Chapter 9

Cities as hubs for data-driven innovation

This chapter provides an overview of data production and examples of opportunities for data-driven innovation in cities, as well as a discussion of related policy implications. The focus is on data-driven innovation i) that increases the efficiency of urban systems, including through system integration; ii) that enables new business opportunities, for example in urban mobility and accommodation markets; and iii) that improves urban governance. Examples in each of these areas show that the potential of data-driven innovation in cities has only begun to be tapped, and that the conditions to unleash it need to be improved. Issues to be addressed by policy makers to improve such conditions include interoperability, regulation, digital security risk management, and privacy.

"Cities have the capability of providing something for everybody, only because, and only when, they are created by everybody." (Jacobs, 1963)

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

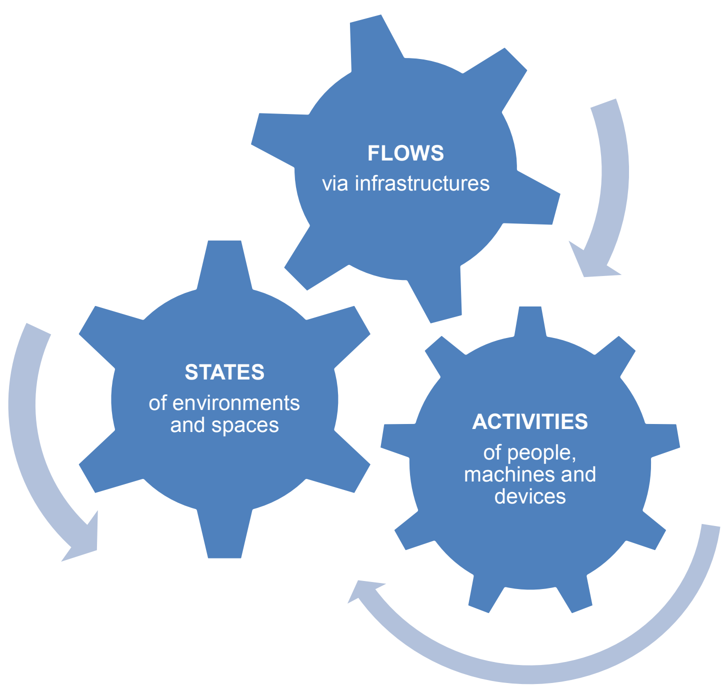
Sensors embedded in connected infrastructures, machines and devices, which are concentrated in urban areas, are producing an increasing variety and volume of data that are of significant worth for cities. A large share of the 65 million sensors estimated to be deployed worldwide in security, health care, the environment, transport and energy control systems today are embedded in urban infrastructures, facilities and environments (MGI, 2011). In US cities alone, an estimated 30 million CCTV cameras are installed in public spaces (Koonin, 2014). With around three-quarters of the OECD area population expected to be living in urban areas by 2022, cities will host at least 10 billion out of the 14 billion devices[1] estimated to be in use in member countries by then (OECD, 2010; OECD, 2012a).

9.1. The urban data ecosystem

Urban data production

The data produced in cities can be divided into three categories: data on flows, states and activities (Figure 9.1):

Figure 9.1. **Urban data categories**



- *Flows* – Cities are structured by and pervaded with different types of infrastructures (e.g. ICTs, transport, water, energy, waste networks) that facilitate movement and flows of resources, products, people and information across cities. Sensors embedded in urban infrastructures increasingly allow the digitisation and datafication of these flows. Some of the movement in cities is controlled by gateways, such as entrance doors, that are equipped with connected sensors, scanners, radio frequency identification (RFID) tags, etc.; these often require authentication to authorise entrance in specific areas.

- *States* – Urban inside spaces and outside environments are subject to constant natural and manmade changes. The particular state of urban spaces and environments – the density of people, air temperature and quality, light and sound levels, etc. – is increasingly monitored by sensors, including cameras; through synoptic instruments such as satellites; or in continual observations from urban vantage points. These states are being digitised and datafied in different forms and formats, including audio files, images, infrared and hyperspectral imaging, or radar.
- *Activities* – Connected machines and devices used for both personal and professional activities in cities allow measurement of transaction, consumption and communication patterns. These patterns include in particular: 1) people's activities, communication and interactions; 2) interaction between people and their environment; and 3) interactions among components of their environments, such as communicating and autonomous machines and devices. Furthermore, interactions and transactions of individuals and businesses with public institutions (e.g. tax records, land use, sales, inventories, public health, crime records, school outcomes, workforce development), with businesses (e.g. credit card payments, consumption behaviour, sales records), and individuals (e.g. social networking) create transactional data on activities in cities.

These data, created through the sensing, measuring and recording of flows, states and activities in cities, can also be distinguished by the extent to which they are location specific:

- data produced by stationary sensors embedded in urban infrastructures and environments, mostly describing flows and states in cities;
- geo-locational and geo-referenced data generated in cities, often from mobile devices and sensors, describing mainly the activities (actions, interactions, transactions) of connected people, machines and devices; and
- other data generated in cities that do not necessarily have geographic properties, such as data on financial transactions.

Actors in the urban data ecosystem

Many actors are involved in data collection and use in cities. Chapter 2 of this volume gives an overview of the data ecosystem as different layers and key actors (Figure 2.2): Internet service providers; IT infrastructure providers; data analytics providers; data providers; and data-driven entrepreneurs and innovators. While all of these actors are present in cities, this chapter mainly focuses on data providers and data-driven entrepreneurs and innovators.

The list below gives an overview of the key urban actors in the data ecosystem, which are the most relevant for the focus of this chapter. Each of them is in principle connected to all the others, through a digital layer and in multiple possible combinations. Each can be involved both in data collection and data use, at different times and in different functions:

- citizens and consumers
- innovators and entrepreneurs
- governments and utilities
- data brokers and platforms
- system operators and service providers.

The extent to which data can be exchanged among these actors and across systems in cities, as well as the extent to which they can easily be reused for different purposes, determines their potential for data-driven innovation (DDI) (see Chapter 2 of this volume). The main focus of this chapter is on data-driven innovations that i) increase the efficiency of urban systems, ii) enable new business opportunities, and iii) improve urban governance. By focussing on these topics, the chapter attempts to differentiate several issues that tend to be addressed in generalising discussions of the "smart city", with the aim to better understand the implications of DDI in cities for policy makers (Box 9.1).

Box 9.1. **"Smart City"**

The term "smart city" was mainstreamed by IBM's marketing campaigns and tends to cover a large range of different technologies, applications and services offered by companies like Siemens, Hitachi, General Electric, Cisco, Alstom, Arup, Microsoft and IBM itself, to name just a few of the biggest. The global smart cities market is estimated to grow to around USD 400 billion by 2020, technologies and services included (UKDBIS, 2013). A report by Navigant Research (2014) estimates that worldwide revenues from smart city technology will grow from USD 8.8 billion in 2014 to USD 27.5 billion in 2023.

An overwhelming number of cities have bought into the smart city narrative, much of which seems to remain a promise so far. In the EU-28, around 90% of cities with over 500 000 inhabitants identify themselves as a smart city. However, only half of these cities have actually implemented relevant initiatives, most of which are small in scale. That indicates the extent to which the smart cities market is characterised by a vendor push rather than by market and government pull (EP, 2014; Schaffers, 2011).

The term "smart" was defined in an earlier OECD report to be applicable when: "An application or service is able to learn from previous situations and to communicate the results of these situations to other devices and users" (OECD, 2013a). This definition can be applied to individual applications, services, machines and devices. However, it is unlikely to capture all aspects of the various systems that enable the functioning of cities, each of which is complex in itself and all of which potentially interact with each other. The term "smart" seems even less appropriate to capture the heterogeneity of a city beyond its technical components and systems, such as its human, social, environmental and economic realities.

Despite its widespread use, the term "smart city" does not provide a useful framework for analysing specific opportunities and policy implications of DDI in cities. It is thus not used in this chapter.

Source: UKDBIS, 2013; EP, 2014; Schaffers, 2011; OECD, 2013a.

9.2. Opportunities for data-driven innovation in cities

Efficiency gains

Much of the data on flows and states, and some of the data on activities in cities, can be used to increase the efficiency and promote integration of urban systems. The availability of historical and real-time[2] data on flows in transport, energy, water and waste systems enables analysis at unprecedented depth and granularity, as well as targeted interventions in and better management of urban systems. This section first looks at opportunities to improve the efficiency of urban systems; it then considers the potential for digitally integrating urban systems.

Opportunities in transport, electricity, water and waste systems

Promising effects of information and communication technologies (ICTs) and data use in cities can be found in transport. A main lever for data-driven improvements in transport is the direct match of demand and supply, based on fuller and often real-time information. There are, for example, mobile applications (apps), such as moovel or Citymapper, that inform urban travellers of the fastest connection from point A to point B, taking into account all available transport modes and traffic conditions. Matching demand and supply in real time allows shaving peak demand by redistributing it in space, reducing road congestion. This can save people time and money and reduce pollution and emissions in cities. Open data use in transportation, such as for apps providing real-time information on multimodal trips, prices and traffic conditions, is estimated to generate USD 720 billion to USD 920 billion per year (MGI, 2013).

Transport systems can be further optimised by dynamic road pricing and other types of traffic management based on real-time data analytics. Road pricing can be applied in different ways and for different objectives: dynamic road pricing to reduce peak time traffic (Singapore); dynamic parking fees to reduce the number of cars coming into congested areas (New York); or differentiated road pricing that favours environmentally friendly cars (Stockholm). Congestion charging in Stockholm has reduced traffic by 22% (100 000 passengers per day) and CO_2 emissions by 14% (25 000 tons annually) in the city centre, just in its seven-month trial period (CCLA, 2014; OECD, 2013b; KTH, 2010). The Intelligent Traffic Management System of London not only uses near-time traffic information to constantly adapt traffic light circuits, but also is able to learn from ongoing statistical observations of traffic patterns. It is becoming increasingly able to predict traffic and guide flows in anticipation of traffic volumes (TfL, 2010). The system is estimated to have reduced congestion in London by around 8% annually between 2014 and 2018 (TfL, 2011).

Electricity is another sector that can benefit from fuller capacity utilisation through data-based matching of demand and supply. Smart electricity grids are expected to yield energy savings for homes and businesses, in particular if combined with home and business energy management systems. Smart electricity meters inform households and businesses of real-time electricity prices based on current power demand and supply in electricity grids. Low prices incentivise consumption, whereas high prices discourage people to consume electricity. This levels out peaks in demand and thus reduces the necessary base load in the grid. Through the use of smart meters, European households are expected to save 10% of their energy consumption per year (EC, 2011). In the United States, the savings from smart grids are estimated to be 4.5 times the needed investment of USD 400 billion (EPRI, 2011).

DDI can furthermore yield efficiencies in water and waste systems. "Smart water solutions" are estimated to save water utilities USD 7.1 billion to USD 12.5 billion globally per year, through better i) leakage and pressure management techniques in water networks, ii) water quality monitoring, iii) smarter network operations and maintenance, and iv) data analytics in capital expenditure management (Sensus, 2012). Comprehensive and data-enabled approaches for waste reduction, recycling, reuse and waste-to-energy conversion can reduce energy consumption and emissions. For example, New York State's "Beyond Waste" strategy estimated to save as much energy as consumed by 2.6 million homes each year (280 trillion BTUs) and to cut New York's greenhouse gas emissions by around 20 million metric tons annually (DEC, 2014).

Potential synergies of urban system integration

Beyond improvements within separate urban systems, synergies can be reaped through integration of these systems. Understanding urban infrastructures and sectors as systems, a city can be considered a "system of systems", within which ICTs and the digitisation of urban flows are creating the potential for deep integration (CEPS, 2014). Already in an analogue world, urban systems were integrated to some extent; in Stockholm, for example, the transport, energy and waste systems are integrated to the extent that Stockholm's buses and taxis drive with biogas produced in the city's wastewater recycling plants (OECD, 2013b). Increasing digitisation of these systems will enable exchanging real-time information across the different systems involved, which in turn would allow optimising and scaling up such an approach. The same principle could be applied to other integrated systems, such as in the city of Kitakyushu, Japan, where industrial excess energy (heat) is reused to heat residential buildings through a district heating system that connects industrial with residential areas (OECD, 2013c). The use of real-time data on demand, supply and flows in urban systems can help deepen system integration and reap potential synergies of such integration.

A good example of a system that is becoming increasingly integrated with other urban systems, notably through the use of ICTs and real-time data, is the electricity grid. A key aspect of such "smart grids" is demand- and supply-side management, enabled by smart meters, that contributes to energy savings. A wider potential of smart grids, however, lies in integrating fluctuating renewable energy supply as well as electric vehicles. Electric vehicles can serve both for energy storage and supply, either at times of peak demand or in order to balance fluctuating renewable energy supply (OECD, 2012c; IEA, 2011). ICT-enhanced electricity systems thus enable a direct integration of transport and energy systems. Electricity grids can also be used to connect communicating devices in homes, and thus serve as an information system (OECD, 2013a). The "Internet of Things" will in any event multiply the systems, machines, devices and services connected via electricity grids and information systems, such as solar cells on roofs, weather stations, home heating systems and air conditioning, washing machines, light bulbs, electric vehicles, refrigerators, smartphones, supermarket stocks, etc. (see Chapter 2 of this volume).

Innovation hubs

Cities as living laboratories

The increasing collection and availability of data in cities have the potential to turn urban areas into large-scale experimental test beds for data-driven innovation. In contrast to many product and process innovations, large-scale system innovations – such as in transport or energy – require experimentation and testing at scale, ideally in real-life settings. Aiming to seize the opportunity of providing such settings, cities have started to define themselves as "living labs", such as the 340 European cities that are part of the European Network of Living Labs. This network defines urban living labs through four key elements: co-creation of new services by users and producers; exploration of emerging usages, behaviours and market opportunities; experimentation with implementing live scenarios within a community of lead users; and evaluation of concepts, products and services (Schaffers, 2011; ENoLL, 2014). Most urban living labs focus on providing the conditions for data-driven innovation, including through public-private and triple-helix collaborations (Box 9.2). The private sector has also discovered cities as ideal environments for DDI. Startupbootcamp accelerator programmes established in several European cities focus on DDI in mobile, near field communication, health and e-commerce; and companies like Microsoft have established incubators in cities like Paris, London and Berlin (Startupbootcamp, 2014; Microsoft Ventures, 2014).

Box 9.2. **Porto Living Lab and Guadalajara Creative Digital City**

Positioning itself as a living lab, Porto, Portugal aims to provide ideal conditions for DDI. At the core of the approach is an optical fibre backbone for high-speed Internet. The city collaborates with the University of Porto and an array of public and private stakeholders that constitute an institutional ecosystem for data-driven innovation. This ecosystem is open to researchers, private companies, public authorities and end users, which experiment and collaborate on data-driven products, services and applications, addressing specific challenges Porto is facing. Current projects include a platform for open data sharing, a machine-to-machine communication enhanced harbour management system, and a real-time traffic information service feeding connected buses and taxis in Porto.

The Ciudad Creativa Digital (CCD) Guadalajara, Mexico, is a joint effort of the Ministry of Economy, the governments of Jalisco and the City of Guadalajara, in coordination with the Massachusetts Institute of Technology (MIT) and private companies. Guadalajara aspires to set up digital infrastructures and an environment that attracts skilled creative human capital in order to develop digital content sectors and other innovative services. The city aspires to become a digital hub in Mexico and to serve as a living laboratory for DDI.

Source: Barros, 2013; Future Cities Project, 2014; Mexican Secretariat of Economy, 2015.

Beyond technical and institutional infrastructure, access to data is a key condition for fostering data-driven innovation in cities. In addition to giving access to city data via open data portals, many cities have started to directly incentivise data-driven innovation by rewarding programmers and entrepreneurs for developing data-driven applications. A common way of doing so is to organise hackathons, during which cities make data available to programmers, hackers and entrepreneurs and reward the most innovative applications, which usually are developed quickly. While these events tend to be very productive, so far they rarely have produced solutions that address deeper urban challenges. This seems to be partly due to a lack of focus in these events on actual challenges cities are facing (Townsend, 2014). Another shortcoming observed is a lack of resources to further develop promising applications and scale them up (Mulligan and Olsson, 2013). More recently, the private sector has started embracing the concept of hackathons and making private sector data publically available, such as during the Dutch Open Hackathon in Amsterdam (DutchOpenHackathon, 2014).

In recent years, many cities in OECD member countries have launched their open data portal. A City Open Data Census lists 70 US cities and provides metadata on their data sets (OKNF, 2014). In the European Union, over 120 open data initiatives and portals of cities or regions are listed, and a pan-European beta-version for a search portal (publicdata.eu) harvests metadata (EC, n.d.). In most cases cities publish structured (linked) data in machine readable formats to facilitate commercial and private use; however, few cities as yet offer application programming interfaces (APIs) (Open Cities, 2013). Many cities are using open source data portal platforms or software such as CKAN or Socrata, but no standards for open data portals exist so far.

New business opportunities

Over the past years, innovative start-ups have penetrated established urban markets with data-driven mobile apps and online platforms. Known under the label “sharing economy”, these platforms allow people to rent (“share”) cars, rides and bikes or space. They enable owners of assets and durable goods to turn them into services and thus make excess capacity available for collective consumption. For example, car owners can rent their car if they are not using it, sell seats on trips they do anyway, or work as a private driver when time permits; real estate owners can rent living or commercial space whenever vacant. On the demand side, urbanites get more and cheaper mobility options, and travellers a larger and cheaper choice of accommodations; freelancers gain flexible access to office and commercial space. While this creates additional choices for consumers, it also raises questions with regards to quality control and insurance, and creates new competition for incumbents, notably for taxis and hotels.

People have shared cars and rides for a long time, but smartphones and real-time access to geo-locational data have allowed entrepreneurs to reinvent and scale up shared mobility commercially. Cars are among the most expensive and underused assets individuals own. On average, cars in cities are parked for 95% of their lifetime and are expensive: a US household spends USD 8 776 per year for its car, including gas, insurance, depreciation, vehicle payments and other expenses (ITF, 2012; *Time,* 2012). Car or ride sharing might not be cheaper per se, but they offer a flexible alternative to car ownership for many, in particular urbanites. And owners can top up their income by sharing their car or rides. The different variations of "sharing" in transport include private car rentals (Zipcar), ride sharing (Uber, Lyft, blablacar), and rentals of either free floating (Car2go, DriveNow) or station-based cars (Autolib'). Most of these services require subscription and are paid only if used. All transactions involved in using the service – from finding a ride or car to ordering and paying it – are taken care of by the online platform or mobile app. All participants in the service – drivers, car owners and passengers (renters) – can rate each other, which aims at creating trust, improving the quality of service and helps identify fraud or misuse. Similar principles are applied by other mobility apps, such as for shared parking spaces (justpark) and bicycles (Velib'). Studies on the potential effects of car and ride sharing in urban transport estimate that the size of car fleets in cities could be reduced significantly (Box 9.3).

Box 9.3. **Potential effects of shared mobility in urban transport**

Sharing cars, rides and bikes increases transport options in cities, can reduce resource consumption and has the potential to change the overall face of urban mobility. Ratti et al (2014) find that road mobility demand in Singapore could be met with only 30% of the vehicles currently in use in the city. A further 40% could be cut if all people on similar routes were to share their cars with others. Altogether, today's road mobility demand in Singapore could be met with about one-fifth of cars in the city (Ratti, 2014). A slightly more conservative calculation by the International Transport Forum estimates that car sharing could reduce the fleet size in cities by half and presents a scenario that combines high-capacity public transport with self-driving "TaxiBots" (self-driving shared vehicles) in which only 10% of cars would be needed (ITF, 2014).

These scenarios present a theoretically optimal version, which is not likely to be realised any time soon however. In the first place, shared mobility services could actually increase the number of cars on city roads, as early evaluations of car sharing systems have found. A main reason for this is that users of car-sharing services do not necessarily give up their private car, if they own one, and many users that sign up for car sharing offers did not own a car in the first place (Le Monde, 2013).

Given that it is early days for car and ride sharing systems, it is premature to judge their overall impacts on urban mobility. However, their successful adoption in many places and their economic potential indicate that their impacts will need to be considered: free-floating car-sharing systems alone are projected to generate annual revenues of EUR 1.4 billion in OECD cities with over 500 000 inhabitants by 2020 (Civity, 2014).

Source: ITF, 2012; ITF, 2014; Time, 2012; Ratti et al, 2014; Le Monde, 2013; Civity, 2014.

Another frontier in the "sharing economy" is the rental of living, working and commercial space via online platforms or mobile apps, mainly in cities. Again, home exchanges and temporary office rentals are nothing new, though the speed and scale at which short-term rentals of private spaces have become common practice is unprecedented. Similar to ride and car sharing, home sharing significantly builds on trust created by mutual ratings of landlords and guests as well as personal profiles and ID authentication. The online platform of Airbnb provides all basic services for the transactions between renters and guests, from advertising the place and securing direct communication between landlord and renter to providing a booking system, including payment, billing and insurance. Similar online platforms offer flexible office (ShareDesk) or shop rentals (Storefront), but are still small in scale. The former tend to be used by freelancers, the latter for pop-up stores**,** marketing campaigns or exhibitions. Home sharing in cities may affect local economies, however it is still unclear how (Box 9.4).

Box 9.4. **Potential economic effects of home sharing**

There is no comprehensive assessment yet of the economic effects of home sharing. However, anecdotal findings provide some insights. For example, for the case of New York, Airbnb claims that its guests are likely to generate more income for the city than hotel guests and that Airbnb guests tend to spend their money in areas which have traditionally not profited much from hotel guests and tourism.

The Airbnb study claims that in 2013, 416 000 visitors booked accommodation in New York through Airbnb, generating economic activity worth USD 632 million. On average, an Airbnb guest stayed 6.4 nights (compared to 3.9 for hotel guests) and spent USD 880 at NYC businesses (compared to USD 690 for average New York visitors). Most Airbnb listings in New York (82%) are outside the main tourist area of midtown Manhattan, compared to 30% of hotels located in these areas; and 57% of Airbnb visitors' spending occurs in the neighborhood in which they are staying.

While these figures give some indication about the behavior of Airbnb users, they do not represent a full picture of economic effects that Airbnb and other home sharing services have in a city. For example, there is no consideration of how home sharing affects the market share of hotels and the effects this could have on the local tax base and employment (Zervas et al., 2015). Neither is local spending of hotel employees taken into account, versus spending by Airbnb apartment owners, which are likely to be absent from the city, if they rent their entire home.

Source: Airbnb, 2014; Zervas et al, 2015.

Urban governance

Leveraging new sources of data

City administrations are increasingly using crowdsourced data to gain real-time and fine-grained information on public service delivery and infrastructure needs and conditions. Mobile apps like SeeClickFix in the United States or the BuitenBeter app in the Netherlands allow citizens to report on stray garbage, potholes, broken lamps and the like via their smartphone, directly to city hall. While this approach implies proactive citizens, mobile apps such as StreetBump in Boston report automatically; making use of the accelerometer (motion detector) and GPS, the StreetBump app reports on street conditions in Boston, notably on potholes and bumps, via drivers' smartphones. Also reporting automatically, the app Incidències 2.0 reports on commuter rail service interruptions or delays in the metropolitan area of Barcelona; and the app Cycle Track informs transport planners in San Francisco of bicycle trips made throughout the city. The fine grained data collected through such mobile apps enables city governments to better target infrastructure investments, deliver tailored public services and increase efficiency in operations and maintenance. A more general account of possible uses of data by governments, including local governments, is given in Chapter 10 of this volume.

Online, crowdsourced and real-time data can also play an important role in disaster management in cities. For example, Crowdsense, a spin-off of the Dutch national applied research institute (TNO) and technical university (TU Delft), uses online and social media data for early warning systems and incident management services (Crowdsense, 2015). During the 2013 European floods, a citizen of Dresden, Germany, developed an online map that provided instant updates on flood hotspots and guided volunteers to places where help was most needed (DLI, 2013). In Japan, the Ministry of Internal Affairs and Communications (MIC) and the Tokushima Prefecture tested an evacuation system, which relies on IC cards, which are distributed to residents and linked to their home TVs. In case of an evacuation, the system displays the evacuation order with the residents' name on their TV screen. The residents' IC cards are scanned at the shelter to attain evacuees' up-to-date information. Furthermore, the system can recognise which residents watched TV just before an evacuation, so rescue workers can be dispatched to targeted houses. As a result, the evacuation time and the time to retrieve evacuees' information could be shortened significantly. While these examples give an idea of the multiple opportunities of using data for disaster management, such tools can only be one, albeit growing element within a city's risk and disaster management strategy, an increasingly important part of which in turn is digital security risk management, discussed below.

Applying data analytics

Crowdsourced, social media and other online data are increasingly used in city police departments, including for predictive data analytics and anticipatory decision making. CitiVox, a start-up that allows citizens to report crimes anonymously, provides governments with data from SMS and social media that can complement official crime statistics; policy makers and enforcement agencies can thus identify crime patterns they would not detect otherwise (CityVox, 2012). This is particularly useful in areas where fewer crimes are reported, such as in Central and South America. In the Netherlands, the application Buurt Bestuurt offers citizens the opportunity to engage with the city and other citizens in various ways to improve living conditions, including safety, in urban neighbourhoods (TNO, 2014). Some city police departments, such as in Los Angeles, Chicago, Memphis, Philadelphia and Rotterdam, are developing the capacity to analyse large and diverse data sets, including from social media, to support predictive policing. For example, data analytics may help identify potential future crime hotspots, prompting police to step up patrolling; or, it might be used to identify specific persons that are estimated to be prone to commit a future crime, as well as to determine surveillance levels for ex-prisoners. It should be noted that neither the effectiveness nor the privacy implications of such practices have as yet been thoroughly evaluated.

More comprehensive data on resource consumption allow policy makers to design more targeted and effective incentives to curb consumption – which may, however, have unintended consequences. For example, volumetric tariffs, such as applied for energy or water bills in many places, have proved successful in reducing resource consumption of households (OECD, 2012d). The increasing availability of data on other flows in cities allows similar models to be applied to other areas, such as waste disposal and recycling.

Recent research found that social network incentives could be a significantly more effective alternative to such traditional economic incentives. Instead of financially rewarding or punishing individuals for their actions (directly), as economic incentives do, social network incentives reward the friends of those who act. An experiment with incentives to save energy in Swiss municipalities has revealed that social network incentives were up to four times more effective than traditional incentive schemes (Pentland, 2014). While reducing resource consumption may be a desirable aim, the implications of nudging people's behaviours to become more rational are not yet well understood. As Frischmann (2014) points out, techno-social engineering might not only ignore the values of those being nudged by a modified "choice architecture", but also, if applied in institutional decisions, may generate path-dependency.

Greater data availability and more powerful computing are bringing urban modelling back to the forefront of urban planning. Urban modelling was first used over 50 years ago, but its imperfections – notably due to limited data and computing power – restricted its success. Its resurgence with the appearance of geographic information systems (GIS) in the 1990s and 2000s coincided with a shift from modelling aggregate equilibrium systems to complex, evolving "systems of systems" and urban dynamics (EUNOIA, 2012; Jin and Wegener, 2013). Geo-referenced data collected via crowdsourcing, remote sensing, social networking, smart transit ticketing, mobile phones and credit card transactions – combined with new computational power, including cloud computing – offer fresh possibilities for urban modelling, notably as applied to transport or integrated land use and transport planning (Nordregio, 2014). Opportunities for data-intensive urban modelling and simulations are being explored, both theoretically – as in the European EUNOIA project (Evolutive User-centric Networks for Intraurban Accessibility) – and practically. An example of the latter is the LakeSim project in Chicago, which has made extensive use of computational modelling to understand the impacts of alternative design, engineering and zoning solutions (UCCD, 2012). Data analysis and modelling of societal needs for urban infrastructures and services have the potential to significantly improve the pertinence of resource allocation and of investment decisions in urban areas.

9.3. Policy priorities

The extensive production and increasing variety and use of data in cities create great potential to spur DDI in urban systems, markets and governance. The extent to which such opportunities can be seized will depend considerably on policy makers at the national and sub-national levels. This section looks at some of the most important issues to be addressed.

Fostering interoperability

An important condition for integrating urban systems and advancing system-to-system communication is interoperability across different systems and components at different levels. International standards developed by standard-setting bodies – such as the International Electrotechnical Commission (IEC), the Institute of Electrical and Electronics Engineers (IEEE), the International Telecommunication Union (ITU) and the International Organization for Standardization (ISO) – will be crucial in scaling up the implementation of complex systems such as smart grids and in furthering integration of urban systems. Harmonised standards are key to achieving interoperability, at i) the *technical* level; ii) the *informational* (and semantic) level; and iii) the *organisational* level (CEPS, 2014). Many such standards do not as yet exist, but some have begun to be developed. ISO currently works on a standard for smart community infrastructures, with the aim to foster complex system integration**.**

At the *technical* level, a major challenge comes with bringing a large number of companies, products and standards from different sectors into one increasingly integrated "system of systems". For example, the implementation of smart grids often necessitates large consortia of companies from domains that have not always collaborated before. The smart grid project in Issy-les-Moulineaux, Paris, for example, unites urban infrastructure actors such as Bouygues Immobilier, engineering and energy companies such as Alstom, EDF (Électricité de France), ERDF (Électricité Réseau Distribution France), Schneider Electric and Total, and communications and IT firms including Bouygues Telecom, Microsoft and Steria, in addition to various start-ups (CGDD, 2013). Beyond smart grids, important technical issues will need to be resolved for the joint functioning of mobile network architecture, ICTs, and Internet-based system architecture (Mulligan and Olsson, 2013).

Another technical challenge related to systems integration comes from the differing life cycles of different technologies, networks and infrastructures. This was pointed out in previous work by the OECD, which estimated life cycles (Table 9.1). Furthermore, many technologies are part of a complex legacy of existing networks and infrastructures, most of which were not designed for the data-driven applications or services discussed above.

Table 9.1. **Life cycles of selected technologies, networks and infrastructures**

Technologies, networks, infrastructures	Estimated life cycle in years
Consumer electronics	2-10
Home appliances	10
Vehicles	15
Telecom networks	10-50
Energy networks	15-50
Roads (maintenance)	30 (10)

Source: OECD, 2013a.

At the *informational* level, cross-sector data sharing is likely to pose challenges. Data collected in different sectors tend to be stored in different formats and few incentives exist for harmonising them. Without standards, data sharing may be limited by and locked into proprietary formats. Another issue for data sharing is privacy protection, which can be achieved to some extent through anonymising data before making it available. Some companies are proactive in this area. The company Orange, for example, uses the "Floating Mobile Data" technology to anonymise mobile phone data, which it offers for reuse, both for commercial purposes – such as in navigation systems and traffic management – and for research.

At the *organisational* level, the increasing need for data sharing will challenge vertical silos in public administrations and necessitates more co-operation among jurisdictions and levels of government. Co-ordination among different departments and agencies in public administrations has long been recognised as a crucial element of efficient and effective urban governance (Rodigo, Allio and Andres-Amo, 2009). These principles become even more pertinent in the context of cross-sectoral data sharing and data analytics (Koonin, 2014). Until now, few cities have provided good practice in this area. An exception is Barcelona, which has mechanisms in place to enhance co-ordination across different city departments as well as for public-private co-ordination on urban data and other horizontal issues. Furthermore, the multiple jurisdictions that make up large urban areas, and multiple levels of government, need to be co-ordinated to improve data sharing. In the United States for example, city school districts, jails, criminal courts and public housing are often not under mayors' jurisdictions. Also, data from welfare programmes (e.g. Medicaid) are not usually available to cities. This means that US cities need to request specific agreements, which slows down or impedes the use of data and thus the potential for data-driven innovation and decision making in urban areas (Lane et al., 2014).

In the private sector, large companies tend to offer systemic and vertically integrated solutions, too much of which could lead to horizontal market separation. Some of the largest players in the "smart cities" market offer a systemic approach with proprietary solutions, ranging from sensor technology to the "city cockpit", in which all vital functions of a city should be monitored (Siemens, 2011). Other established firms in important sectors, notably in energy and communications, have started purchasing companies up- and downstream to gain control over larger parts of the value chain. Examples include AT&T Digital Life and the joint venture of Vodafone and British Gas with smart meters (OECD, 2013a). While vertical integration can to some extent help overcome vertical fragmentation in markets that are characterised by too many proprietary solutions along the value chain, it might lead to horizontal market separation and a lack of competition.

Reviewing legal and regulatory frameworks

New businesses labelled under the "sharing economy" have overcome high entry barriers and created new competition in established markets, notably in urban mobility and accommodation. Debates are ongoing in many places about how to react to new entrants like Airbnb competing with hotels, or Uber competing with taxis. In many places, these companies are operating in a legal and regulatory context which was shaped before their existence and that may need to be updated. Some countries and cities are trying to protect incumbents by punishing new entrants or making their activity illegal altogether. Others are reforming and providing clarity with new legislation and regulations. France, for example, passed a bill (ALUR) that allows renting both primary and secondary residences via Airbnb, and cities like Amsterdam or Hamburg have supportive policies towards Airbnb. Other cities, including New York and San Francisco, reacted with stricter regulation of the market. Regulators both at the national and sub-national level need to address the questions that arise through new business practices and consumer behavior, taking into account technological and societal developments that influence DDI.

Opening access to data

As highlighted in Chapter 4 of this volume, data can be considered as an infrastructure along with traditional infrastructures such as for transportation, communication or public utilities. The (re)use of such infrastructures typically generates positive spillover effects in particular when access is granted on equal and non-discriminatory terms (Frischmann, 2012). Recognising the value of public sector data for citizens, innovators and entrepreneurs, many cities have started to make their data available based on non-discriminatory access regimes such as through "open data". The interest in public sector data and its use to society are the subject of the OECD (2008) *Recommendation of the Council for enhanced access and more effective use of public sector information*, which suggests that governments implement the principles of openness, access and transparent conditions for reuse – and, where possible, for no or marginal cost. City initiatives should be guided by these principles and be aware of the challenges related to opening data to the public.

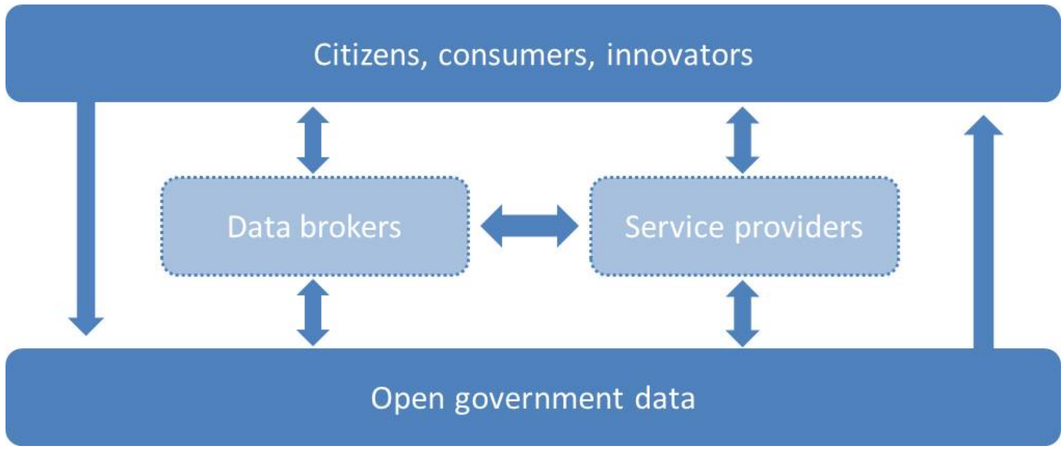
Opening access to data can be complicated. There are transaction costs stemming from agreements between different agencies; contractual and legal issues can arise from data collection; and existing rules are not adapted to data-driven service delivery or decision making in cities (Koonin, 2014). For example, in the Netherlands, Stadsbeheer, which uses citizen data collected via the BuitenBeter app to detect public incidents, cannot directly register this data in the Stadsbeheer back office, because that would infringe existing quality assurance protocols. Similarly, data from twitter and a more formal police app used in Rotterdam cannot be included in police reports for courts, given strict protocols the police have to follow.

Sensitive questions need to be addressed when it comes to what type of data cities should collect in the first place and what they should publish thereafter. Political considerations, regulatory frameworks, interests and values can influence the decision whether or not to collect and publish specific data (Kitchin, 2014). The University of Rotterdam, Netherlands, has developed a decision model to help urban policy makers determine whether and how a data set should be published for reuse (Gemeente Rotterdam, n.d.). In general, privacy guidelines[3] should be consulted; however, more specific discussions are needed – for example, on whether minimum requirements for city open data portals are useful, and which data should or should not be made public (Lane et al, 2014).

Another challenge for cities is to build the requisite capacity and skills for collecting, storing and analysing data in a depth and at a scale that are unprecedented, in addition to acquiring the infrastructure and computing power needed to store and process all the data. Best practice in the field of building capacity and skills are offered by the New York Mayor's Office of Data Analytics and that city's Center of Innovation through Data Intelligence or the Mayor's Office of New Urban Mechanics in Boston and Philadelphia, United States. Attracting data scientists to build in-house capacity will not be easy for many cities, notably given that similar skills are of great value in the private sector as well. With respect to infrastructure and computing power, many cities will not have the financial means or know-how to build and maintain local servers, and are likely to turn to cloud computing – which in turn raises new questions about security and privacy.

Private data providers, including data brokers, make additional data available but there is a lack of incentives and rules for providing private data to the public (see Chapter 4). Commercial data platforms like Esri or Sense-OS collect and (re)package data, make them publically available and provide analytical services. Focusing on data from the Internet of Things (IoT), the UK-based platform Thingful positions itself as a signpost for "the public IoT". Thingful helps find data and provides interaction among its users. Data brokers like Experian or Factual collect open and proprietary data and provide market intelligence; however, they do not necessarily facilitate interaction or data sharing among various interested players, mainly due to commercial interest (TNO, 2014). In other cases, regulation impedes private companies to make better use of their data in ways that could benefit the public. The interactions between open and propriety data are constantly evolving, and it might be too early to fix principles or rules to govern them. However, when starting to develop such principles, policy makers should be aware of the complex relationships among the actors engaged in producing, collecting, handling and using proprietary and open data (Figure 9.2).

Figure 9.2. **Key actors handling proprietary and open data in cities**



The multitude of actors involved in collecting and managing individuals' data in cities raises questions about the conditions under which data may be accessed and controlled by individuals. As a connected citizen, it has become difficult to know who is collecting, using, storing and sharing personal data where, when and with whom, and equally difficult to opt out of data collection. Only a few private companies that collect data from individuals enable data portability. Data portability would allow individuals to access their data when they end a contract with a firm at the latest, in order to keep it or use it in another context (Hemerly, 2013). Examples include start-ups like Handshake and Green Button: Handshake promises to keep individuals' data private, and allows them to hand those data out if they so wish for a reasonable price, and Green Button allows electricity consumers to have access to all data from their smart meters. Some public initiatives are aiming to offer services that move in this direction. For example, under the *Midata* initiative developed by the UK Government in co-operation with industry in the energy, finance, telecommunications and retail sectors, consumers will be provided with easier access to their consumption and transaction data in a portable and electronic format. This will enable them to gain insights into their own behaviour and make more informed choices about products that meet their interest. In France, Fing (Fondation Internet Nouvelle Génération) maintains MesInfos, an online platform through which consumers can access their financial, communication, health, insurance and energy data that are being held by businesses.

Better guidelines may be needed to ameliorate access to data throughout the economy and to help overcome existing barriers to data access, linkage and reuse. Existing frameworks that promote better access to data, some of which are sector specific, may need to be reviewed and eventually consolidated to foster coherence among public policies related, again, to data access, linkage and reuse. This would also include the OECD (2008) Council Recommendations promoting better access to data, including in particular the 2008 *Recommendation of the Council for Enhanced Access and More Effective Use of Public Sector Information*, and the 2006 *Recommendation of the Council concerning Access to Research Data from Public Funding*, both of which are currently under review.

Managing digital security risks

Increasing digitisation of urban systems and digital system integration in cities can yield benefits, but it also creates new risks.[4] The more ICT, energy, transport and other critical urban infrastructures and systems are digitally interconnected, the more a city as a system-of-systems will become vulnerable to both internal and external threats, ranging from technical failures to cyber-attacks and natural disasters. For example, the flood caused by the 2012 Hurricane Sandy in New York City triggered a power blackout, which immediately affected critical urban infrastructures including transport and health, as well as telecommunications backhaul to over 2 000 cell sites in and around New York (Townsend, 2014). While in this case the shock that triggered system failures was a storm and the main system through which disruptions propagated into other systems was the electricity grid, in a different scenario the shock could come from a cyber-attack and disruptions would propagate through information and communication systems. Once the communication system, including the Internet, breaks down, an increasing number of critical urban functions will be affected. The fact that increasing digitisation and digital integration of urban systems will expose cities to new risks has been ignored by most cities so far (Cerrudo, 2015).

Critical urban infrastructures are becoming a key target for cyber-attacks. In 2013, the highest number of the US Industrial Control System Cyber Emergency Response Team's (ICS-CERT) responses in critical infrastructure sectors was in energy systems; sector specific on-site support by ICS-CERT (2011-13) concentrated on water and wastewater systems, transportation and energy (ICS-CERT, 2013). The majority of attacks address the digital component of the respective system. Israel Electric Corp. reported receiving around 6 000 attempted hacks per second on essential systems such as water, electricity, banking, rail and road infrastructures. In October 2012, for example, Haifa's traffic management system for a major artery in the city was hacked and caused hours of traffic chaos (Kitchin, 2014).

The increasing dependence of urban systems on digital functions and integration with other systems makes digital security risk management an important element for the economic and social development and resilience of cities. The core elements of a digital security risk management framework are addressed more in depth in Chapter 5 of this volume. Such a framework helps determine how to reduce risk to an acceptable level in light of the expected benefits, through security and preparedness measures that fully support the economic and social objectives at stake. Digital security risk management focuses on the uncertainties related to possible loss of the confidentiality, integrity or availability of digital activities that are becoming increasingly essential for the functioning of urban systems and services. In cities, digital security risk management should be fully integrated within overall risk management frameworks and approaches that address other types of uncertainties (i.e. not related to the digital environment). It should also take into account interdependencies among both digital and physical systems. The large number of actors involved will make co-ordination and co-operation across jurisdictions and levels of government – as well as among interdependent infrastructure, business and IT actors – crucial conditions for managing digital security risks.

Implementing privacy protection

Many of the opportunities and practices discussed in this chapter have implications for the protection of privacy. The framework for privacy protection in the context of data-driven innovation, elaborated in Chapter 5 of this volume, applies to cities as well. The

OECD (2013d) *Recommendation Concerning Guidelines Governing the Protection of Privacy and Transborder Flows of Personal Data* (OECD Privacy Guidelines) should provide guidance to implementing the principles provided by this Recommendation, for sub-national policy makers much as for those at national or international levels. Policy makers need to step up efforts to implement privacy protection, in particular when the market provides insufficient incentives to protect personal data, and to find answers to questions that arise with new practices such as predictive analytics applied by city police departments. Using and linking large data sets, including personal data, to inform anticipatory decision making raises new privacy concerns that need to be addressed (White House, 2014). Finally, cities are likely to make increasing use of cloud computing, outsource storage and computing outside the city's jurisdiction and perhaps abroad. Potential issues of privacy protection in relation to cloud computing should therefore also be of concern to cities.

9.4. Key findings and policy conclusions

Cities are hubs for DDI, but this chapter has shown that the opportunities for DDI in cities have only begun to be tapped, and that policy makers play an important role in improving the conditions for DDI in cities. It can be noted in particular that:

1. *Urban systems can become more efficient through DDI, in particular through deeper system integration*. While separate urban systems such as for transport, energy, water and waste are already becoming more efficient through DDI, underexploited potential lies in deeper system integration. A fundamental condition for advancing such integration is interoperability among urban systems at technical, informational and organisational levels. Important enablers for interoperability are harmonised standards as well as multi-level governance and co-ordination across sectors and jurisdictions.
2. *Cities can be leveraged as laboratories for DDI*. Many cities have positioned themselves as "living laboratories" and new data-driven services are emerging, for example in mobility and accommodation markets. Two enabling conditions for DDI in cities are better access to urban data and appropriate review of legal and regulatory frameworks, taking into account technological and societal developments that influence DDI.
3. *DDI can improve urban governance*. Data collected from various sources, including crowdsourcing, can improve the evidence base for and precision of urban decision making. This applies to many areas, such as public service delivery, policing, incentive design, urban modelling, and disaster management. Two issues that need addressing by policy makers for each of these domains are digital security risk management and privacy; response to the latter could be guided by, inter alia, the principles of the OECD Privacy Guidelines.
4. *Better incentives and rules for sharing data*. Overall, the multiple public and private actors collecting and using data in cities need better incentives and rules for sharing that data in the interests of innovation. The design of such rules and incentives needs to balance both public and private interests, a challenge that policy makers have to face both at national and sub-national levels. This calls for coherence among open data frameworks, many of which relate to access, linkage and reuse (see Chapter 4 of this volume).

Notes

1 This does not take into account the increase in devices in non-OECD economies, nor the increase in devices for industrial applications.

2 In this chapter the notion "real time" stands in most cases for near-real time.

3 See the OECD (2013d) *Recommendation of the Council concerning Guidelines Governing the Protection of Privacy and Transborder Flows of Personal Data* (OECD Privacy Guidelines).

3 Risk is here understood as the effect of uncertainty on objectives.

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