

IBM Institute for Business Value

A vision of smarter cities

How cities can lead the way into a prosperous and sustainable future



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By Susanne Dirks and Mary Keeling

An urbanizing world means cities are gaining greater control over their development, economically and politically. Cities are also being empowered technologically, as the core systems on which they are based become instrumented and interconnected, enabling new levels of intelligence. In parallel, cities face a range of challenges and threats to their sustainability across all their core systems that they need to address holistically. To seize opportunities and build sustainable prosperity, cities need to become “smarter.”

A century ago, fewer than 20 cities around the world had populations in excess of 1 million people.¹ Today, that number has swelled to 450 and will continue to grow for the foreseeable future.²

As cities grow in both numbers and population, they are taking their place on the world's center stage, with more economic, political and technological power than ever before. Economically, they are becoming the hubs of a globally integrated, services-based society. Politically, they are in the midst of a realignment of power – with greater influence, but also greater responsibility. From a technology standpoint, advances are underway that can provide them with better understanding and control of their operations and development.

Operationally, cities are based on a number of core systems composed of different networks, infrastructures and environments related to their key functions: city services, citizens, business, transport, communication, water and energy. The city services system constitutes the operational activities and coordination of service delivery provided by the city authority, such as coordinating delivery across different agencies, allocating public funds, conducting physical planning activities and more. A city's citizens system includes public safety, health and education and is central to whether it delivers a good quality of life for its citizens. A city's business system refers to the environment that businesses face in terms of policy and regulation. Cities offer citizens and business the ability to move things around through their transport systems and to share ideas and information through their communication systems. Cities also offer two core utilities necessary for all economic and social activity – water and energy.

These systems are not discrete, however. They interconnect in a synergistic fashion that, ideally, promotes optimum performance and efficiency. These core systems, in effect, become a “system of systems.”

However, while providing the potential for significant positive transformation, each element of this “system of systems” faces significant sustainability challenges and threats. For example, cities are confronted by considerable service coordination and planning challenges as a result of urban sprawl. Citizens face healthcare threats, such as infant mortality and the worldwide HIV pandemic. For businesses, cities must balance regulatory requirements with the need to decrease costly administrative overhead. Inefficient transportation systems continue to drive up costs. Increasing communications and connectivity demands challenge the ability of cities to meet the needs of its citizens and businesses. Water resources fall victim to leakage, theft and poor quality. And current energy systems are often insecure and inefficient.

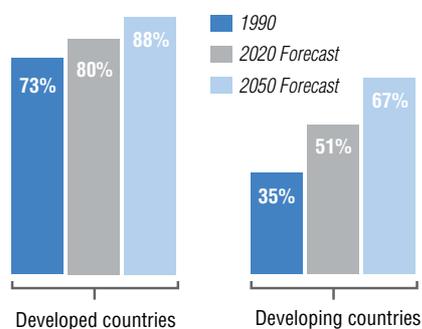
As cities face these substantial and interrelated challenges, it becomes clear that the *status quo* – business as usual – is no longer a viable option. Cities must use their new power to become *smarter*. They must act now, using new technologies to transform their core systems to optimize the use of limited resources.

The opportunity presented by smarter cities is the opportunity of sustainable prosperity. Pervasive new technologies provide a much greater scope for instrumentation, interconnection and intelligence of a city’s core systems. Around the world, leading cities are putting in place smarter systems, such as Galway’s *SmartBay* advanced water management system, Songdo’s *Wired City* initiative or Singapore’s *eSymphony* transport system.

Becoming a “smarter city” is a journey, though, not an overnight transformation. Cities must prepare for change that will be revolutionary, rather than evolutionary, as they put in place next-generation systems that work in entirely new ways. City administrations must decide what activities are core, and, therefore, what they should shed, retain or expand into. Not only that, cities must “assemble the team” – integrate their own administrations and work with other levels of government, especially country-level, as well as private and non-profit sectors. Cities must also take into account the interrelationships among the systems they are based on, as well as the interactions among the challenges they face.

Power and responsibility as cities take center stage

In 2008, for the first time in human history, the majority of the world's people lived in cities.³ And cities for the foreseeable future will continue to grow faster than the countryside surrounding them (see Figure 1). Globally, the number of people living in cities of 1 million or more will grow from about half a billion in 1975 to almost 2 billion in 2025.⁴ As a result, cities have assumed a central role in the urbanized world of the 21st century. They are wielding more economic power, developing greater political influence and increasingly employing more advanced technological capabilities to enhance their operations.



Source: IBM Institute for Business Value analysis of United Nations data.

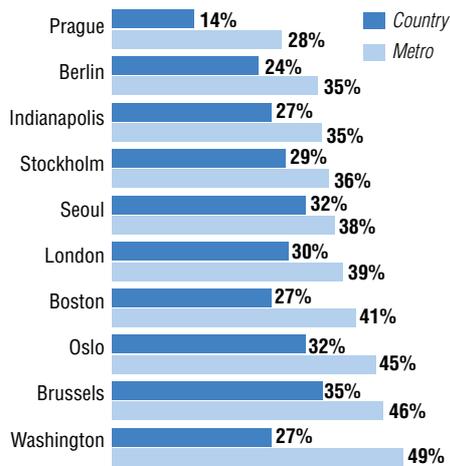
Figure 1. Percentage of total population living in cities, 1990-2050 (forecast).

The world economy is now globally integrated and services-based, with cities as its hubs

The nature of commerce has transformed appreciably since 1990, with global trade now accounting for two-thirds of all output, compared to only one-third 20 years ago.⁵ In developed economies, service provision has supplanted production as the primary economic activity, accounting for nearly three-quarters of all trade.⁶

A globally integrated, services-based world economy means that business will locate activities where capital – both human and physical – is concentrated, i.e., cities. Three-fifths of businesses list availability of qualified staff (human capital) and quality of telecommunications (physical capital) as absolutely essential.⁷ Cities have higher levels of physical and human capital compared to the countries around them. They have higher shares of workforce with tertiary education (see Figure 2) and a stronger capacity for innovation – more than 81 percent of Organization of Economic Cooperation and Development (OECD) patents are produced in urban regions.⁸

Cities are based on a number of different systems central to their operation and development.



Source: IBM Institute for Business Value analysis of OECD and US Census data.

Figure 2. Percentage of workforce with tertiary education, selected cities compared to country average, 2005 or latest.

The political landscape has changed, with cities becoming more important actors

Politically, systems around the world are migrating away from the nation-state model prevalent in the past century. This has led to the emergence of multi-level governance, giving cities greater freedom. New forms of vertical collaboration are emerging among different levels of government. Within metropolitan regions, organizations are choosing a range of levels of cooperation – from informal networks, such as

those in Spain's Bilbao and Germany's Rhine-Ruhr, right through to amalgamation of formerly separate urban districts as in Melbourne, Australia, and Montreal, Canada. This has expanded across borders with the growth of international cities such as Basel-Mulhouse-Freiburg (Switzerland, France and Germany) and Copenhagen-Malmo (Denmark and Sweden). Cities are also assuming greater legal and fiscal powers. And more cities now have directly elected mayors, instead of political appointees.

Technological advances mean that cities can better understand and control their operation and development

Technological advances mean that aspects of the operation and development that city managers have previously been unable to measure – and therefore unable to influence – are increasingly being digitized. This instrumentation creates brand new data points about, for example, the efficiency of a city's water or transport systems. In addition to being instrumented, different parts of a city's systems can be interconnected, so that information flows between them. With the greater digitization and interconnection of a city's core systems, the newly gained information can be used for intelligent and informed decision making.

Today's challenges put cities under pressure to act now

Cities are based on a number of core systems

Cities are based on a number of different systems – infrastructures, networks and environments – central to their operation and development: city services, citizens, business, transport, communication, water and energy. The effectiveness and efficiency of these systems determine how a city works and how successful it is at delivering its goals. These systems are not discrete and must be considered holistically, as well as individually.

- *City services*: The city services system is the operational activities and coordination of service delivery provided by the city authority, such as coordinating delivery across different agencies, allocating public funds, conducting physical planning activities and more.
- *Citizens*: A city's citizens system refers to its human and social networks. These include public safety (fire, police and disaster recovery), health, education and quality of life.
- *Business*: A city's business system encompasses its regulation and policy environment and includes planning regulations, openness to foreign trade and investment, and labor and product market legislation.
- *Transport*: A city's transport system includes all aspects of its road network, its public transport network and its sea and air ports, from provision to pricing.
- *Communication*: A city's communication system includes its telecommunications infrastructure, including telephony, broadband and wireless. The ability to access and communicate information is central in a modern economy and key to a smarter city.
- *Water*: A city's water system is an essential utility that includes the entire water cycle, water supply and sanitation.
- *Energy*: A city's energy system, as essential as its water resources, includes its power generation and transmission infrastructure, as well as its waste disposal.

These core systems are interconnected and must be treated as such. Understanding one system and making it work better means that cities must comprehend the bigger picture and how the various systems connect.

Cities are being empowered at a time when they face significant *challenges* and *threats to sustainability* in each interrelated system and must act now to secure future prosperity.

City services: From greater individualization to fiscal constraints, city services are coming under increasing pressure

Greater demands for individualized and tailored service delivery mean that city authorities are under increasing pressure to transform their approach to managing service delivery to citizens. This is reflected in opinion polls showing that people want greater choice in the use of services, with people looking for public services that are more responsive to the needs and wants of individual citizens.⁹ Tony Blair summarized the challenge to public service delivery as follows: "In simple terms, we are completing the re-casting of the 1945 welfare state to end entirely the era of 'one size fits all' services and put in their place modern services which maintain at their core the values of equality of access and opportunity for all."¹⁰ This in turn requires far greater integration of the different services and actors involved in their delivery, in order to give greater focus on the end user rather than the individual provider of services.¹¹ Meeting the growing demands of citizens is made more difficult by the severe budget constraints facing many cities. For example, a review of 13 major U.S. cities found that 12 of them faced budget deficits ranging from 5-20 percent of the general funds available.¹²

Citizens: From demographic changes to health, cities face major challenges and threats to their sustainability

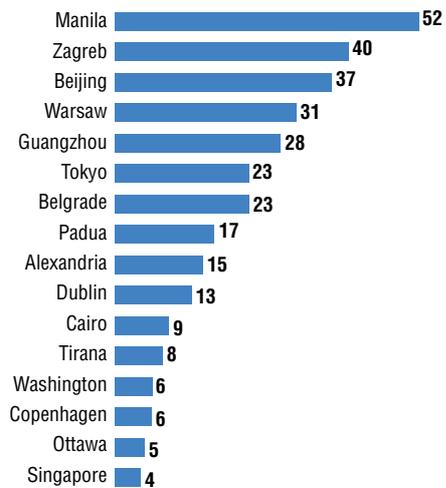
While on average urban populations are growing, cities in developed countries often face shrinking populations – in the last 30 years, more cities in the developed world shrank than grew.¹³ These cities will require new ways to stay globally competitive and attractive to skilled labor. In developing cities,

even though they are growing, the skills challenge is likely to be just as great due to brain drain, the flight of people with skills to areas perceived to offer greater economic opportunity.¹⁴ Cities also face significant healthcare challenges, ranging from infant mortality to the HIV/AIDS pandemic. With growing health challenges, the fiscal sustainability of health systems will be pushed to the limit. In North America, for example, the costs of healthcare are anticipated to increase dramatically – to 20 percent of GDP in the United States and more than half of provincial tax revenues in Canada.¹⁵

Business: Cities must balance complex regulatory requirements with the need to minimize unnecessary administrative burdens

Cities depend on their business systems for their prosperity. Less efficient administrative systems can cost as much as 6.8 percent of GDP in some economies.¹⁶ A 25-percent reduction in administrative costs – e.g., time spent filling out forms – could yield savings of up to 1.5 percent of GDP, or some €150 billion (approximately US\$209 billion).¹⁷ As Figure 3 shows, the number of days it takes to undertake the same process – starting a business – in different cities varies dramatically, even within the same country. With cities becoming more important actors politically and economically, solving the dichotomy between where laws are made and implemented will be central to the efficiency and effectiveness of cities' business systems.

Issues such as traffic congestion are costly and are likely to only get worse as cities grow.



Source: World Bank Doing Business Sub-national reports.

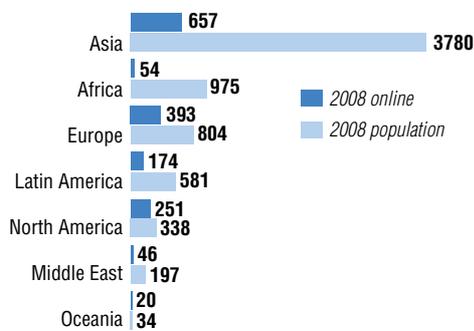
Figure 3. Number of days to start a business, various cities, 2007/2008.

Transport: Inefficient systems will continue to drive up costs without city action

Urbanization and globalization create more commuters and more freight traffic in the world's ports. Traffic congestion cost the U.S. economy US\$78 billion in 2005, resulting in 4.2 billion lost hours, as well as pollution and wasted fuel.¹⁸ These costs are growing at 8 percent *per annum*.¹⁹ The economic costs of congestion in New York alone are close to US\$4 billion a year.²⁰ A number of estimates suggest that congestion costs – in developed and developing cities – are between 1 percent and 3 percent of GDP.²¹ In emerging market cities, car ownership rates are currently a fraction of the 75-90 percent of OECD countries. As car ownership grows from less than one in ten people to one in three or higher, even greater strain will be placed on the transport infrastructure.

Communication: Cities face challenges in meeting ever-greater demands for connectivity

The last 20 years have seen a revolution in how we communicate and inform ourselves, in particular the ability to share information through the Worldwide Web. However, while the online population has grown by almost 350 percent since 2000, the vast majority of the world’s population – 5.1 billion – is still not online and is denied the benefits of tapping into a worldwide network of information (see Figure 4). The speed of connectivity has also become increasingly important. In March 2009, average speeds for those with broadband varied from 4.6 megabits per second in Asia to 1.1 megabits per second in Africa.²² As the citizens of Tokyo and Yokohama prepare for gigabit-per-second connectivity, city managers must begin planning for a terabit world.²³

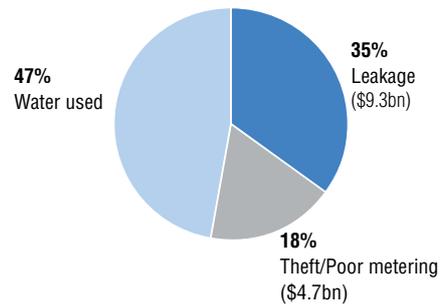


Source: Internetworldstats.com; UNCTAD.

Figure 4. Online versus total population (millions), by continent, 2008.

Water: Problems with water efficiency, leakage, quality and the threat of flooding pose a significant threat to cities’ sustainability

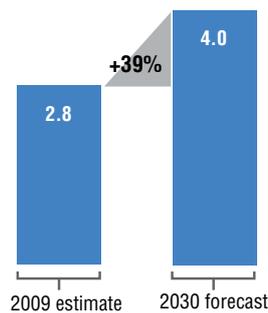
Water is fundamental for sustaining human life. Every economic exchange involves a virtual exchange of water. As cities grow, so does their thirst for water. Cities today account for 60 percent of all water allocated for domestic human use.²⁴ However, globally, less than half of water supplies are accounted for (see Figure 5). Leakage rates often represent up to 60 percent of water supplied, costing water utilities worldwide US\$14 billion every year.²⁵



Source: World Bank, 2006.

Figure 5. Usage of global water supplies and estimated costs.

Currently, 2.8 billion people, or 44 percent of the world’s population, live in areas of high water stress.²⁶ Present trends suggest that this will rise to almost 4 billion by 2030 (see Figure 6).²⁷ Globally, water shortages are estimated to cause an annual loss to economic growth of about 3.6 percent.²⁸ In California, the cost of water issues is already 2 percent of the state budget.²⁹



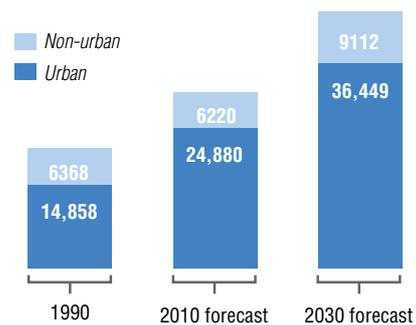
Source: World Economic Forum.

Figure 6. Global population in high water stress areas (billions).

Energy: Cities are realizing current energy systems are insecure, inefficient and unsustainable

Global emissions of CO₂, the principal greenhouse gas, are expected to have increased by more than 45 percent between 1990 and 2010, driven largely by the growth of cities (see Figure 7). Cities generate the vast bulk of CO₂ emissions; therefore reducing their CO₂ emissions is necessary for a healthier planet. As a result, city policymakers are under growing pressure – from citizens and from investors – to incorporate into their policymaking environmental sustainability in general and greenhouse gas emissions in particular. Cities are starting to rise to this threat to their sustainability, with the mayors of 400 European cities, for example, pledging in February 2009 to make “drastic” cuts in CO₂ emissions by 2020.³⁰

Sustainability challenges are significant and interconnected.



Source: U.S. Energy Information Administration Annual Outlook 2008; IBM Institute for Business Value estimates.

Figure 7. Global CO₂ emissions (metric tons), 1990, 2010 and 2030, urban/non-urban.

Providing secure and sustainable energy for their citizens is a key challenge for cities over the coming generation. Globally, almost one in three people lack access to electricity. And while access to energy is widespread in more developed cities, it is still not secure. In the United States, for example, blackout threats are increasing in the wake of an overall reduction of baseload energy reserves from 30 percent in the early 1990s to only 17 percent in 2007.³¹

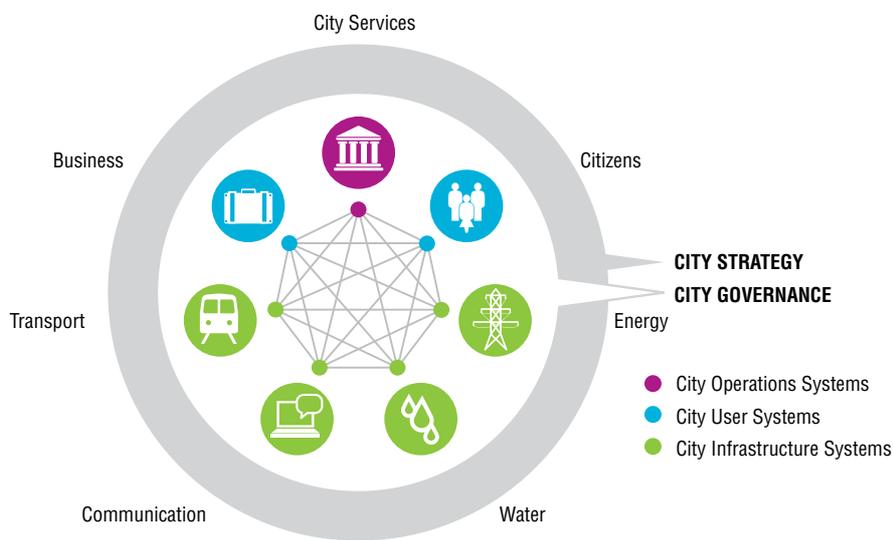
Cities face interconnected challenges

These challenges and threats to sustainability are not only significant in and of themselves, they are also interrelated (see Figure 8). For example, a city’s information and *communication* infrastructure is central to its attractiveness to business and mobile investment. The *business* networks of a city are a key factor for *transportation* usage, itself a primary consumer of energy and an emitter of greenhouse gases – buildings and transport alone account for 25 percent of all emissions.³²

Energy production currently accounts for between 30 and 40 percent of all *water* withdrawals in the OECD.³³ Assuming business as usual, energy-related *water* consumption will more than double in the next 20 years in the European Union and the United States.³⁴ Water underpins all economic activity – be it the 2,000 gallons required to make one gallon of milk or the 39,000 gallons to make a car.³⁵ Water is also one of the most important factors for a city’s *health*, with water-borne disease affecting hundreds of millions of people around the world. Some of these intricate interrelationships are outlined in Figure 8.

“Smart” cities know how to transform their systems and optimize use of largely finite resources

The scale and nature of the challenges facing cities across each of their core systems mean that business as usual is not a viable option. Despite these challenges, cities have a range of goals they want to deliver for their citizens. They strive to provide a healthy, pleasant and safe living environment for their residents. They also endeavor to attract business, help it thrive in a competitive global economy, as well as provide an effective and efficient infrastructure in a sustainable way. To deliver the goals they have established, cities must look to the systems on which they are basing their aspirations and make them more efficient and effective, i.e., *smarter*.



Source: IBM Center for Economic Development analysis.

Figure 8. Cities systems and their interrelationships within the larger framework of the city’s strategy and governance.

Smarter cities make their systems instrumented, interconnected and intelligent

Pervasive information and communication technology means that there is much greater scope for leveraging technology for the benefit of cities:

- *Instrumentation*, or digitization, of a city's system means that the workings of that system are turned into data points and the system is made measurable. By 2010, there is likely to be 1 billion transistors, the building block of the digital age, for every human being.³⁶
- *Interconnection* means that different parts of a core system can be joined and "speak" to each other, turning data into information.
- *Intelligence* refers to the ability to use the information created, model patterns of behavior or likely outcomes and translate them into real knowledge, allowing informed actions.

Smarter cities transform their systems and their "system of systems"

A smarter city is one that uses technology to transform its core systems and optimize the return from largely finite resources. By using resources in a smarter way, it will also boost innovation, a key factor underpinning competitiveness and economic growth. Investment in smarter systems is also a source of sustainable employment. It has been estimated that a US\$30 billion investment in smarter broadband communication, healthcare and energy systems grid could create almost 1 million jobs in the United States alone.³⁷ Imagine the possibilities across all the world's cities.

Each of the core systems identified can be made smarter, by taking advantage of the potential to digitize systems and, thereby, enable more informed decision making.

The city as a "system of systems"

It is critical that the interrelationship between a city's core systems is taken into account to make this "system of systems" smarter, too. No system operates in isolation; instead, a web of interconnections exists. For example, transport, business and energy systems are closely interrelated – the transport and business systems are key users of energy. Connecting these systems will deliver even greater efficiencies and address the interrelated, long-term threats to sustainability. The connection between smarter water and energy systems is another example of the linkages that exist between systems. A substantial amount of electricity generated goes toward pumping and treating water. In Malta, for example, a new smart utility system will inform citizens and business about their use of both energy and water, enabling them to make better decisions about resource consumption.

Becoming "smart" is a journey, not an overnight transformation

Cities have limited resources. To deliver on the range of ambitious goals they have, cities must take account of the interconnected challenges they face and the interrelated systems they influence. This is a journey for cities, not an overnight transformation. But the first step requires a shift in thinking and a break from the past.

To become smart, city administrators must develop an integrated city-planning framework and leverage the city's core competencies.

Today...	What if a city could...	Already, cities are...
City services <ul style="list-style-type: none"> • Service delivery in silos with one size fits all 	<ul style="list-style-type: none"> • Tailor services to the needs of individual citizens 	<ul style="list-style-type: none"> • Using technology to integrate the information systems of different service delivery agencies to enable better services for citizens
Citizens <ul style="list-style-type: none"> • Cities have difficulty using all the information at their disposal • Citizens face limited access to information about their healthcare, education and housing needs. 	<ul style="list-style-type: none"> • Reduce crime and react faster to public safety threats, by analyzing information in realtime? • Use better connections and advanced analytics to interpret vast amounts of data collected to improve health outcomes? 	<ul style="list-style-type: none"> • Putting in place a new public safety system in Chicago, allowing realtime video surveillance and faster more effective response to emergencies • Giving doctors in Copenhagen instant access to patients' health records, achieving the highest satisfaction and lowest error rates in the world.³⁸
Transport <ul style="list-style-type: none"> • Transporting people and goods is dogged by congestion, wasted hours and wasted fuel. 	<ul style="list-style-type: none"> • Eliminate congestion and generate sustainable new revenues, while integrating all transport modes with each other and the wider economy? 	<ul style="list-style-type: none"> • Bringing in a dynamically priced congestion charge for cars to enter Stockholm, reducing inner-city traffic by 25 percent and emissions by 14 percent, while boosting inner-city retail by 6 percent and generating new revenue streams.³⁹
Communication <ul style="list-style-type: none"> • Many cities have yet to provide connectivity for citizens • "Going online" typically means at slow speeds and at a fixed location. 	<ul style="list-style-type: none"> • Connect up all businesses, citizens and systems with universal affordable high-speed connectivity? 	<ul style="list-style-type: none"> • Merging medical, business, residential and government data systems into a so-called ubiquitous city in Songdo, Korea, giving citizens and business a range of new services, from automated recycling to universal smartcards for paying bills and accessing medical records.
Water <ul style="list-style-type: none"> • Half of all water generated is wasted, while water quality is uncertain. 	<ul style="list-style-type: none"> • Analyze entire water ecosystems, from rivers and reservoirs to the pumps and pipes in our homes? • Give individuals and businesses timely insight into their own water use, raising awareness, locating inefficiencies and decreasing unnecessary demand? 	<ul style="list-style-type: none"> • Monitoring, managing and forecasting water-based challenges, in Galway, Ireland, through an advanced sensor network and realtime data analysis, giving all stakeholders – from scientists to commercial fishing – up-to-date information.
Business <ul style="list-style-type: none"> • Businesses must deal with unnecessary administrative burdens in some areas, while regulation lags behind in others. 	<ul style="list-style-type: none"> • Impose the highest standards on business activities, while improving business efficiency? 	<ul style="list-style-type: none"> • Boosting public sector productivity, while simplifying processes for business in Dubai through a Single Window System that simplifies and integrates delivery and procedures across a range of almost 100 public services.⁴⁰
Energy <ul style="list-style-type: none"> • Insecure and unsustainable energy sources. 	<ul style="list-style-type: none"> • Allow consumers to send price signals – and energy – back to the market, smoothing consumption and lowering usage? 	<ul style="list-style-type: none"> • Giving households access to live energy prices and adjust their use accordingly, as in a Seattle-based trial, reducing stress on the grid by up to 15 percent and energy bills by 10 percent on average.⁴¹

Source: IBM Center for Economic Development analysis.

Figure 9. How cities can and have transformed their core systems.

This means that city administrations should develop an integrated city-planning framework, based on deciding where their internal expertise lies – in essence identifying a city’s core competencies – and bringing in outside expertise where necessary (see Figure 10). This will rarely align to a city’s current allocation of tasks, meaning cities must look at which activities to shed, which to retain and potentially reorganize, which to partner for, and which new activities to expand into. Structured modeling tools, such as component business modeling, can help city administrations map out the activities in each of their systems and identify where they should retain, expand, shed and partner.⁴²

What cities need to do to become smarter

To put in place a plan for transforming into a smarter city, a city needs to do more than just strategize:

- *Assemble the team:* No city is an island. Administrations – at city level and elsewhere – are recognizing the importance of “perpetual collaboration.” To deliver the goals a city has set, city administrations will need to work seamlessly across their own organizational boundaries and partner effectively with other levels of government, as well as with the private and non-profit sectors.⁴³ Many issues that cities face will require significant collaboration among city, state and national levels of government. In addition to formulating new policies themselves, cities must be able to articulate the challenges they face to influence policies made elsewhere.



Source: IBM Center for Economic Development analysis.

Figure 10. A framework for strategic planning.

- *Think revolution, not evolution:* Rising to the challenges and threats to sustainability requires a city to be more than just focused or efficient; it will require the next generation of city to emerge – one based on smarter systems. These systems are interconnected – people and objects can interact in entirely new ways. These systems are instrumented – the exact condition of the system's different parts can be measured. These systems are intelligent – cities can respond to changes quickly and accurately, and get better results by predicting and optimizing for future events.
- *Don't forget the big picture:* The interrelationships between the various systems mean that while cities obviously must prioritize, just "solving one" is not a viable long-term option. The challenges and threats to sustainability come from all angles and require a holistic strategy that addresses all factors and feedback mechanisms.

Conclusion

“The 19th century was a century of empires, the 20th century was a century of nation states. The 21st century will be a century of cities.”

– Wellington E. Webb, former Mayor of Denver, Colorado⁴⁴

Ultimately, a city aims to deliver sustainable prosperity for its citizens. Cities stand on the cusp of their century, with new power – and new responsibility – economically, politically and technologically. Across all systems on which cities are based, they are facing significant challenges and threats to their sustainability. Cities must use new technologies to transform their systems into *smarter* systems that optimize the use of finite resources. Many cities around the world are already starting to seize this opportunity. Is yours?

This study was written by the Center for Economic Development, in Dublin, Ireland, which is part of the IBM Institute for Business Value. To learn more about this IBM Institute for Business Value study or the Center in Dublin, please email Susanne Dirks at susanne_dirks@ie.ibm.com. You can also browse a full catalog of IBM Institute for Business Value research at:

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