffer the same fate as the machine universe of Fritz Lang's 1927 film *Metropolis*—another vision that will inspire designers but will ultimately fail to materialize? Masdar is perhaps a bit of both. It is providing an effective template for how to use pervasive computing to optimize urban systems, from transport to energy. Yet after five years and more than \$1 billion, Masdar is also showing shortcomings of the centralized approach; a large replanning exercise will effectively turn it into a more conventional real estate development. More than smart systems that improve efficiency are needed to make the city “smart.”

Taking a more bottom-up view of how cities actually develop gives us an opportunity to radically rethink what intelligent, connected communities of the future could look like and how they can be designed, built and lived in. By empowering people to devise ways to run their daily lives as smartly as possible, we can make their extended community—the actual embodiment of a city—smarter, too. ■

MORE TO EXPLORE

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Building a Smarter Favela: IBM Signs Up Rio. Greg Lindsay in *Fast Company*; December 27, 2010. www.fastcompany.com

Massachusetts Institute of Technology's Senseable City Laboratory: <http://senseable.mit.edu>

SCIENTIFIC AMERICAN ONLINE

Animations of smart city apps can be viewed at ScientificAmerican.com/sep2011/ratti