

From Smart to Cognitive: A Roadmap for the Adoption of Technology in Cities

Robert Moyser and Sabina Uffer

Abstract With ever more of the world's population living in urban areas, cities face immense challenges ranging from providing basic human needs, to adapting to the impact of climate change, to improving the quality of life for its citizens. Addressing these issues, cities increasingly turn towards technology as the solution. Advancement in information communication technologies allows the collection of data from urban infrastructure systems relating to people's consumption patterns, therefore enabling resource optimization and more informed decision making. The adoption of technology however also brings many challenges. Taking leads from the academic literature on smart and—more recently—cognitive cities as well as the authors' own experience in implementing technology infrastructure, the chapter explores the role of technology in helping to create successful cities, analyses the challenges that technological solutions carry, and provides a roadmap to the adoption of technology. The chapter concludes that technology is simply one part of city systems. To create truly livable cities, city administrators need to develop a vision, engage the community and stakeholders, and undertake their due diligence in adopting technology.

Keywords Smart city · Cognitive city · Information communication technology · Smart infrastructure · Living City

1 Introduction

The future will be more urbanized than ever. Since 2010, more than half of the world's population live in urban areas. The UN estimates that by 2050, this number will jump to over 70 % [21]. As urban migration continues, cities face immense

R. Moyser (✉) · S. Uffer
BuroHappold, London, UK
e-mail: robert.moyser@burohappold.com

S. Uffer
e-mail: sabina.uffer@burohappold.com

challenges ranging from meeting basic human needs for clean water, food, and shelter to dealing with waste and pollution, to providing mobility and access to jobs and services, and meeting aspirations for a high quality of life and greater well-being. Climate change and its immediate and future impacts are aggravating these challenges. Cities account for around 70 % of global energy consumption and over 70 % of energy-related carbon emissions [7]. Similarly, waste generation is foremost an urban issue and is therefore accelerating in parallel with urbanization. According to a World Bank report, urban solid waste generation will increase 70 % in the next decade [24]. This not only affects our natural environment and is directly linked with natural resource depletion, but ultimately also impacts upon our health and well-being.

While cities and the people living in them generate these problems, they are increasingly also considered to be the solution to them (see, for example, [11, 21]). It is cheaper and more resource efficient to provide public transportation, housing, electricity, water, and sanitation on a per capita basis for a densely settled urban area than for a dispersed rural population [21]. Cities also have the economic and social capital needed for rapid and radical change.

City authorities increasingly understand that urban environments are complex, adaptive systems of systems in which economic, social, spatial, environmental, and infrastructural systems must be managed in an integrated manner. Meeting the requirement for enhanced outcomes in terms of quality of life on the one hand and greater resilience (successful adaptation to fast and slow moving shocks and stressors) on the other, necessitates ever greater sophistication of governance. To tackle these urban challenges, technological solutions are being increasingly promoted under buzzwords such as ‘smart cities’, ‘digital cities’, ‘intelligent cities’, or—the latest addition to the debate—‘cognitive cities’.

Some [1, 12] argue that the digital revolution may transform our lives in the same way the industrial revolution has over the past two centuries. Information communication technologies enable ubiquitous connectivity and super-fast access to Internet at ever lower cost. Increasingly, the technology not only allows for communication between people, but also between sensor-embedded digital devices and databases [19]. This ubiquitous use of technology is changing the way we live, work, shop, and play. The greatest change has occurred at an enterprise level. In business, information technology has overhauled how companies and entire industries operate. The fact that financial transactions can now be undertaken in a matter of milliseconds has completely transformed the banking industry. Similarly, in buildings, advances in design through intelligent systems have improved resource efficiency. On an individual level, the rise of smartphones has revolutionized how we communicate and travel. Advances in human cognition and artificial intelligence have the potential to further transform our work and lives through extending machine-to-human interactions to machine-to-machine interactions.

While the advancement in technology has been scaled up to support cities (e.g., real-time information on public transport services to sensor embedded energy grids), there is still very limited demonstration of integrated information communication systems across city departments and between stakeholders [15]. There are a

number of reasons for this and they cover political, regulatory, economic, social, and technological challenges. Cities and their departments are inherently complex systems; decisions take time, involving multiple stakeholders, and procurement processes that do not always align with the private sector and their timeframe to respond [19]. The integration of information communication technologies is thus not as simple as adopting a new vendor together with their proprietary technology. Moreover, cities will need to think beyond information communication technology to issues such as equality, sustainability, and quality of life.

Addressing the question of why cities have not fully embraced the opportunity offered by technology and what is needed to adopt technology, is the subject of this chapter. After a short introduction to the concepts of smart and cognitive cities as well as the role of information communication technology infrastructure, the chapter examines the barriers for the roll-out of technology across city systems. It then outlines the conditions required for a successful city—be it smart or cognitive. In doing so, the authors argue that, for smart or cognitive cities to be successful, technology alone is not sufficient but needs to be integrated in broader strategic planning and urban management practices. Finally, the authors propose a roadmap for the implementation of technology to achieve more livable, sustainable, and resilient urban environments.

2 From Smart to Cognitive

To understand the relatively new concept of the cognitive city, it makes most sense to start with a definition of the smart city. While there is no single accepted definition of the concept, smart cities (and their variants) can be defined as the leveraging of information communication technologies such as satellites, wired and wireless technology, sensors, and other forms of data collection devices to help citizens, businesses, and governments to make data-driven, intelligent decisions to address environmental, economic, and social issues [10], Townsend [20]. Smart city initiatives can support better public services and infrastructure, access to social and economic opportunities, personal safety and security, effective healthcare, efficient transport systems, and—maybe most importantly—foster more resource efficient behavior among citizens.

Among a small number of academics, smart city debates have been pushed further by introducing cognitive theory. Cognitive theory, in a nutshell, posits how knowledge is produced through memory creation based on experience and observation. The still limited literature relating to cognitive cities defines the concept as “an extension of smart cities using cognition theory” [9: 1] in the sense that implies the “existence of learning, memory creation and experience” embedded in a city such that technology is leveraged to continuously improve the way it works. Learning, in this case, is not only undertaken by humans alone, but by various information holders (e.g., smart phones, computer systems, infrastructure operation systems, etc.). A cognitive system is able to sense, perceive and respond to changes

in the environment and can therefore improve a system's performance by increasing its adaptive capacity [13: 4]. This means information technology as well as human cognition is used to adapt and respond to changes in the environment in order to improve urban governance.

In more concrete terms, in the smart city, individual citizens predominantly receive information on urban infrastructure such as traffic conditions or service outages; in the cognitive city, they also deliver information to others (e.g., other devices and sensors, machines, operating platforms, humans) to allow these systems to learn from and adapt their behavior [13]. This allows citizens to move towards a more efficient and sustainable use of resources and it allows service providers such as utility companies or transportation authorities to continuously adapt to provide more efficient and cost-effective services [10]. One such example, at an individual level, is the fact that our devices (i.e., our smart phones, tablets, etc.) will increasingly be able to interact with each other. If someone's device notes that the person is late for an appointment due to traffic or a previous appointment, it will automatically alert the person's next meeting's participants and recalibrate time and location for the meeting [8].

The technological possibilities to enhance our lives are exciting and advances in technologies represent an obvious area to explore, embrace, and adopt. The growth in access to data and improved communications, for instance, can provide the opportunity for citizens to interact with each other more efficiently and to establish greater engagement and transparency between themselves as well as those that manage communities, towns, or cities on their behalf. Technology has the potential to make urban dwellers' lives easier, more convenient, and less wasteful. It allows city governments to make more informed choices based on real-time data gathered. It enables more efficient service provision through better demand and supply management of key resources such as energy and water. It can make provision of utilities more resilient with less disruption of services. In addition, beyond the planning and automation of infrastructure, digital technology has the enormous economic potential of allowing the creation of new industries centered on citizen centric services, providing critical communication vehicles for citizens and communities to support their daily lives. It can help bring communities together and support them both in their daily routines as well as in extreme situations such as disaster.

Leveraging technology however also carries with it risks and the potential of unintended consequences. The creation of successful cities—cognitive or not—thus requires more than just technology. It requires the careful interaction of human and artificial intelligence across different urban systems. This includes exercising caution over how and by whom technology is leveraged. Authors such as Townsend [20] or Greenfield [5] argue for more 'grassroots' approaches to the cognitive city where citizens are empowered to use technology to improve their quality of life. It should be remembered that, first and foremost, cities are places for people—and one can take from this the fundamental principle that everyone within a city should be able to take benefit from the adoption of technology.

2.1 Role of Information Communication Technology (ICT)

The advances made in the field of Information Communication Technology (ICT) are enabling the development of cognitive cities. ICT has become the fourth utility sitting alongside the other three utility infrastructures (electricity, gas, and water) which are crucial to the delivery of successful developments in existing and new cities. ICT provides the infrastructure that enables communication through national and international voice, video, and data interconnectivity. Below and above ground infrastructure communication technologies provide an urban ‘nervous system’ and an interface between the city’s primary assets and its end users. This nervous system then acts as an integrator for other city infrastructure layers.

Typically, implementation of ICT systems is categorized according to the seven layers of the Open Systems Interconnection (OSI) model developed by the International Organization for Standardization (ISO). In short, there is a physical layer that refers to the deployment of fixed (e.g., fiber, ADSL) and wireless (e.g., WLAN) data communications and telecommunication outside plants (OSP). It incorporates the physical space allocated to cable routes, underground civil infrastructure, street furniture, cellular and wireless antennae and access points (AP’s), central plant and equipment rooms. On top of this ‘hardware’ is a range of ‘soft’ layers such as network operating systems, data-conversion utilities, and applications that enable the successful exchange of data from infrastructure to end user. Whilst the hard and soft layers of ICT provide the infrastructure, other considerations such as governance, procurement, asset lifecycle planning, and the business case are equally important to deliver an appropriate ICT architecture for any adopting city. The design of efficient and resilient ICT systems is key for the success of cognitive cities.

2.2 Application of ICT Infrastructure

A well planned and future-ready physical ICT infrastructure system forms the backbone that allows for sensor installations, integration of applications, and ubiquitous data collection. This, in turn, permits the development of a wide range of city improvement initiatives. These can generally be distinguished as top-down or bottom-up initiatives. Top-down initiatives focus on the wide use of information communication technology integrated with city systems “that enable central planning and an integrated view of the processes that characterize urban operations” [16: 7]. Traditionally, these initiatives are implemented by partnerships between city government and technology companies. The focus lies on smart city initiatives that improve the efficiency of infrastructure systems and services such as energy, waste, water, environment, and transportation. IBM and the City of Portland, USA, for example, collaborated to develop a computer simulation to understand how the city’s core systems work together and, in turn, identify smart city opportunities [6].

The top-down approaches of corporations has however led to a wide distrust by cities and citizens who have become increasingly skeptical of the broader opportunity, due to the often high cost, lack of transparency, appearance of closed market place, and little discernable benefit for citizens.

Bottom-up initiatives, in contrast, are decentralized by definition. Whilst still relying on ICT, they emphasize the ways in which citizens generate, collect, and make use of the data. Initiatives focus on the improvement of the user experience and the enhancement of quality of life. They are typically developed by service providers, often software companies and start-ups, which are targeting consumers or end users Townsend [20]. Examples include applications that provide citizens real-time information to indicate the fastest (and cheapest) route to travel at any given time or on-demand and instant services such as one-click food orders, car-, or laundry-services. Problems associated with bottom-up approaches are the lack of joined-up systems, the time it takes to make a broad and meaningful contribution to city life, and the rate of failure of such initiatives Townsend [20]. In both cases, the top-down and bottom up approaches, the hard and soft infrastructure of information communication technology plays a key role.

These initiatives—both bottom up and top down—have tended to remain singular, localized interventions in urban governance and development. Moreover, these initiatives do not necessarily go beyond the ‘smart city’ approach defined above. Cognitive city approaches and initiatives where the capacity of learning and experience is integrated into the software, application, or ‘machine’ is harder to come by and is only in its very early stages with applications such as Waze or Snips¹ [8]. The following section explores why neither smart city nor cognitive city initiatives have yet managed to take a greater role in urban development and governance. This is analyzed through the lenses of political, regulatory, economic, and social challenges.

3 Challenges to Adopting Infrastructure Technology for Smart or Cognitive Cities

Compared to buildings, businesses, or even entire industries, cities are far more complex with a wide range of social, economic, and environmental networks and systems interacting with each other on a daily basis. They therefore present a multitude of challenges to the implementation of city-wide technology infrastructure, be it for smart or cognitive systems. These challenges can be categorized as political, regulatory, economic, social, and technological.

¹<https://www.waze.com/>; <http://snips.net/> [accessed 02.10.15].

3.1 Political Challenges

City administrations face enormous pressure from citizens and businesses to deliver a higher quality of life and an enhanced business environment and to do so equitably, responsively, and transparently. At the same time, limited resources, both environmental and financial, constrain their options, demanding a high degree of effective governance capable of prioritizing and implementing technology infrastructure rapidly.

In meeting this need, cities face three key issues. First, urban sprawl in the twentieth century was not always accompanied by a comparable extension of the administrative boundaries of city governments. While citizens cross these administrative boundaries on a daily basis through commuting to work, attending cultural events, or through their social ties, city administrations do not often have the necessary authority to govern or implement projects beyond their own boundaries. For example, there may be individual public authorities, such as the Port Authority of New York and New Jersey, which coordinate the air and water transportation in the metropolitan region, but there is no overarching authority for governing the metropolitan area of New York [14]. The mismatch between the urbanized areas and jurisdictional boundaries often hinders procurement and implementation of new or upgrading of existing infrastructure to smarter or more cognitive systems.

The second political challenge cities face is that, over the last century, they have become increasingly organized along functional structures with sector-specific agencies and city departments providing individual public services. The water provider(s), the transportation agency(ies), the energy provider(s), or the housing department operate each within their own organizational siloes and with their own departmental management structure and budgets. This creates an isolated and highly channeled approach to service provision and complicates the introduction of new technology where high set-up costs may be involved. Pressures to reduce the size of governments with the consequence of municipal services increasingly being contracted out to the private sector and third-party organizations aggravate the issues, mainly because of a lack of mechanisms for the transfer of information [14]. An often cited example is that when streets get opened-up several times a year to provide access for the different utility providers, other relevant city departments do not coordinate their maintenance efforts. Even when advanced information communication technologies have been adopted, the embedded organizational structure often hinders learning and memory creation across sectors.

Another political challenge is the alignment of timescales and the actual time horizons for transformation. City leadership and planning processes have often a lifecycle of four to five years which restricts their ability to act at the speed of technological transformation which may be as short as a few months or one to two years. At the same time, city leaders are rarely thinking beyond the election cycles, which goes against the needs of long-term coordinated land use and infrastructure planning, which require a twenty year or even longer perspective. Processes of planning, delivery, and experiential learning are thus interrupted by political timelines.

3.2 *Regulatory Challenges*

The use of technology will not only increase the volume of data collected, but also the complexity of how systems interoperate with each other (e.g., traffic control system with energy control system—therefore creating a ‘system of systems’) [2]. This poses a range of regulatory challenges, predominantly in the domain of data privacy, data security, and commercial liability when things go wrong. Current regulatory frameworks and legal policies are often not sufficient enough to deal with ownership of data, privacy protection, and security breaches. This can impact the acceptance of technology by end-consumers, especially when the media reports high profile stories of security services collecting personal information without people’s knowledge.

Sharing data, be it through one’s personal or home devices or in a public space, is becoming ubiquitous. Technology enables us as individuals and companies through data harvesting to increasingly collect a wide range of personal data. For example, detailed information might be gathered on when residents are at home, whether they are watching TV, or cooking dinner. It is however unclear how privacy is or should be protected when data is transferred across multiple systems and technology owners. This includes the protection of personal information (e.g., social identity, health information, etc.), personal communication (e.g., emails, text messages), and personal behavior (e.g., information on daily routines) [2]. These issues become even more pronounced when information is exchanged not just between an end-user and the government or a private company, but between multiple users in real time and for commercial gain.

Another area of regulation that is becoming more complex is the issue of security and liability. Questions around who is responsible for security breaches or other accidents when machine to machine communication fails need to be resolved. An example of where this will become increasingly crucial is the deployment of automated vehicles on city streets. If an automated vehicle drives into a parking lot based on geospatial data, but crashes into another car, responsibility could be with the manufacturer of the automated vehicle, the software producer, or the data provider.

3.3 *Economic Challenges*

A city-wide ICT infrastructure and the overarching software to achieve it, whilst requiring significant investment, are nonetheless often an order of magnitude smaller in cost terms than the main city infrastructures such as highways, transport systems and fixed utility systems. However, these systems have struggled to attract funding. At its core, the value proposition for smart and cognitive cities has still not been made effectively and investments have not been packaged into manageable chunks with clear outcomes related to key business cases. In part, this stems from the fact that with few examples of city-wide and sector-integrated roll-out of

technology infrastructure, it is still difficult to justify investment following a traditional methodology.

Technology companies looking for new market opportunities have contributed to this challenge without offering any suitable alternatives [5, 18]. IBM, Siemens, HP, Cisco, Toshiba, Hitachi, and others have smart city research and product development divisions that target cities with the opportunity for direct investment in their product lines. This model has not demonstrated clear social or financial value to the cities and has not worked as city administrators do not have the capital required or the desire to lock themselves into costly service contracts over a long timeframe.

It is noted that there are a few initiatives that are invested in by the cities' own operational budgets [generally via a Public Private Partnership model (PPP)] if a sufficient return on investment is demonstrated. An example is PARK Smart in New York City,² which combines real-time parking information via web and smartphone with progressive meter rates. Occasionally, such smart systems can be incorporated as part of major upgrades of utilities. In the wake of Hurricane Sandy, local utility companies received permission to undertake large-scale strengthening of their networks and were allowed to set aside 10 % of the funding to create much smarter networks [22].

Most smart city initiatives in Europe and North America are however financed by small scale research funding and pro bono investment on small pilots by technology companies hoping to demonstrate proof of concept and thus to progress to larger and better paid contracts. Research bodies such as the EU Horizon 2020 program or the UK's Technology Strategy Board will continue to invest in the next round of smart (or eventually cognitive) city ideas as it supports the broader macro-economic opportunity by fostering the next generation of creative and digital companies.

However, for larger-scale implementation of smart and cognitive systems, the cities still face major challenges: City administrations do not always understand the potential value of the digital opportunity and face therefore difficulties in assessing or justifying the up-front and on-going operational costs needed for the investment. At the same time, utility companies do not always want to invest in smart infrastructure because, while it could save consumers money, they perceive a reduced level of return on the investment in assets already installed and operational, and returning a good level of profitability.

3.4 Social Challenges

There are several social issues that cities face when dealing with new technologies. For instance, shared economy applications such as the car service Uber or the

²PARK Smart NYC: <http://www.nyc.gov/html/dot/html/motorist/parksmart.shtml> [accessed 02.10.15].

short-term rental application Airbnb are beginning to restructure and challenge the way we traditional move and inhabit our cities.

Citizens are the ultimate stakeholders in the city and questions such as who owns personal information and what can be done with it become crucial to address. If, in a cognitive city, citizens are persuaded (either consciously or unconsciously) to provide information about the way they behave in the urban environment, there will be a need for clear and transparent regulations around (data) privacy and security [13]. This is especially important as citizens often do not have the knowledge and understanding of how they are interacting with technology and what the benefits and drawbacks might be. The success and optimization of any technology systems will rely on the ultimate user actually using it in the way it was intended. Initiatives that are solely technology-oriented and do not consider the needs of end-users will more than likely fail.

In addition, questions of inequality and segregation are rarely addressed in technology debates. When technology is becoming ubiquitous, there is a danger that those without the educational, financial, or technological capital to participate in the transformation are left behind. Often these are the most vulnerable segments of the population such as the elderly or low-income communities. This is illustrated by two examples. Crowdsourcing applications such as SeeClickFix³ let citizens report problems through their smartphones or online; governments can then use this information to address the problems. If city governments start only to address (or prioritize) those problems reported through the app, those neighborhoods that do not have an active ‘online’ population will be left out Townsend [20]. Similarly, those businesses that do not have an online presence are in danger of becoming obsolete in a world where decisions on choice of business are based on search ratings. There is thus a real danger that technology reinforces existing social inequalities and spatial segregation—unless these issues are specifically addressed.

3.5 *Technological Challenges*

Traditional infrastructure such as electricity grids or transport systems tends to have a long lifecycle in comparison to the short lifecycles of ICT systems and even shorter lifecycles of software applications. Infrastructure networks need to be adaptable to support changes both in peak demand and in the implementation of new systems over time that might be faster and more efficient than legacy systems. Ideally, infrastructure networks should have the ability to ‘plug and play’ new technologies as they become available. It is however not just the engineering robustness and flexibility that has to be considered. Cities are often locked into these legacy systems with well-established contractual, commercial, and legal structures that deter innovation and adoption of new technologies.

³See ClickFix: <http://en.seeclickfix.com/> [accessed 02.10.15].

At the same time, technology systems have traditionally been developed to be deployed in functional silos, with proprietary hardware and protocols that do not allow ease of integration with other systems. In a similar vein to the issues with legacy infrastructure, the well-established commercial, contractual, and legal structures also hinder the adoption of new technology systems. At the rate that technology is currently changing, this has (or will have) a major implication in relation to the commissioning and adoption of new systems.

There are thus a number of challenges to deliver a cognitive city in a physical context, in addition to the lack of common interfaces and operating systems, there is the problem of the capacity and capability to collect, store, and analyze the vast amount of data that is transferred every second. Currently, standards for interoperability for smart or cognitive city systems are still in the early phases and even the way data is collected, stored and presented may vary between different departments within a city. If a simple step such as a comprehensive data management framework can be implemented, monitored, and governed by an appropriate body within the city's municipal organization, cost savings in processing, storage and database management can be achieved. Additionally, improved access to data collated from multiple sources can provide a far richer picture of what is happening at a system and citizen level, enabling more informed decision making through real-time learning and adaption.

Finally, cities not only need to adopt new technologies that help them collect data, they also need to be able to easily access and analyze the data in real time to enhance the learning and memory creation through which improved systems responses emerge. This requires a certain degree of standardization of data collection, storage, display, and reporting across city systems—and preferably within a common and aligned time-frame. Operating systems that formalize standard schemas and adhere to an open and transparent data management policy can help the city with such standardization. There are a small number of operating systems that have been successfully developed as pilot schemes; Living PlanIT's Urban Operating System (UOS)⁴ and IBM's Intelligent Operations Center⁵ are two examples. Neither, however, has been deployed at city scale covering the full range of city departments and city systems.

Having explored the political, regulatory, economic, social, and technological challenges, perhaps the most important challenge of all is the need to understand the city as a complex, adaptive system. Too often technologies are deployed in an un-coordinated way, trying to solve one problem but ignoring many other inter-related issues. Or they tend to solely focus on the advancement of technology and the system efficiency that they bring. Or they focus on the possibility of collecting data without being able to effectively process and use it. One way or another there is the danger of ambivalence and 'death by data'.

⁴Planit UOS: <http://www.living-planit.com/> [accessed 02.10.15].

⁵IBM Intelligent Operations Center: <http://www-03.ibm.com/software/products/en/intelligent-operations-center> [accessed 02.10.15].

4 Successful Cities—Technology Is Only One Component

The success of cities is context- and path-dependent. While there have been attempts to build ‘smart’ cities from scratch, like Masdar City in the United Arab Emirates or PlanIT Valley in Portugal, most people will not live in these newly built cities, but continue to live in already established cities. Successful smart or cognitive cities are thus cities that can leverage technology to enhance the living standards of their incumbent and future populations and the performance of their existing economies. Cities are foremost places for human interaction: to do business, to live, and to enjoy the economic, social, and cultural benefits that dense human settlements provide. Technology is thus not the end goal, but a mean to address the various challenges outlined previously.

4.1 *Livable Cities*

Successful cities enhance the quality of urban living by providing education, job, and business opportunities, support social well-being through its built environment and services, and minimize the environmental impact. They also provide open and transparent government and public service and infrastructure systems that are affordable and reliable. In short, they are livable cities (see Fig. 1).

Technology can enhance these aspects of the city, but in order to harness the full benefits of technology, cities and their governments need to understand the opportunities and risks. And they need to evaluate their use of technology on the basis of how it creates added value through memory creation and learning to improve the environmental, social, and economic aspects of a city. This requires integrated thinking that connects the various physical and social infrastructure systems of the city to deliver better services with more value for citizens.

Cities such as Amsterdam and Copenhagen have developed strategies that broadly demonstrate how smart cities *could* evolve. The same cannot be said for cognitive cities. Copenhagen however, aims to be the first carbon neutral capital by 2025 (stateofgreen.com) and has recently announced its partnership with Hitachi Consulting to develop a citywide urban operating system. This will allow the city to improve its systems through feedback loops that measure changes in the system in real-time, therefore enhancing the machine-to-human and machine-to-machine learning. The city will use technology and innovation not just to advance its technology sector, but to apply a system-wide thinking that benefits its citizens and the city’s livability. The city has made great advancement in waste reduction through educational outreach, new composting and recycling schemes, and an upgrading of its waste-to-energy plants. With landfill from waste reduced to 1.8 and 98 % coverage by district heating, its results are impressive compared to most other cities.



Fig. 1 The Living City. (©BuroHappold)

Similarly, Amsterdam Smart City (amsterdamsmartcity.com) has an ambitious agenda of thinking across sectors. A pilot project called Vehicle2Grid,⁶ currently underway, allows residents to control their own energy supply. An open data platform connects households with car batteries or electric charging stations and a smart grid. A smart phone app then allows residents to decide how they want to use the locally produced energy from solar panels or wind farms. The energy can be fed into the smart grid, used immediately to drive a car or run household appliances, or stored in the battery of an electric car. This strategy demonstrates the benefits in terms of greater control and choice for consumers over their energy consumption and provides resilience in energy supply.

⁶Vehicle2Grid: <http://www.amsterdamvehicle2grid.nl/> [accessed 02.10.15].

Both examples mentioned here demonstrate how technology is just one component of many (e.g., regulatory, educational, social etc.) that create a successful urban environment.

4.2 Engaged Communities

A successful city is a city that encourages its residents to engage. This does not mean that everyone needs to be involved at every level of decision making or activity. Instead, it means that city governments work to get the buy-in for new initiatives from stakeholders and allows them to contribute to the development of technology strategies.

Engaging with residents and communities through communicating the benefits to them is crucial for the deployment of technology strategies; even more so if individuals can be encouraged to provide data for the improvement of urban systems. In the US, for example, the introduction of smart meters has been highly controversial with users raising concerns over cost, privacy, and health. An early pilot scheme in Boulder, Colorado failed to inform its customers of the benefits to be derived from the newly installed smart meters and the opportunity to check one's energy use online. Public engagement and education campaigns are therefore crucial in order to successfully leverage the benefits of technology improvements.

Allowing individuals and communities to contribute to the implementation of technology may mean encouraging citizens to use the opportunity by creating open data policies and offering educational programs. This enables individuals and communities to create new ways to experience and improve cities, services, and information. It also creates a vibrant community of creative thinkers and entrepreneurs. An interesting example of achieving this can be found in Chicago. The City of Chicago, together with its partners MacArthur Foundation and the Chicago Community Trust, has funded Smart Chicago, a civic organization that is devoted to increasing access to the Internet amongst Chicagoans, improving skills required to use the Internet, and developing products from data to enhance the quality of life in the city (smartchicagocollaborative.org). It is through these early adoptions of technology that cognitive cities can emerge where technology is used to learn, create, and adapt.

4.3 High Capacity, Integrated, and Resilient ICT Infrastructure

Without a high capacity and resilient ICT infrastructure, cities will not be able to fully harness the benefits of technology. It also needs to be coordinated with and integrated into other infrastructure systems and networks across the city both physically and virtually. As Moss-Kanter and Litow [14: 2] put it: "Infusing

intelligence into each sub system of a city, one by one—transport, energy, education, health care, building, physical infrastructure, food, water, public safety, et cetera, is not enough to become a smarter city. A smarter city should be viewed as an organic whole—as a network, a linked system.” With regards to ICT infrastructure, this means a network of sub systems, interconnected and integrated through open standards, shared infrastructure and common protocols.

South Korea is probably most advanced in this regards. It has invested enormous public funds into ICT infrastructure and relaxed regulations to provide a competitive platform for telecommunication service providers. Today, Seoul has a free public Wi-Fi that offers the world’s fastest Internet speeds. South Korea however has not stopped there and has just announced the upgrade of its mobile infrastructure with the aim to increase its Internet speed by 1000 times. As a consequence, South Korea increasingly competes with Silicon Valley for investment into the information technology industry [25].

Cities are complex systems of systems that are the outcomes of various social, economic, and institutional relationships. Technology can play a significant role in improving the efficiency of these relationships, therefore contributing to resource maximization and waste minimization. Successful cities require more than simply the adoption of smart and cognitive devices and systems. This also needs to be considered when implementing a roadmap for adopting technology.

5 Roadmap to Adopting Technology

While there are no ‘one-size-fits-all’ solutions to adopting technology, there are a number of key ingredients which will facilitate the creation of smart and cognitive cities. These can be broadly divided into five categories: vision, leadership and organization, citizen engagement, financing, and technology (see Fig. 2).

5.1 *Create a Shared Vision*

The first step in adopting technology and building cognitive cities is the creation of a shared vision. Questions such as what, why, and how need to be answered. The process of developing a vision includes the evaluation of existing conditions, the assessment of future opportunities, and finally the development of a framework or plan that establishes the vision, goals, strategies, targets, and key performance indicators. In developing this plan, those responsible for governing cities need to understand what they want to achieve and what the required return on their investment is. Plans should not be considered as set in stone and need to be flexible and adaptable to new circumstances and innovations. It is thus essential that these plans are reviewed and, where necessary, updated on a regular basis. In summary, plans should be ambitious, achievable, accessible, accountable, and adaptable.

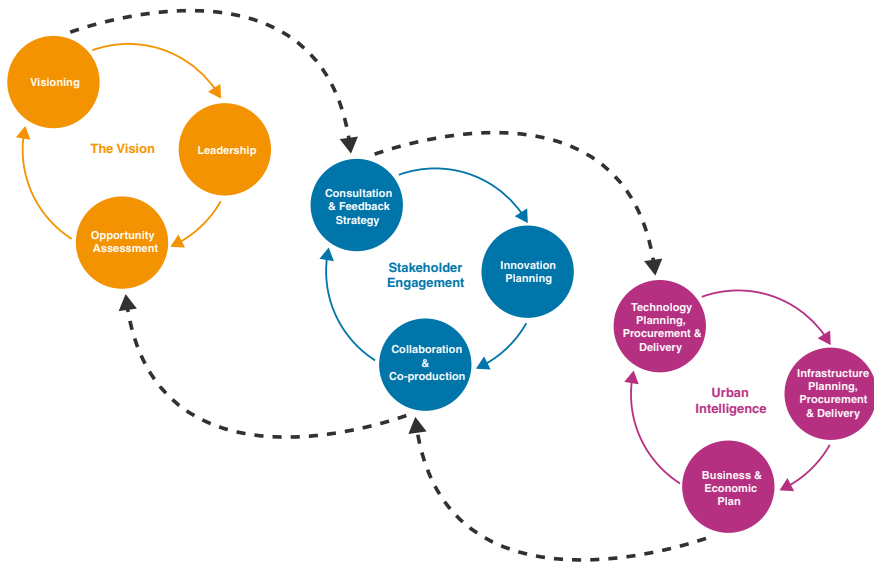


Fig. 2 Roadmap—vision, engagement, intelligence. (©BuroHappold)

Cities with strong smart city aspirations (no city has officially declared any cognitive city aspirations yet) have developed policy frameworks setting out their vision, key performance indicators, and strategies for delivery. New York was one of the earliest proponents of promoting technology to improve the city. In its 2011 “Roadmap for the Digital City”, it outlined four goals, namely: to ensure that all New Yorkers can access the Internet, to support open government policies to unlock public information and increase transparency, to enable citizen-centric and collaborative governance through digital tools including social media engagement and, finally, to support a digital media sector [3].

More recently developed, the Smart London Plan considers the role of digital technology in planning for London’s future population growth challenges. It has a clear vision statement aiming to “use the creative power of new technologies to serve London and improve Londoners’ lives” and is set within an overarching framework of the Mayor’s 2020 vision. It outlines a set of high-level goals from placing “Londoners at the core” to “enable London to adapt and grow”. Each of the goals has a number of strategies and measures of success. Taking the goal of enabling London to adapt and grow, the plan outlines six strategies, including the “promotion of smart grid technologies” to help meet the increased demand for electricity and “experiment with new ways of reducing light freight” to tackle the rise in congestion and pollution caused by increased e-commerce. Indicators to measure progress include “work towards a reduction of greenhouse gas emissions to reach 40 % below 1990s levels by 2020” [4]. Whilst both examples demonstrate forward thinking, they could go still further by placing greater emphasis on the

benefit of integrating data across systems and creating targets and metrics that support this.

Fundamentally, any vision should include input from stakeholders, and ensure it is transparent, accountable, and accessible. As highlighted earlier, citizens are key to the success of any cognitive city initiative and, if they are not engaged, the benefits of introducing technology will not be realized in full.

5.2 Establish Strong Leadership, Organizational Structure, and Regulatory Framework

The adoption of technology will need more than a vision and a plan. Implementation requires a strong leadership that is committed to the long term development of the city and the wellbeing of its citizens. Structures of city administrations vary; in some cities strong mayors will lead progress towards technology solutions, in others a chief technology officer will be responsible. In addition, the role of city departments and their capacity and capability to deliver, operate, and maintain technology solutions will also be key. This is often a challenge for local authorities as they have to compete with the private sector for the best employees. It should be recognized that leaders and staff often change and there is always the risk that last year's priorities and efforts become this year's abandoned follies. This needs to be considered and measures put in place to ensure that long term strategies and targets have broad support and are deliverable. Creating a culture to think long term will also set the attitude regarding appropriate timetables for delivery, return on investment, and the sustainability agenda. Finally, the city needs to develop a regulatory and legal framework around data privacy, data security, and liability.

New York demonstrated strong leadership in developing the digital roadmap, with Mayor Bloomberg spearheading the early adoption of open data and online governance services. Mayor Bloomberg also managed to establish an organization that carries forward the legacy. New York City's Department of Information Technology and Telecommunications is charged with the modernization of IT infrastructure, the transparency of city government through its open data portal, and the development of innovative solution to improve the delivery of city services. It is one of the largest cross-sector technology city departments with approximately 1200 employees, an operating budget of \$375 million, and a capital budget of \$1 billion over four years [17].

Smaller cities will not have the resources to establish such departments. However, they may still be able to develop a policy framework and hire a chief digital officer to operate across departments to coordinate and integrate otherwise channeled efforts. Townsend [20] goes further in recommending that cities without the capacity to build their own software applications should use the many bottom-up initiatives developed by start-ups across the world. They can work with

third-party partners such as academic institutions and private companies to integrate some of the innovative solutions.

5.3 Engage Stakeholders Through the Process

The key aim of the cognitive city has to be to create benefits for citizens and to improve their quality of life through use of technology. For any city administration this takes on a number of aspects: engaging residents in the process of helping to develop strategies, creating physical and virtual space to provide input and feedback to planning proposals, supporting open data, encouraging entrepreneurship via incubators and shared working spaces, and ensuring buy-in through public outreach.

Singapore has developed one of the most advanced water treatment systems to recycle sewage water and purify it into ultra clean drinking water. Without gaining the buy-in of Singaporeans to drink this water, the initiative could have been a complete failure. Singapore's national water agency staged a large-scale public education and awareness campaign to create acceptance and demand for the treated water and has thereby established a successful outcome.

Gamification is one area that cities are now exploring to enhance citizen engagement. Governments apply the principles of computer gaming to encourage people to learn online, encourage participation in planning discussions (for example about planned bus routes), and volunteer their time. In Stockholm, for example, the city administration used gamification to encourage safer driving. A speed camera entered the details of those who obey to speed limit into a lottery funded by those who are fined for traffic violations. The impact was that traffic speed decreased by 22 % [23]. Software companies like MetroQuest are increasingly being employed by cities to help create portals that allow the public to interact and take part in making decisions on projects that have a citizen focus.

5.4 Develop Business Case, Financing Mechanisms, and Procurement Models

Smart and cognitive systems require a large number of technology-based infrastructure interventions to be deployed. The integration of these has been difficult to realize at a large scale, primarily due to poor business case planning and market engagement but also due to the immaturity of integrated solutions. Too often, cities have passively waited for other actors to formulate propositions, most of which have been rejected as inappropriate to city needs. In the future, the city will need to play a more active role in developing propositions—even where the investment participation of other stakeholders will be required.

Investment in upgrading infrastructure to become smart or cognitive usually requires high upfront costs with long-term and potentially volatile returns that may or may not appeal to private investors and some of which may not be of a financial nature. To resolve this, it will most likely require a combination of public and private sector funding. It also suggests that a realistic articulation of private sector benefits (internal rate of return) and public sector benefits (socio-economic return) will need to be at the center of decision-making.

The need for a clearer understanding of long-term benefits will require cities and investors in cities to model scenarios before making any decision on large-scale investments. This will help with the engagement of the private sector by demonstrating the commercial and financial viability (or not, as the case may be). Any financial model should identify market potential. Typical components of one will include:

- *Required rate of return*: Return that is at least as good (and ideally higher) as an investment in the financial market with similar risks.
- *Debt and equity ratio*: Lower debt ratio normally indicates a less risky investment due to the volatility of interest rates; it will however depend on the type of solution proposed and its market drivers.
- *Costs*: Operational (OPEX) (the ongoing cost for running a system such as an electric grid with sensors and meters) and capital (CAPEX) (the capital upfront investment for the installation and adoption of a system) expenditures as well as additional charges (e.g., licenses, management charges, operating costs).
- *Revenues*: Income from user fees and sales or rental of infrastructure and equipment. This is typically linked to an appropriate length of contract.
- *Discount rate*: Rate required to calculate the present value of future cash flow. Higher discount rates should be used to adjust for risk and opportunity cost associated with specific forms of digital solution, particularly those that are relatively untested in the market.

It is important to note that technologies can have a positive (or negative) impact beyond the narrowly defined return on investment. In some cases, the return on investment might be marginal or neutral at best, but its wider economic impact (e.g., employment creation, health benefit etc.) may be substantial. Parties to such a potential investment therefore need to undertake robust socio-economic impact assessments in order to understand the wider benefits that may accrue from technology solutions. Typical components of a socio-economic impact assessment include:

- *Direct impacts*: Growth/decline related to project activity and/or construction phase.
- *Indirect impacts*: Growth/decline related to supply and wider value chains.
- *Induced impacts*: Shifts in income emanating from direct and indirect impacts.

- *Multipliers*: Overall growth based on indirect and induced impacts.
- *Socio-economic impacts*: Economic competitiveness, health and well-being, marketability, environmental impact, etc.

Financial models and socio-economic impact assessments will help identify appropriate procurement models to engage the market. Different types of investors will have different risk and return strategies and will want to buy in (or sell out) at different points in the development process. City administrators therefore need to create and manage procurement models that provide a ‘win-win’ for the city, consumer, and provider over appropriate time periods.

5.5 *Technology Identification and Selection*

In a fast changing sector such as technology, it is key to identify and select the appropriate technology systems to ensure that the vision and goals are met within an acceptable budget. Following on from the procurement strategy, it is important that early engagement of the broader technology market takes place in order to identify and assess the alternative solutions that can be delivered to meet outcomes specified by those promoting the infrastructure and support structure. This is summarized through the following broad steps.

There needs to be a consistent market scanning and knowledge sharing across cities. The current technology market is vast and trying to undertake a comprehensive procurement exercise without the benefit of a thorough understanding of the market offer and its performance increases the risk of selecting an inappropriate technology solution or missing a cost-effective response. Cities should consider sharing their experience and knowledge on a continuing basis to ensure that best practice and knowledge is propagated.

Evaluation criteria need to be developed to support the procurement process for technology selection. These could include technological feasibility, regulatory feasibility, fit with context, interoperability, business case, and support of quality of life conditions.

Once the broad business and system requirements of the technology solution are understood, an expression of interest (EOI) to vet the market’s appetite should be issued to the market. This allows those responsible for procurement to not only broadly understand what the market can offer, but it also provides information on the maturity of the solutions, the economic and financial standing of the market to deliver the solutions, and the appetite of the market to engage with different procurement models.

In parallel to gathering early expression of interest proposals from potential developers, there should be consideration of the impact of any proposed technology on the infrastructure networks (existing and proposed) required to support it. This review should cover not only the spatial impact but also the impact that shared data may have on organizational and commercial structures.

Proposals should be shortlisted based upon the evaluation criteria before advancing to the next stage. The next stage should request more detailed proposals (technology and commercial) of the solution and have greater definition of the required specification and the business, system and data requirements so as to help ensure that the technology fulfils expectations. This stage is commonly referred to as the RFP (Request for Proposals). It will lead to a final recommendation, contractual and commercial negotiations, and contract signing (with an optional back-up proposal in case the preferred commercial deal falls through).

6 Conclusion

In the twentieth century, many cities were re-designed to accommodate car travel, resulting in a long-term legacy that has negatively impacted the environment and health and well-being of citizens. Whilst smart and cognitive city technologies may seem less obtrusive than highways, their legacy will similarly impact our cities and citizens for decades to come. Having outlined the key steps to overcome the current challenges to the adoption of technology, we ultimately argue for careful consideration of how we harness technology to fully realize the opportunities of it.

Technology has enormous potential to help tackle the challenges of our rapidly growing cities. It can improve decision making based on real-time data, memory creation, and learning, enabling cities to provide better services to increase quality of life, and to do so in a more financial and natural resource efficient way. There is however a real risk that technology could do more harm than good. Technology can easily become an excuse to continue our resource-intensive consumer behavior with the argument that technology will, eventually, solve all problems. The enthusiasm around self-driving cars is a case in point. It is argued that self-driving cars will eliminate any traffic accidents and improve efficiency. However it will not necessarily solve the problem of congestion of our car-oriented, unhealthy lifestyles.

To make the most of technological advancement, cities and their administrators need to focus on the end user needs and on long-term outcomes. A successful city actively enhances the quality of life for its citizens using technology as an enabler. There is thus an urgent need to understand the impact of technology. Whilst there is an abundance of literature on smart city initiatives, there is little research being undertaken on the impacts of these initiatives on individuals, neighborhoods, and broader city communities. Academia could play a critical role in bringing insight into the consequences of smart and cognitive cities. Ultimately, better analysis and better delivery models are required to be developed for technology solutions.

Successful cities are places where people want to live, work, and play. Being conscious of this, city administrators should develop a roadmap that makes their priorities clear. And whilst technology should be afforded an important place in their considerations, it is just one infrastructure layer among many other interrelated components, both physical and social that makes our cities successful.

Acknowledgments The authors would like to thank their colleagues at BuroHappold Andrew Comer, Paul Goff, and Lawrie Robertson for their contributions and comments.

References

1. Avent, R.: The third great wave. *The Economist*, Oct. 4th (2014)
2. Bartoli, A., et al.: On the ineffectiveness of today's privacy regulations for secure smart city networks. In: *Proceedings of third IEEE International Conference on Smart Grid Communications*, Tainan City Taiwan, 5–8 Nov 2012
3. City of New York: Road Map for the Digital City. Achieving New York City's Digital Future (2011)
4. Greater London Authority: Smart London Plan (n.d.)
5. Greenfield, A.: Against the smart city. Do projects, New York City (2013)
6. IBM: IBM and City of Portland Collaborate to Build a Smarter City. New release, 09 Aug 2011, Portland, Oregon. <http://www-03.ibm.com/press/us/en/pressrelease/35206.wss> (2011). Accessed 24 Jun 2015
7. IPCC: Climate Change 2014: Mitigation of Climate Change—Chapter 12 Human Settlements, Infrastructure and Spatial Planning. Potsdam, IPCC—Working Group III (2014)
8. Kaltenrieder, P., et al.: Enhancing multidirectional communication for cognitive cities. In: *eDemocracy & eGovernment (ICEDEG)*, 2015 Second International Conference, Quito, 8–10 Apr 2015 (2015)
9. Kaltenrieder, P., et al.: Applying the fuzzy analytical hierarchy process in cognitive cities. In: *Conference Proceedings of the International Conference on Theory and Practice of Electronic Governance*, pp. 259–262 (2014)
10. Khansari, N., Mostasharti, A., Mansouri, M.: Impacting sustainable behaviour and planning in smart city. *Int. J. Sustain. Land Use Urban Planning* **1**(2), 46–61 (2013)
11. LSE Cities: Cities and the New Climate Economy: the transformative role of global urban growth. In: *NCE Cities—Paper 01. The Global Commission on the Economy and Climate*, Nov 2014
12. Mayer-Schöneberger, V., Cukier, K.: Big data: a revolution that will transform how we live, work, and think. Hachette, London (2013)
13. Mostashari, A., Arnold, F., Mansouri, M., Finger, M.: Cognitive cities and intelligent urban governance. *Network Ind. Q.* **13**(3), 4–7 (2011)
14. Moss-Kanter, R., Litow, S.: Informed and interconnected: a manifesto for smarter cities. Harvard Business School Working Paper 09–141 (2009)
15. Moyser, R.: Planning for smart cities in the UK. <http://www.burohappold.com/blog/post/planning-for-smart-cities-in-the-uk-2179> (2013). Accessed 2 Jun 2015
16. Neirotti, P., De Marco, A., Cagliano, A.C., Mangano, G., Scorrano, F.: Current trends in smart city initiatives: some stylised facts. *Cities* **38**, 25–36 (2014)
17. NYC Department of Information Technology & Telecommunications (NYC DoITT): Strategic Plan 2015–2017 (2015)
18. Robinson, R.: Creating successful Smart Cities in 2014 will be an economic, financial and political challenge, not an engineering accomplishment. *The Urban Technologist*. People. Place. Technology March 2, 2014. <http://theurbantechnologist.com/2014/03/02/creating-successful-smart-cities-in-2014-will-be-an-economic-financial-and-political-challenge-not-an-engineering-accomplishment/> (2014). Accessed 2 Jun 2015
19. The Climate Group, Arup, Accenture, Horizon: Information Marketplaces. *The New Economics of Cities* (2011)
20. Townsend, A.: Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia. W. W. Norton & Company (2013)
21. UN (United Nations): World Urbanization Prospects. 2014 Revision. United Nations (2014)

22. Warshay: Upgrading the Grid—How to modernize America’s electrical infrastructure. Foreign Affairs March/April 2015 (2015)
23. Wood, C.: Gameification: governments use gaming principles to get citizens involved. Government Technology, 28 Aug 2013. <http://www.govtech.com/local/Gamification-Governments-Use-Gaming-Principles-to-Get-Citizens-Involved.html> (2013). Accessed 08 Jul 2015
24. World Bank: What a Waste: A Global Review of Solid Waste Management. World Bank (2012)
25. Wortham, J.: What Silicon Valley can learn from Seoul. New York Times June 2, 2015. http://www.nytimes.com/2015/06/07/magazine/what-silicon-valley-can-learn-from-seoul.html?smid=nytcore-iphone-share&smprod=nytcore-iphone&_r=0 (2015). Accessed 4 Jun 2015

Towards Cognitive Cities

Advances in Cognitive Computing and its Application to
the Governance of Large Urban Systems

Portmann, E.; Finger, M. (Eds.)

2016, XVII, 215 p. 49 illus., 34 illus. in color., Hardcover

ISBN: 978-3-319-33797-5