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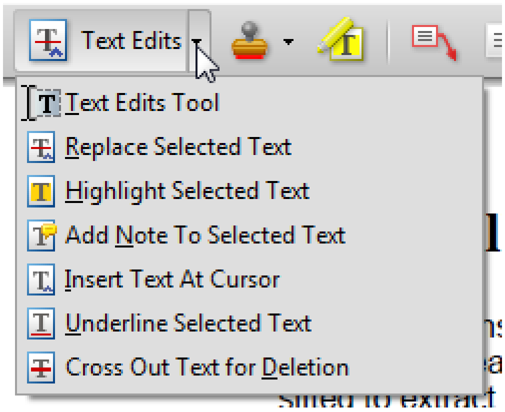

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Technological Innovation and Complex Systems in Cities

Mark Dodgson and David Gann

ABSTRACT *Many solutions to the problems confronting cities involve the integration of systems of systems. The complexity of integrating diverse systems requires approaches that are adaptive and collaborative. This paper argues that these approaches can valuably draw on a range of emerging technologies, such as virtual representations, using the massive increase in available data from ubiquitous instrumentation. It contends that the interrelations in cities between different systems can be better explored, and decisions improved, through using this technology. A brief case study of some elements of IBM's Smarter Cities strategy, based on instrumentation, interconnection, and intelligence is presented. The company's Emergency Response System in Rio de Janeiro is provided as an example of the role technology can play in developing an integrated system of systems. This exploratory paper concludes that the new innovation technologies can contribute to effective approaches for dealing with emerging challenges in cities.*

Introduction

Cities provide the stimulus and location for most of the world's creativity and innovation. Historically, this has always been the case. Literature, art, and architecture flourished in the city-state of Athens in the fifth century BCE with continuing consequences for the world today. Florence was the crucible of the Renaissance in the fourteenth and fifteenth centuries. For the historian Fernand Braudel (1981) cities can be likened to electric transformers with national economic growth generated by Venice and Genoa from the thirteenth through the fifteenth centuries, Antwerp and Amsterdam from the sixteenth through the eighteenth centuries, and London in the eighteenth and nineteenth centuries.

Contemporarily, cities are the major contributors to the supply of and demand for innovation and provide primary sources for economic and employment growth (Acs, 2002; Simmie, 2001). Most patents emanate from, and research and development is conducted in, cities, and their citizens' higher disposable incomes ensure greater consumption of innovation (Marceau, 2008). Cities also employ more tertiary educated people than elsewhere (Dirks amd Keeling, 2009).

The world's rapid urbanization is a major stimulus to innovation. In 1900, 13 percent of the world's population lived in cities. According to UN data, by 2007 the majority were urban dwellers, and this is expected to increase to 70 percent by 2050, by which time the world's population will have risen from 6 to 9 billion (see: http://esa.un.org/unup/p2k0data.asp). This poses enormous chal-

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lenges for the provision of energy, transportation, and health, as well as for security and law and order. The difficulties for city planners and authorities are seen in the way cities are responsible for 75 percent of global energy consumption and 80 percent of greenhouse gas emissions (Marceau, 2008). Congestion costs in cities around the world are estimated to be of the level of between 1 and 3 percent of GDP (Dirks and Keeling, 2009).

The study of the relationships between space and innovation commonly focuses on regions and clusters, but there is a diverse literature on innovation- and technology-related issues in cities. Empirical research focuses on matters such as entrepreneurship (Acs, 2002) and technological specialization versus diversity (Feldman and Audretsch, 1999); it also explores the contributions of institutions such as science parks (Komninos, 2002), public infrastructure (Martin and Rogers, 1995), and particular technologies, such as telecommunications (Moss, 1987). Most of this scholarship focuses on research and development and high-tech industries and jobs.

Other approaches examine the advantages of physical propinquity for the transfer of knowledge and creativity in the creation of "innovative milieux" (Florida, 2002; Cooke and Morgan, 2000). Innovation is stimulated by large numbers of people in close proximity; by what Samuel Johnson called the "wonderful immensity" in cities. Economic advantages derive from the ways the costs of transactions and transportation are reduced by co-location, and organizations in close association stimulate the creation and diffusion of innovation through improved awareness and knowledge of each other (Baptista, 2001; Krugman, 1991). When knowledge is even moderately complex, and tacit rather than codified, its transfer is more successful when people are socially proximate rather than distant (Sorenson et al., 2006). Virtuous cycles of localized creativity and innovation produce wealth that invests in the educational and cultural capital that feeds creativity and innovation (Florida, 2002; Landry, 2008). When large numbers of people congregate, governance is demanded to provide sanitation, health, energy, and transportation systems, and thus markets are created and public provision organized for such services.

Cities can be alienating and disturbing places in which to live (Sennett, 1998). The Spanish poet, Lorca, described them as "geometry and anguish." But there are social and cultural stimuli to innovation derived from shared identity and higher trust when groups of people are affiliated and cohesive (Cooke and Morgan, 2000). According to the sociologist, Manuel Castells (Castells, 1996), major metropolitan centers provide the greatest opportunities for personal enhancement, social status, and individual gratification. The anthropologist, Margaret Mead (1957) refers to the: "unique contribution of the city: A chance for rich, variegated, unexpected, easy, multidimensional human contacts...." Proximity produces the face-to-face **Q1**
communications conducive to stimulating "buzz" (Storper and Venables, 2004).

Historic Florence still holds lessons about the creation of that buzz. The Medicis, despite their intense personal and political intrigues, played a catalytic role in Florence's ascendance by funding creative people from a wide range of disciplines, including Leonardo, Michelangelo, and Brunelleschi. Because of the Medicis and a few other Florentine families, scientists, poets, philosophers, financiers, painters, and architects were attracted to work in the city. There, in the words of Johansson (2004): "they found each other, learned from one another, and broke down barriers between disciplines and cultures." They epitomized Ralph Waldo Emerson's observation that "cities give us collision." **Q1 Q2**

New technologies to address the problems confronting cities will require, as with all Schumpeterian innovation, the combination of diverse perspectives, knowledge bases, and resources. A strand of research on the qualities of association connects with another arguing the value for innovation of systemic connectivity (Lundvall, 1992; Lundvall et al, 2002; Cooke, 2001). The large and diverse literature on innovation systems that emerged at a national level (Nelson, 1993; Lundvall, 1992), and has incorporated analysis at a sectoral, technological (Carlsson et al., 2002), and regional level (Asheim and Gertler, 2004), takes both an institutional and relational perspective. Just as important as the institutions of research, business, finance, and law in innovation are the quality of the relationships between diverse component actors.

These analyses inevitably refer to the challenges of complexity that arise in any interactions among institutional, technological, and human systems (Rycroft and Kash, 1999). This research has addressed the nature of adaptable, changeable systems and the factors that encourage their development, often under the guise of complex, adaptive systems (Miller and Page, 2007). This concern has underlain much systems thinking. Checkland (1993), for example, argued systems thinking is concerned with emergence, hierarchy, communication, and control, and he contended that the most crucial characteristic of designed systems is the emergent properties of the whole. Complexity is managed when the system allows for its emergent development, based on the availability of new data, experimentation, and collaborative negotiations over decisions.

The literature shows that proximity is a stimulus to innovation, especially when it draws on diversity. It shows complexity increases with diversity, requiring adaptive and emergent capacities in the systems that cities comprise. This sets the background for the question we explore in this paper on the potential use of new technologies in finding innovative solutions for the systemic problems confronting cities. Our perspective lies not with economic geography, sociology, or urban planning, and the perspectives they bring to discussion of "cybercities" (Graham, 2004; Shiode, 2000) but with examining from an innovation perspective the relationships between emerging new technologies and the complex, systemic challenges in cities. Our definition of innovation encompasses the outcomes that result from the successful application of new ideas (such as new technologies), and the process by which innovation occurs and involves connections between diverse parties (which may involve the application of new technologies) (Dodgson and Gann, 2010; Dodgson et al., 2008).

The first part of this paper examines the systemic complexities in cities. We then discuss the use of specific new technologies being applied to city problems, including discussion of our case study, IBM. Through its Smart Cities initiatives, IBM is in the vanguard of corporate technological investments to support innovation in city systems (see, e.g., www.ibm.com/smartercities). We conclude the paper with consideration of the implications of our exploratory study and some future research questions. We argue that the explosion in available data and the existence of a range of innovation-supporting technologies, have the potential to contribute to more efficient and collaborative approaches to dealing with the emerging challenges in cities.

The case study resulted from a long-term research engagement with IBM. The two authors have been researching IBM's strategy for services and use of new technologies to support innovation since 2006, involving numerous visits to major laboratories in the United Kingdom, the United States, and Australia;

formal interviews with 36 IBM vice-presidents, managers, and engineers; and the conducting of three workshops with IBM staff. One author attended the launch of IBM's Smart Cities program in Berlin, in October 2009; the other attended the IBM Smart Cities program in Shanghai, in June 2010.

Systemic Complexities in Cities

Historically, the growth and development of cities is inextricably linked to technological innovation. Based on Freeman and Perez (1988) and Hall (1999), Figure 1 presents a highly stylized representation of examples of major technologies that have been critical to the growth and success of cities. It includes Hall's (1999) representative example cities that have been central to the development of key technologies.

The importance of technology is widely accepted, even if there remain widely different views about its consequences. The implications of information and communications technologies are, of course, profound, and continue to be enacted. But they have been argued by some to be likely to redistribute the concentration of technology and work in cities by bringing about the "death of distance" and rearranging the "fate of location" (Cairncross, 1997). In stark contrast, Hall (2002) discounts such predictions, arguing that new technologies create new industries that are concentrated in traditional urban places. Hall (1999) also contends that the cities of the twenty-first century will be driven, as in the past, by technology. The question is what forms of technology will be most influential. And this depends on the nature of the challenges that cities have to confront.

Systems of Systems

Cities are systems of systems. Many of the key technologies described in Figure 1 are systems, including: transportation, water and waste recycling, food and products, energy and electricity, buildings and construction, and healthcare. Tra-

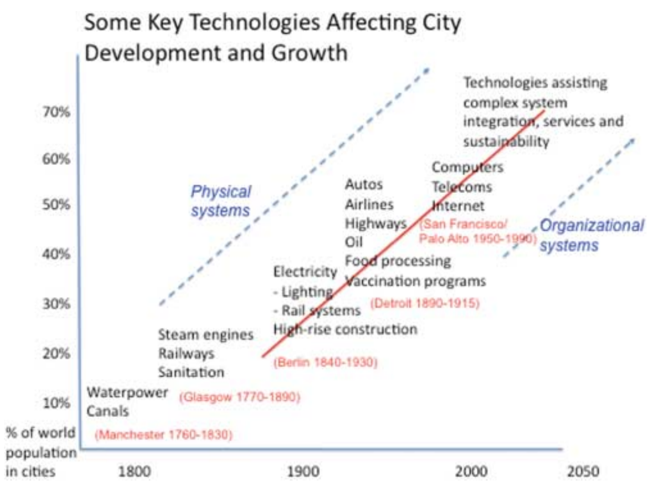

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Figure 1. Some key technologies affecting city development and growth
SOURCES: Freeman and Perez (1988) and Hall (1999)

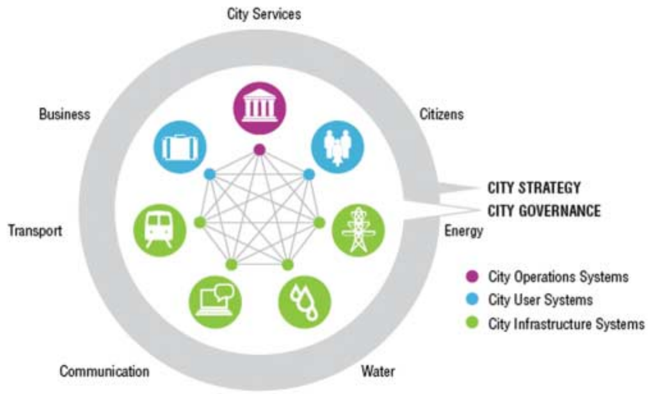

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Figure 2. Cities as a system of systems
Source: Dirks and Keeling, 2009

ditionally, these systems have been developed and operated independently, but they are interconnected.

The transportation system, for example, is intimately linked to the energy provision system. Increased use of hybrid cars reduces petrol consumption but increases the demand for electricity. Improved telecommunications infrastructure increases opportunities for home working and telemedicine, affecting transportation and health systems. The provision of potable water depends upon high levels of energy provision for processing and transfer. Large amounts of water are needed to cool power stations.

A representation of this system of systems, developed by IBM (Dirks and Keeling, 2009), is presented in Figure 2, which distinguishes among the city operation system (how cities perform civic duties and comply with national and regional governance); city user systems (businesses and citizens); and city infrastructure (energy, water, communications, and transport). They argue that, "Understanding one system and making it work better means that cities must comprehend the bigger picture and how the various systems connect" (Dirks and Keeling, 2009:5).

Organizational Systems

The technologies that have affected cities so much in the past—steam engines, electricity, autos, microprocessors etc.—are natural and engineered physical systems, commonly based on scientific advances in physics and biology. Irving Wladawsky-Berger (2010) contrasts these with organizational systems that, despite similarly involving extensive infrastructures, multiple technologies, and vast numbers of components, are even more complex and unpredictable because they are human-centered. Cities are complex organizational systems and play multiple and complicated economic and social roles, placing enormous demands on governance mechanisms and the skills of politicians and administrators as well as the imaginations and willingness of city populations to finance and accommodate innovation (Marceau, 2008:136). Q3

The key technologies for the future development of cities will be those that use organizational systems to help address the stresses and strains brought about by the massive increase in urbanization and that use collaboration to take advantage of diversity, thus producing cities that are efficient, sustainable. and agreeable places to live and work. As Wladawsky-Berger (2010) points out: because the organizational systems of the future involve people, they are quite different from physically engineered systems, displaying considerable more variations, and necessitating design approaches that are emergent and collaborative. This accords with the approach of Batty (2007), who argues that more people are becoming involved in urban planning, and as we move from a "top down" to a 'bottom up'' approach: "the system we are dealing with changes, from one where we assume that all things about the system are ultimately knowable to one where this assumption is no longer tenable. Systems of cities are no longer thought of as being complicated but rather complex in that there is always uncertainty about the outcome of processes of change" (Batty, 2007:xiv).

In this way, many challenges in cities can be described as "wicked problems" (Rittel and Webber, 1973). These problems are persistent and have no complete solution, lacking a clear set of alternatives and little room for trial and error. They are characterized by contradictory certitudes among protagonists and strategies for dealing with them involve coping rather than solving and searching for what is feasible, not optimal.

Cities are constantly evolving and changing to deal with such problems and meet the demands and needs of businesses, city authorities, service providers, and citizens. To meet changing needs, systems and buildings have to be adapted and new ones added. This creates "churn" in city infrastructure and systems that in itself can be highly disruptive to economic activity and quality of life.

When technological systems are overlaid by the organizational and political systems associated with city governance, with their conflicts and lengthy change processes, added to the tensions between sunk investments in old technologies and new demands and opportunities, then innovation in cities confronts an amalgam of complexities, rigidities, and uncertainties.

This points to the value in understanding cities holistically, which in turn depends on information about the function and performance of cities, both historic and current. With new data and understanding, decisions can be made that catalyze innovation. We now turn to some technologies that have the potential to help deal with city problems.

Emerging Technologies

Emerging new technologies use what has been called the "data deluge" (Bell et al., 2009) available in cities. Data can be collected from sensors, RFID devices, mobile telephones, and cameras to provide real-time information about how people and organizations behave. According to IBM estimates, there are one billion transistors for every person on the planet and 33 billion RFID tags in use. We use over four **Q4**
billion mobile phones and one billion camera phones. And we are increasingly connected: it is estimated that two billion people are connected on the Internet and one trillion objects are connected with one another (Palmisano, 2006). This massive amount of data is being processed by supercomputers and cloud computing data centers, improving our capacity to understand complex systems and improve their design (Palmisano, 2010).

Innovation Technologies

The technologies using these data include what we call "innovation technology" (IvT) (Dodgson et al., 2005). They include simulation, modeling, visualization, and virtual reality technologies. The use of IvT can help model and simulate the implications of decisions in cities, and their visualization capacities help communications and the informed involvement of diverse parties to assist the building of consensus necessary to solving problems. It intensifies innovation by providing economies of effort and greater definiteness of aim (Gann and Dodgson, 2007; Gann and Dodgson, 2008). They are the technologies for the integration of complex organizational and physical systems. IvT works well in situations where there is a "culture where planning and design emerge from the bottom up, where individuals are in touch with the problems of the city and know best how to tackle them" (Batty, 2007:2).

City infrastructure is constructed by a sector renowned for under-performance in the key performance parameters of cost, time, and quality. With some notable exceptions, the construction industry's projects—in buildings, roads, bridges, tunnels, and other transportation infrastructure—rarely delight or leave lasting legacies of which future generations will be proud. The industry is seen as expensive, lacking innovation, dependent on low skilled manual labor, and struggling to deal with its environmental impact.

The industry is, however, drawing on lessons from manufacturing and other industries to seek significant improvements in innovation and productivity through automation and greater use of technology. A recent report "Advancing the Competitiveness and Efficiency of the U.S. Construction Industry" (National Research Council of the National Academies, 2009) identified a range of "opportunities for breakthrough improvements" involving technology and innovation.

Innovation technology (IvT) has an important role to play. Construction projects involve a diverse set of stakeholders—owners, users, including the general public, designers (architects, engineers, interior designers), general contractors, subcontractors, labor, suppliers, manufacturers, and operators, as well as urban planners, environmental activists, regulators, financing institutions, legal representatives, insurance and bonding companies, and others. Each of these groups can contribute to a project from a multiplicity of disciplines, organizations, and professions, each with differing objectives. IvT provides a common basis for shared conversations between all these diverse stakeholders to produce agreement on how things should proceed (Dodgson et al., 2007).

Digital prototyping, for example, provides the ability to explore a complete project in a virtual format before it is built. It can create, validate, optimize, and manage designs from the conceptual phase through to the manufacturing process. A single digital model of a project can bridge the gaps that usually exist between conceptual designs, engineering, manufacturing, and operations teams. It can provide technology to help manufacturers build fewer physical prototypes, reducing design and production costs. By using a digital prototype, the performance of designs—functional, economic, and environmental—can be simulated and visualized, allowing much more collaborative and efficient decision-making (Gann et al., 2011).

IBM and Smart Cities

IBM's "smarter planet" strategy has an element focusing on smarter cities. The smart planet strategy is based on the idea that "intelligence is being infused into the systems and processes that enable services to be delivered; physical goods to be developed, manufactured, bought, and sold; everything from people and money to oil, water, and electrons to be moved; and billions of people to work and live" (Palmisano, 2010:2). It depends on the data deluge. In IBM's terms, the smarter planet, and smarter cities, are more instrumented, interconnected, and intelligent. The "smart" approach to cities is an attempt to gain understanding and better decision-making about systems of systems.

The company has invested heavily in the promotion of smart cities, in websites (such as www-03.ibm/innovation/us/thesmartercity), and about 100 conferences held around the world. As the strategy is so new, there is little independent verification of its impact, and much of the information about the problems it seeks to address and the ways they are being addressed, is derived from IBM sources. The following outlines some key principles of IBM's approach.

Instrumentation: depends upon the data deluge to measure and influence the efficiency of the operation of systems such as transportation or energy. Palmisano (2010:6) provides the examples of a bridge in Hong Kong that is monitored by 1,000 connected sensors and the 10,000 security cameras in London connected to the web. He claims that in the four cities for whom IBM has managed congestion, peak traffic volume has been reduced by up to 18 percent; CO_2 emissions from motor vehicles have been reduced by 14 percent; and public transport has increased by up to 7 percent.

Interconnection: is based on the principle that it is valuable to have data from various systems connected. Merging data from several sources provides information that allows comprehension of the bigger picture on how various systems influence each other, increasing the efficiency of the overall infrastructure. IBM provides the example of the City of Albuquerque that is using a business intelligence system to automate data sharing among its 7,000 employees in more than 20 departments in municipal services, from residential and commercial development to water to public safety, so every employee and citizen gets the same information. The company claims a 2,000 percent improvement in efficiency has been achieved by sharing information across agencies in the city. Another example provided by IBM is its work with the New York Police Department (NYPD), undertaking sophisticated analytics and providing search capabilities to make connections across multiple databases of information, including traditional sources kept in filing cabinets or on index cards, or in handwritten notes. The company claims critical data can be relayed instantly to officers where they need it, and what once took days now takes minutes.

Intelligence: is based on the use of information developed with analytical techniques that reliably simulate and model behavior and allow better decision-making. In railway systems, for example, devices along the track can monitor acoustics, heat, and wheel impacts of trains. The ubiquity of monitoring devices can identify the location of rail cars; passengers can be charged based on actual usage; maintenance can be initiated based on need predictions, rather than regulated schedules; and better security can be provided for passengers. Mobile monitoring systems can provide intelligence through continuous real-time capture and analysis of data, such as on the health of rolling stock, as well as operational data, allowing diagnostics to be conducted remotely, and timetables to be optimized. When information is available on road traffic and weather conditions, the planning of rail timetables can be related to a whole system of transportation, rather than within a single element.

In other areas, IBM has formed a coalition of utility companies to accelerate the use of smart grid technologies, and water systems from rivers and reservoirs to homes are being monitored, measured, and analyzed in the entire cycle.

An example of the collaborative approach to developing technological solutions to the problems associated with the system of systems that are cities, emerged from an innovation workshop held between IBM and the regional government of Rio de Janeiro in May, 2010. Rio had recently experienced devastating landslides that killed over 250, and it faced the forthcoming challenges of hosting the Olympics and the soccer World Cup. Over the two days of the workshop, 100 participants discussed various "smart" options for the city, with a proposal emerging to produce an Emergency Response System. This involved real-time automated command and control of emergency responses, produced in the form of an Executive Dashboard. The system uses integrated business analytics and intelligence with predictive trend analysis. It senses and reports data, monitors and analyzes the environment, and along with its predictive capacities, provides information to assist proactive decisions.

The project involved meteorologists, engineers, and multiple crisis response teams and, apart from IBM, other corporate partners such as Samsung. A large video wall provides a single unified view of all the data required to assess and make decisions, including maps, surveillance images, news coverage, weather details and forecasts, simulations, information about incidents, and availability of resources. Simulations can be undertaken of the potential impact of forthcoming weather events. If a crisis is looming, the system helps coordinate the various response teams in ways ranging from accurate descriptions of the present and likely consequences of the event, to ensuring that appropriate equipment and materials are available. Having assessed weather and traffic conditions and the capacity of local hospitals at that time, the system provides information for those dealing with the crisis on the ground about access to and availability of nearby medical assistance. Post emergency, the system assists in planning clean up.

The mayor of Rio is reported to have claimed as a result of this system, Rio is among the world's smart cities (*Wall Street Journal*, 27/12/2010). Senior IBM man- **Q2**
agers claim this was IBM's first system of systems project, and it is progressing so that it will eventually integrate 18 different city systems.

Discussion and Conclusions

Cities and technological innovation develop symbiotically. Historically, cities have played crucial roles in the development of the most important technologies. Cities are also the location of some major problems and future challenges. For these reasons, we agree with Jane Marceau when she argues "…it is now time to show how innovative cities and innovation in cities, the fulcrum of modern dilemmas of sustainability, wealth creation and distribution, infrastructure investments, poverty and exclusion reduction, work as well as play, can be made to work effectively and sustainably for the good of all." (Marceau, 2008:145).

As in the past, technology will be the driver of the new kind of city in the twenty-first century, and we have analyzed the kinds of innovation technologies that will play a central role and how a leading organization is using it. We also concur with Hall's view of technology that:

> … it will not drive, indeed never has driven, in any simple or determinist way: new technology shapes new opportunities to create new industries

> and transform old ones, to present new ways of organizing firms or entire societies, to transform the potential for living but it does not compel these changes. . . There will be choices and societies can influence those choices by conscious decision. (Hall, 1999:943)

These choices are complex and have emergent properties. Technically, the challenges of integrating systems of systems are immense. Add the need to combine physical and organizational systems, and they may reveal characteristics of wicked problems, involving conflicting and potentially irreconcilable differences.

The technologies we describe, being used by companies such as IBM, provide the opportunity for better choices to be made about very highly complex organizational and physical systems. The amount of data being collected and made useful will aid decision-making, especially when it reveals the interconnectedness in the system of systems that are cities. The capacity of the technologies to represent plans and options virtually, in ways that are comprehensible to all interested, and often variegated, parties will improve the levels of engagement in decision-making processes, and hence improve designs and restrict opposition to them once they have been implemented.

The use of the technologies we have discussed has even greater relevance because of the idiosyncrasies of cities. Innovation problems differ according to industrial and political history, geography and topology, and the varying national or international roles and connections of cities. As Marceau (2008) points out, each city needs to be treated on its own terms and cities are still experimenting and have to learn major lessons themselves, and not assume that what works in Stockholm or Amsterdam will work in Melbourne or Singapore, let alone in the huge cities of China and Korea.

The technologies reviewed in the cases in this paper offer an opportunity to improve the ways in which cities develop and adapt to meet changing needs. IBM's approach to massive sensing, data collection, and modeling may enable a better understanding of how city systems work and how they can be improved to better serve citizens while reducing environmental impact. Much more work is needed in this area, particularly if scientists and engineers are to be able to build credible and useful models of interactions in systems of systems. This itself is only now becoming possible because of the development of high-performance, exascale computing.

These innovations have been driven by recognition of the problems facing cities. But they represent and illustrate another layer of technology in what has already become a complex set of vintages and web of systems. It appears that cities cannot continue to thrive without such technological innovation, but there is as yet uncertainty as to whether it will solve more problems than it may create. Our contention is that benefits will arise from the use of all the new data and IvT, but technological change is unpredictable and its consequences contentious. There are real concerns about the use of city data to curtail personal freedoms, and the capacity of technologies to engage multiple parties could conceivably lead to decision paralysis: the downside of Emerson's "collision." Further work is needed to understand the full consequences, costs and issues relating to the reliability, resilience, safety, and security of such approaches. There are bountiful opportunities to explore the use of these technologies in improving sustainability, perhaps the most pressing problem confronting cities, and one given little attention in this paper.

There are plentiful opportunities for experimentation. Cities are digital laboratories of infinite variety. There are continual opportunities for learning from the use of new technologies in cities with long histories, such as London, where decisions about new investments in infrastructure have to account for decisions made centuries past. And there are opportunities to put experience to good use in new cities, such as Masdar City, which is being built near Abu Dhabi and is aiming to be the world's first economically and environmentally sustainable city, with zero carbon emissions. This city can draw on the expertise of scientists, engineers, and urban planners to use IvTs in a totally systemic way. These are massive experiments, but smaller-scale efforts such as the Rio Emergency Response System also valuably contribute to the learning that is necessary as the technology develops. As Checkland (1993) reminds us, the most important aspect of designed systems is their emergent properties, and this depends on the ability to learn and respond to such experiments.

An intention of this paper is to add to the growing body of literature on spatial aspects of innovation that look at issues apart from regions and clusters. Cities matter for innovation. We hope that we have shown that, furthermore, there is a pressing need for more research on innovation in cities that looks beyond "high-tech" industries and research and development. The technologies we have analyzed have profound implications for the process and outcomes of innovation not only in cities but also, given their growing significance, for nations. It is our contention that there is much value in additional research into technologically mediated innovation processes used to deal with complex problems in cities.

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