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# DATA-DRIVEN INNOVATION FOR GROWTH AND WELL-BEING

## Chapter 10: Data-driven Innovation in Cities

*This revised chapter is issued to the Committee for Digital Economy Policy (CDEP) for information and declassification by written procedure as part of the overall report on "Data-driven Innovation for Growth and Well-being" which includes the outcomes of Phase II of the OECD project on New Sources of Growth: Knowledge-Based Capital with a focus on data (KBC2: DATA).*

*Delegates' comments during and following the CDEP meeting in December have now been taken into account.*

*Action requested:*

*CDEP Delegates are now invited to review the revised chapter. If no objections to the changes are made by 13 April 2015, they will be accepted and the chapter will be declassified.*

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**NOTE BY THE SECRETARIAT**

This chapter provides an overview of the opportunities and challenges of data-driven innovation (DDI) in cities as well as a discussion of related policy implications.

This revised version of the document reflects the comments received after the December 2014 meeting of the Committee for Digital Economy Policy (CDEP) and takes into account the discussions at the fourth meeting of the OECD Global Forum on the Knowledge Economy (GFKE) on "Data-driven Innovation for a Resilient Society" held in 2-3 October 2014 in Tokyo, Japan (http://www.gfke2014.jp/). The chapter also reflects comments received from the Regional Development Policy Division of the OECD Directorate for Public Governance and Territorial Development (GOV).

It will be published as Chapter 10 of the final report on "Data-driven Innovation for Growth and Well-being" which includes the outcomes of Phase II of the OECD project on New Sources of Growth: Knowledge-Based Capital with a focus on data (KBC2: DATA).

As agreed at the CDEP December 2014 meeting, the revised document is now issued to the Committee for Digital Economy Policy for information and declassification by written procedure.

***Action requested:***

*CDEP Delegates are now invited to review the revised chapter. If no objections to the changes are made by 13 April 2015, they will be accepted and the chapter will be declassified.*

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# CHAPTER 10. CITIES AS HUBS FOR DATA-DRIVEN INNOVATION

**This chapter provides an overview of data collection and use in cities as well as a discussion of related policy implications. Urban flows, states and activities are increasingly being digitised. The resulting data create opportunities for data-driven innovation in cities. The focus of this chapter is on data-driven innovation i) that increases the efficiency of urban systems, including through system integration; ii) that enables new business opportunities, notably in urban mobility and accommodation markets; and iii) that improves urban governance.**

Most of these examples show that the potential of big data for innovation in cities has only started to be tapped and that the conditions to unleash it need to be improved. The last section discusses policy implications of data-driven innovations in cities, including key issues such as interoperability, regulation as well as digital security risk management and the implementation of privacy principles. Policies that help unleash the potential of data-driven innovation in cities would not only help cities in addressing longstanding challenges, such as congestion or pollution, and to allocate resources more efficiently; increasing efficiency in urban systems, fostering new business opportunities and improving services delivery and quality of life in cities would strengthen the central role that cities are playing in driving economic growth, inclusive development, and the transition to a low-carbon economy.

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

Jane Jacobs

## Data in cities

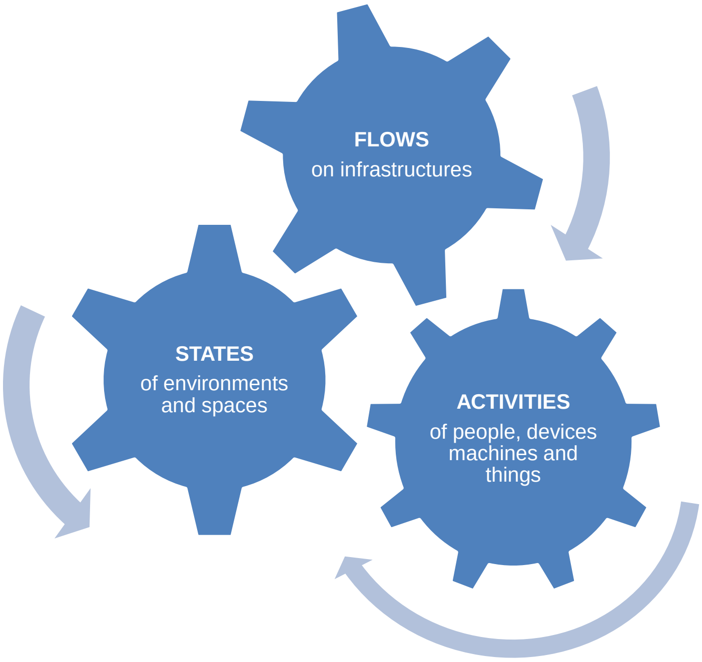
1. Sensors embedded in infrastructures, connected machines, devices and things, which concentrate in urban areas, are producing an increasing variety and volume of data that are of significant worth for cities. A large share of the 65 million sensors estimated to be deployed in security, health care, 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 population expected to be living in urban areas by 2022, cities will host at least 10 out of the 14 billion devices[1] estimated to be in use in OECD countries by then (OECD, 2010; OECD, 2012a).

### *Urban data collection*

2. The data produced and collected in cities can be divided into three types: data on flows, states and activities (Figure 10.1.):

[1] This does not take into account the growth of devices in non-OECD economies nor the growth of devices for industrial applications.

**Figure 10.1. Types of urban data**




- ***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, e.g. entrance doors, which are equipped with connected sensors, scanners, RFID tags, etc., often requiring 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 or things (e.g. vehicles), air temperature and quality, light and sound levels, etc. – is increasingly monitored by in situ sensors, including fixed and moving cameras at street level, through synoptic instruments such as satellites, or in persistent observations from urban vantage points. These states are being digitised and datafied in different forms and formats, including in audio files, images, infrared, hyper spectral, or radar.

- ***Activities***. Connected devices, machines and things used for both personal and professional activities in cities allow measuring transaction, consumption and communication patterns, in particular (1) people's activities, communication and interactions, (2) interaction between people and their environment, and (3) interactions between components of their environments, such as communicating or autonomous machines and devices. Furthermore, interactions and transactions of individuals and businesses with public institutions (tax records, land use, sales, inventories, public health, crime records, school outcomes, workforce development), with businesses (credit-card payments, consumption behaviour, sales records), and individuals (social networking) create transactional data on activities in cities.

3. These data created through sensing, measuring and recording flows, states and activities in cities can also be differentiated in three categories:

- ***In situ data*** produced by immobile sensors embedded in urban infrastructures and environments, mostly describing flows and states in cities;

- ***Geo-location and geo-referenced data*** generated in cities, often from mobile devices and sensors, describing mainly activities (actions, interactions, transactions), of connected people, devices, machines and things;

- ***Data in cities*** including both data born in situ or geo-referenced, but also other data produced in cities which do not necessarily have geographic properties, such as data on financial transactions.

***Actors in the urban data ecosystem***

4. A large number of actors are involved in data collection and use in cities. Chapter 3 of this report gives an overview of the data ecosystem as different layers and key actors (Figure 3.2): Internet service providers; IT infrastructure providers; data analytics providers; data providers; and data-driven entrepreneurs and innovators. While all of these actors are in principle present in cities, this paper mainly focuses on data providers and data-driven entrepreneurs and innovators.

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

- Citizens and consumers

- Innovators and entrepreneurs

- Governments and utilities

- Data-brokers and platforms

- Infrastructure and system operators

6. The extent to which data can be exchanged among these actors and across systems in cities, as well as the extent to which it can easily be re-used for different purposes, determines its potential for data-driven innovation (see Chapter 4). 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. The last section discusses related policy implications. Other important data-driven innovations, such as in social activities or in the political organisation of cities, are beyond the scope of this chapter.

**Efficiency gains**

7. 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 to promote the integration of urban systems. The availability of historical and real-time[2] data on flows in transport, energy, water or waste systems enables analysis at unprecedented depth and granularity as well as targeted interventions in and precise management of urban systems. This section looks first at how the use of data analytics can improve efficiency in key urban systems, notably in

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

transport, and secondly considers the potential for digitally integrating urban systems, focussing on the electricity system.

8. The most promising effects of information and communication technologies (ICTs) and data use in cities can be found in transport and in electricity systems so far. Challenges faced and technical solutions are not the same for transport and electricity, but both systems share an important lever for data-driven improvements: direct match of demand and supply, based on fuller and often real-time information. Whether via a mobile application (app) that gives urban travellers the fastest connection from point A to B, taking all available transport modes and traffic conditions into account, or via a smart electricity meter that informs households and businesses of real-time electricity prices based on current demand and supply in the grid; making demand and supply transparent in real-time allows shaving peak demand by redistributing it in space (notably transport) and time (transport and electricity). This reduces congestion on roads and lowers the necessary base load supply in electricity grids. In turn, people can save time spent in transport and money (and emissions) on electricity. In sum, matching demand and supply in real-time based on available data allows fuller capacity utilisation of both urban transport and electricity systems. Other urban systems that can become more efficient through data-driven innovation include water and waste systems (Box 10.1).

**Box 10.1. Efficiency potential in urban systems**

Smart electricity grids are expected to yield energy savings for homes and businesses, in particular if combined with home and business energy management systems. Through the use of smart meters, European households are expected to save 10% of their energy consumption per year (EC, 2011). In the US, the savings from smart grids are estimated to be 4.5 times the needed investment of USD 400 billion (EPRI, 2011).

Data-driven innovation in transport systems can save people time and money and reduce pollution and emissions in cities. The Intelligent Traffic System of London is estimated to reduce congestion in London by around 8% annually between 2014 and 2018 (TfL, 2011). 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 to 920 billion per year (MGI, 2013). Congestion charging in Stockholm has reduced traffic by 22% (100 000 passengers per day) and CO2 emissions by 14% (25 000 tons annually) in central Stockholm, during its 7 months trial period only (KTH, 2010).

Data-driven improvements in water systems can reduce water losses and cut operations and maintenance costs. “Smart water solutions” are estimated to save water utilities globally USD 7.1 to 12.5 billion per year through smarter leakage and pressure management techniques in water networks, smarter water quality monitoring, smarter network operations and maintenance, and data analytics in capital expenditure management (Sensus, 2012 in UKBIS, 2013).

Comprehensive and data-enabled strategies for waste reduction, recycling, material reuse and waste-to-energy conversion can save money and emissions. New York State’s “Beyond Waste” strategy is estimated to save as much energy as consumed by 2.6 million homes each year (280 trillion BTUs) and to reduce New York’s greenhouse gas emission by around 20 million metric tons annually (DEC, 2014).

*Source*: EC, 2011; EPRI, 2011; TfL, 2011; MGI, 2013; KTH, 2010; UKDBIS, 2013; DEC, 2014.

9. Many of the opportunities of smarter urban systems are being developed and exploited by large companies, which are shaping the emerging “smart cities” market. The term “smart city”, mainstreamed by IBM’s marketing campaigns, tends to cover a large range of different technologies, applications and services offered by companies like Siemens, IBM, Hitachi, General Electric, Cisco, Alstom, Arup or Microsoft, 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 estimates that worldwide revenues from smart city technology will grow from USD 8.8 billion 2014 to USD 27.5 billion in 2023 (Navigant, 2014).

10. An overwhelming number of cities have bought into the "smart city" narrative, much of which seems to remain a vendor push and promise so far. In the EU-28, around 90% of cities with over 500 000 inhabitants identify themselves as smart cities. However, only half of these cities have actually implemented relevant initiatives, most of which are small in scale, which indicates the extent to which the smart cities market is characterized by a vendor push rather than by market and government pull (EP, 2014; Schaffers, 2011). A different approach is practiced by market places like CityMart that facilitate the comparison of technologies and companies and therewith help cities identify appropriate solutions for their local and often specific challenges (CityMart, 2014).

11. 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 indeed be applied to "smart" applications, services, devices and machines. However, it does not capture all aspects of complex urban systems that interact both amongst each other as well as with human behaviour and social dynamics. It seems even less apt to characterise the heterogeneity of cities as compositions of human, social, environmental, economic, political, technical and other spheres. Most of all, despite its widespread use, and for this chapter, the term "smart city" provides no useful framework for analysing specific opportunities and policy implications of data-driven innovation in cities; it will thus not be used further.

***Improving urban mobility***

12. Using fuller and real-time information in urban transport systems can improve urban mobility. One area for improvement is dynamic traffic management. The intelligent traffic management system of London, for example, not only uses near-time traffic information to constantly adapt traffic light circuits, but is able to learn from on-going statistical observations of traffic patterns. It increasingly becomes able to predict traffic and respectively guide flows in anticipation of traffic volumes (TfL, 2010). Another area is dynamic road pricing based on real-time data on road demand. This 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 individualised road pricing that favours environmentally friendly cars (Stockholm) (CCLA, 2014; OECD, 2013b). Again another example are mobile apps such as moovel or citymapper that use real-time data on all transport options in a city and provide precise information on multimodal trips and traffic conditions. These and other data-driven innovations in urban mobility can make urban transport systems significantly more efficient, reducing traffic, congestion and pollution (Box 10.3). Such improvements are central to making cities more attractive to people and firms and to increase well-being and productivity in urban areas.

***Integrating urban systems***

13. Beyond improving single urban systems like transport or waste, synergies can be unleashed by fostering deeper integration of different urban systems. Understanding urban infrastructures or sectors as systems, a city can be considered as a "system of systems" within which ICTs and digitised urban flows are creating the potential for deep system 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 buses and taxis in the city drive with biogas produced through anaerobic digestion in Stockholm's wastewater recycling plants (OECD, 2013c). Real-time digital information shared across the different involved systems on gas demand in transport and gas supply from wastewater treatment plants 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 being re-used for residential heating via a district heating system that connects industrial with residential areas (OECD, 2013d). More systematic use of real-time data on demand, supply

and flows across different urban systems could deepen their integration and unleash synergies that cannot be reaped by optimising single systems in separation.

14. A good example of a single system that is becoming increasingly integrated with other urban systems through the use of ICTs and real-time information exchange is the electricity grid. A key element of such "smart grids" is demand and supply side management with smart meters, which enables efficiencies and savings within the energy system. A wider potential of smart grids however lies in their ability to integrate the energy system with other urban systems such as transport, for example a smart grid that integrates electric vehicles as energy storage and supply to help shave peak load electricity demand and to balance out fluctuating supply of renewable energy sources. Such integration is enabled by real-time information exchange between the energy and the transport systems and unleashes synergies resulting in efficiencies that could not have been reached within either of the systems separately (OECD, 2012b; IEA, 2011). While ICTs and the exchange of real-time information are key enablers in the functioning of a city as a system of systems and bring efficiencies through inter-system synergies, even more comprehensive integration will occur through increasingly pervasive machine-to-machine communication that can help transgressing many more boundaries of segmented activities, flows and systems in cities via the "Internet of Things".

**Innovation hubs**

***Turning cities into living laboratories***

15. The increasing production, collection and availability of data in cities turn them potentially 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 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, 2012; ENoLL, 2014). Many urban living labs focus on creating a favourable environment for data-driven innovation by providing the necessary infrastructure and institutional setting to support and attract innovators and investment (Box 10.2). The private sector has also discovered cities as ideal environments for data-driven innovation. Startupbootcamp Accelerator Programs established in several European cities focus on data-driven innovation in mobile, NFC, health and ecommerce; and IT companies like Microsoft have established their own incubators in cities like Paris, London and Berlin (Startupboocamp, 2014; Microsoft Ventures, 2014).

**Box 10.2. Porto Living Lab and Guadalajara Creative Digital City**

Positioning itself as a living lab, the City of Porto, Portugal, aims to provide ideal conditions for data-driven innovation. At the core is a high-speed network, an optical fibre backbone. 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 the company Cisco, amongst others. 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 high value-adding services, including urban services. The city aspires to become a digital hub in Mexico and to serve as a living laboratory for new approaches in urban development.

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

16. 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 (Box 10.5), 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 through hackathons during which a city makes data available to programmers (hackers) and entrepreneurs and at the end of which it rewards innovative applications, usually developed in a short period of time. While these events tend to be very productive, not many have spawned effective solutions that address deeper urban challenges. One reason might be that such hackathons rarely focus on key challenges cities are facing (Townsend, 2014). Another observed shortcoming is a lack of resources to scale up promising applications after the event (Mulligan, 2013). More recently, private companies have started embracing the concept of hackathons, making some of their data publically available for innovation, such as at the Dutch Open Hackathon in Amsterdam (DutchOpenHackathon, 2014).

***Exploiting new business opportunities***

17. The increasing amount of data on urban activities, flows and states that is accessible via fixed and mobile Internet has enabled new data-driven business models to emerge in cities. Over the past years innovative start-ups have entered markets in core urban sectors such as accommodation and transport by using the Internet or mobile apps as a platform to put idle resources to work. Known under the label "sharing economy", these platforms allow people to rent ("share") cars, rides and bikes or vacant space, including homes, offices and shops, whenever needed and available. They enable owners of assets and durable goods to turn them temporarily into services and to monetise them. Therewith, excess capacity of these assets and goods becomes available for collective consumption. For example, car owners rent their car if not used, sell seats on trips they do anyway or work as a private driver when time permits; or real-estate owners rent living or commercial space whenever vacant. On the demand side, urbanites get more and cheaper mobility options- travellers more choice for accommodation- and self-employed flexible access to commercial space and utility vehicles. Giving access to information assets and goods available for rent creates additional choices for consumers, but also new competition for incumbents in respective markets.

18. People have shared cars and rides for a long time, but smart phones and the use of real-time and geo-location data have allowed reinventing shared mobility models commercially and at larger scale. Cars

are among the most expensive and underused durable goods 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 it offers a flexible alternative to car ownership for many, in particular urbanites. And owners can earn additional dollars 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 them are peer-to-peer (P2P) 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 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 of the potential effects of car and ride sharing in urban transport estimate that it can significantly reduce cities' car fleets (Box 10.3).

**Box 10.3. Potential effects of shared mobility in urban transport**

Sharing cars, rides and bikes increases transport options in cities, reduces resource consumption and has the potential to change the overall face of urban mobility. Ratti et al (2014) find that on-road mobility demand in Singapore could be met with only 30% of the vehicles currently in use in the city. Further 40% could be cut if all people on similar routes were to share their cars with others. Altogether, today's on-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 in cities, as early evaluations of car sharing systems have found. A main reason for this is that car-sharing users do not necessarily give up their private car and many users that sign up for car sharing offers did not own a car in the first place (Le Monde, 2013).

Given that the sharing systems are in their early days, more time, experience and evidence is needed to judge their overall impacts on urban mobility. However, their success and economic potential indicate that their impacts will need to be considered: alone free-floating car-sharing systems are estimated to generate annual revenues of EUR 1.4 billion in OECD cities above 500 000 inhabitants by 2020 (Civity, 2014).

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

19. 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 online platforms like AirBnb have made short-term rentals of private spaces 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 public 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 and self-employed, the latter for pop-up stores, marketing campaigns or exhibitions. Home sharing in cities is likely to affect local economies, however it is still unclear how exactly (Box 10.4).

**Box 10.4. Potential economic effects of home sharing**

There is no comprehensive assessment yet of the economic effects of home sharing. However, exemplary 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 an accommodation through Airbnb in New York, generating economic activity worth USD 632 million. An Airbnb guest stayed 6.4 nights on average (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 of 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 they stay.

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 potentially negative 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 while renting their place.

Source: Airbnb, 2014; Zervas et al, 2015

## Urban governance

### *Leveraging new sources of data*

20. City administrations increasingly use crowd-sourced data to gain fine grained and real-time information on aspects such as public service delivery, system performance or infrastructure conditions. Mobile apps like SeeClickFix in the US or the BuitenBeter App in the Netherlands allow citizens to report on stray garbage, potholes, broken lamps and the like via their smartphone, directly into city hall. While this approach implies pro-active citizens, mobile apps such as StreetBump in Boston report without human intervention. Making use of the accelerometer (motion detector) and GPS, the StreetBump app automatically reports on street conditions in Boston, notably on potholes and bumps, via drivers' smart phones. Similarly, the Spanish app 2.0 incidències 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 on where and how many bicycle trips are done in the city. The fine grained data collected through such mobile apps enables cities governments to do more targeted and cost-effective maintenance, deliver better services and tailor public investments. A more general account of possible uses of data by governments, including by local governments, is given in Chapter 7 of this report.

21. Online, crowd-sourced, real-time and geo-locational data can also play an important role in managing disasters in cities. For example, Twitcident, a private company, makes online and social media useful for early warning systems and incident management services, applying filters and data-analytics to social networking sites like twitter and facebook. During the 2013 European floods, a citizen of the city of Dresden developed an online map that provided real-time updates on flood hotspots and guided volunteers to places where help was most needed (DLI, 2013). In Japan, the Tokushima Prefecture tested an evacuation system "Jointown", which relies on smart cards (IC cards) distributed to the residents, linked with their home TVs. In case of an evacuation the system recognizes which family watches TV and displays the evacuation order on their screen. Rescue workers in turn can be dispatched in a targeted manner. Furthermore, residents IC cards are scanned at the shelter to have up-to-date refugees' information. As a result, the evacuation time could be shortened significantly. While these examples give an idea of the multiple opportunities of using big data for disaster management, such tools can only be one

element of within a more comprehensive risk management strategy of a city, which needs to include digital security risk management, addressed in more detail below.

***Applying data-analytics***

22. Crowd-sourced, 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 and enables policy makers and enforcement agencies to identify crime patterns they would not detect otherwise (CityVox, 2011). This is particularly useful in areas where crimes tend to be less reported, such as in Central and South America. In the Netherlands, the application Buurt Bestuurt offers citizens the possibility to engage with the city and other citizens in various ways to improve living conditions, including safety, in urban neighbourhoods. Some city police departments, such as in Los Angeles, Chicago, Memphis, Philadelphia or Rotterdam, are developing capacity for analysing large and diverse data sets, including from social media, to support predictive policing. For example, data-analytics might help identifying potential future crime hotspots in which the police decides 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 been thoroughly evaluated to date.

23. More comprehensive data on flows in cities allow policy makers to design more targeted and effective incentives, which, however, might have unintended consequences. For example, volumetric tariffs, such as applied for energy or water bills in many places, have proven to be successful in reducing resource consumption of households (OECD, 2012c). The increasing availability of data on other flows in cities allows applying similar models to other areas such as waste disposal and recycling. Alternatively to such traditional economic incentive schemes, recent research found that social network incentives could be significantly more effective. 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 might be a desirable aim, the implications of nudging people's behaviors to become more rational are not yet well understood. As Frischmann (2014) points out, techno-social engineering is not only likely to ignore the values of those being nudged by a modified "choice architecture", but, if applied in institutional decisions, might generate irreversible path-dependency.

24. Larger data availability and greater computing power are also bringing urban modelling back into the spotlight of urban planning and have the potential to improve forecasting of societal demand. Urban modelling has appeared over 50 years ago, but its imperfections notably due to limited data and computing power have restricted its success. Its resurgence with the appearance of Geographical Information Systems (GIS) in the 1990s and 2000s went along with a shift from modelling aggregate equilibrium systems to complex, evolving systems of systems and urban dynamics (Eunoia, 2012; Jin, 2013). Geo-referenced data collected via crowd-sourcing, remote sensing, social networking, smart transit ticketing, mobile phones and credit card transactions, combined with new computational power, including cloud computing, create new potential for urban modelling, notably applied to transport or integrated land-use and transport planning (Nordregio, 2014). Opportunities of data-intensive urban modelling and simulations are being explored both theoretically, such as in the European Eunoia project, and practically: the LakeSim project in Chicago, for example, 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 demand for urban infrastructures and services has the potential to significantly improve resource allocation and investment decisions in urban areas.

**Policy implications**

25. The extensive collection and increasing variety and use of data in cities have great potential to spur data-driven innovation in urban systems, markets and governance. The extent to which these opportunities can be seized will depend significantly on policy makers, at the national and sub-national levels, which need to address issues raised by these data-driven developments. This section looks at some of the most important policy issues to be considered in relation to the data-driven innovations discussed above.

***Improving interoperability***

26. An important condition to advance the integration of urban systems and system-to-system communication is interoperability across different systems and components at different levels. International standards developed by standard setting bodies such as the IEC, IIEEE, ITU and ISO will be crucial for scaling up the implementation of complex systems such as smart grids and to further the integration of urban systems. Harmonised standards are a key element to achieve interoperability at the i) *technical* and syntax, the ii) *informational* and semantics, and the iii) *organisational* level (CEPS, 2014). Many of such standards do not exist yet, but some have started to be developed. ISO currently works on a standard for smart community infrastructures (ISO TC 268/SC 1), with the aim to contribute to harmonising complex system integration. Coordination of standards development to advance systems interconnection can be guided by models such as provided in ISO/IEC-7498-1, which identifies areas for standards development and improvement.

27. 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. A good example is the implementation of smart grids, which necessitates large consortia of companies from domains that have rarely collaborated before. The smart grid project in Issy-les-Moulineaux, Paris, for example unites urban infrastructure actors such as Bouygues Immobilier or ETDE, engineering and energy companies such as Alstom, EDF, ERDF, Schneider Electric and Total as well as Communications and IT firms including Bouygues Telecom, Microsoft and Steria, in addition to various start-ups (CGDD, 2012). Beyond smart grids, important technical issues will need to be resolved in the joint functioning of mobile network architecture, ICTs and Internet-based system architecture (Mulligan, 2013).

28. Another technical challenge related to systems integration comes with differing life cycles of different technologies, networks and infrastructures. This was pointed out in previous work by the OECD, which estimated relevant life cycles (Table 10.1). Furthermore, many technologies are being implemented in a complex legacy of existing networks and infrastructures, which in most cases were not designed for the data-driven applications and services discussed above.

**Table 10.1. 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<br>- maintenance | 30<br>10 |

*Source*: OECD, 2013a.

29. At the *informational* (and semantic) 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 open standards data sharing might 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 being pro-active in this area. Orange, for example, uses a Floating Mobile Data technology to anonymise mobile phone traffic data and make it available for re-use both for commercial purposes such as in navigation systems or traffic management as well as for research.

30. At the *organisational* level, governments have to overcome silo structures in administrations and improve cooperation among jurisdictions and levels of government. Coordination across different departments and agencies in public administrations has long been recognised as a crucial element of efficient and effective urban governance (OECD, 2009). These insights become even more pertinent in the context of cross-sectoral data sharing and data-analytics (Koonin, 2014). Few cities provide good practice in this area so far. Barcelona has put mechanisms in place to enhance coordination across different city departments as well as for public-private coordination on horizontal issues like urban data. Furthermore, the multiple jurisdictions that make up large urban areas, and multiple levels of government need to be coordinated to improve data sharing. In the US, for example, city school districts, jails, criminal courts and public housing are often not under the mayors' jurisdiction. Also data from welfare programmes (e.g. Medicaid) are usually not 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 cities (Lane, 2014).

31. Large companies operating in the "smart cities" market tend to offer systemic and vertically integrated solutions, too much of which could lead to horizontal market separation. Some of the largest players in this market offer a systemic approach with proprietary solutions, ranging from sensor technology to the urban "city cockpit" (Siemens, 2011). Other established firms in important sectors, notably energy and communications, have started purchasing companies up- and downstream to gain control over larger parts of the value chain. One example is AT&T Digital Life, the joint venture of Vodafone and British Gas on smart meters is another (OECD, 2013a). While vertical integration can help overcoming to some extent vertical fragmentation in markets that are characterised by too many proprietary solutions along the value chain, it might lead to horizontal market separation and to a lack of competition in the smart cities market.

***Managing digital security risks***

32. While advancing digital system integration in cities can yield benefits, it also creates new risks (risk understood as the effect of uncertainty on objectives). The more ICT, energy, transport and other critical urban infrastructures and systems are inter-connected the more a city as a system-of-systems becomes vulnerable to both internal and external uncertainties, ranging from technical failures to natural disasters and cyber attacks. For example, the flood caused by the 2012 storm Sandy in New York City triggered a power blackout, which immediately affected critical urban infrastructures, including transport and health, as well as backhaul to over two thousand cell sites in and around New York (Townsend, 2014). While the shock that triggered system failures in this case was a storm, in a different scenario it might be a cyber attack. Much as the electricity system, once the communication system, including the Internet, is down, an increasing number of critical urban functions will be affected and a failure in one system can propagate into other systems. In other words, with progressing digital integration of urban systems, digital risks are becoming new essential risks to be considered by cities.

33. 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; and sector specific on-site support by ICS-CERT

(2011-2013) concentrated in water and wastewater systems, transportation and energy (ICS-CERT, 2013). The majority of attacks are addressing the digital component of the respective system. In Israel, the Israel Electric Corp reported to receive 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 (Kitchen, 2014).

34. The dependency of urban systems on digital functions and interconnectedness makes digital security risk management an important element of a city's resilience, including its economic and social development. The core elements of a digital security risk management framework are addressed more in depth in chapter 6 of this report. Such a framework helps determine how to reduce the risk to the 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 the possible loss of the confidentiality, integrity or availability of digital activities which are becoming increasingly essential for the functioning of urban systems and services. In cities, digital security risk management should be fully integrated to overall risk management frameworks and approaches which address other types of uncertainties, i.e. not related to the digital environment. It should notably take into account interdependencies across digital and physical systems. The large amount of actors involved will make co-ordination and co-operation across jurisdictions, levels of government, as well as among interdependent infrastructure, business and IT actors a crucial condition for managing digital security risks.

***Fostering data-driven innovation***

*Review legal and regulatory frameworks*

35. New businesses labelled under the sharing economy have overcome high entry barriers and have created new competition in established urban markets, notably in 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 context that was shaped before their existence. While their activities thus tend to be at the margin of legality, companies try to establish themselves in existing niches and argue that legal and regulatory frameworks need to be reviewed. Several countries and cities have reacted by punishing new market entrants, protecting incumbents; some have simply declared the firms' activities as illegal or have imposed high fines to practically ban them from the market. Others encourage their activities, identify externalities and issues and started to address shortcomings in their legislation. Overall, given the early stage of development of the sharing economy, it seems counterproductive to simply prohibit the potential for diversifying and growing urban markets. Instead, policy makers need to better understand the economic and social impacts of these businesses in order to be able to address related issues if needed, while supporting traditional businesses to take advantage of new technological to innovate.

36. One example for a new mechanism that needs to be better understood is quality control via P2P ratings. P2P ratings and reviews are central in almost all sharing economy businesses models to create trust, but are not always used so far to their best ability to ensure transparency and quality control. In the sharing economy, buyers and sellers rate each other and write brief reviews, ideally after each transaction. For example, after having rented a flat, the guest rates the place on various aspects, such as cleanliness, and writes a brief qualitative review. The landlord does the same for the guest. This creates an incentive for the guest to behave well and for the landlord to deliver on promised quality. Ratings and reviews help both parties to know what to expect and are applied in a number of sharing economy businesses, including car or ride sharing. The idea of ratings and reviews is to create transparency, ensure quality control and to help

identifying fraud and misuse; however, their current application by many sharing economy businesses has several shortcomings:

- Reviews tend to overrate the service as unhappy users review less than happy ones. Most platforms and applications do not report the percentage of users having (not) rated the service.

- Most platforms or mobile apps reserve the possibility to remove reviews if they violate their review policy, but provide no information on the number of reviews removed.

- When feedback is based on ratings only (e.g. 1-5 stars) and does not provide any qualitative review, neither side receives information on how to improve.

37. Policy makers might consider issuing guidelines with minimum requirements for the application of ratings and reviews in the sharing economy as well as other measures to ensure quality control and consumer protection.

*Improve access to data*

38. Recognising the value of public sector data for citizens, innovators and entrepreneurs, many cities have started to publish their data. The interest and use of data to society is subject of the *OECD Recommendation of the Council for enhanced access and more effective use of public sector information* [C(2008)36], which recommends governments to implement principles like openness, access and transparent conditions for re-use, 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 (Box 10.5).

**Box 10.5. City open data portals**

Over the past years, many OECD cities have launched their open data portal, notably in the US and Europe. A City Open Data Census lists 70 cities in the US and provides metadata on their datasets (OKNF, 2014). In the EU, over 120 open data initiatives and portals of cities or regions are listed, and a pan-European search portal (publicdata.eu, beta version) harvests metadata (Datacatalogs, 2014; EC, n.d.). In most cases cities publish structured (linked) data in machine-readable formats to facilitate commercial and private use, however, only few cities offer APIs so far (Opencities, 2013). Many cities are using open-source data portal platforms or software such as CKAN or Socrata, but no standards for open data portals do exist so far. The EU Open Cities project tasked the German Fraunhofer Institute to develop pan-European specifications for Open Data administration platforms.

Opening access to data can be complicated, because of transaction costs occurring through agreements between different agencies, from contractual or legal issues flowing from data collection, or because existing rules are not adapted to data-driven service delivery and 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 this would infringe existing quality assurance protocols. Similarly, data from twitter and a more formal Police app used by the police in Rotterdam cannot be included in police reports for courts, given strict protocols the police has to follow.

Particular consideration needs to be given to the analytic tools at cities' disposal that enable data-driven insights and innovation. In many instances off-the-shelf business intelligence and data analytics tools are able to perform the required tasks. To what extent these tools suffice or when tailored solutions are required needs to be determined case by case. Common providers of such tools include IBM, SAP, SAS, Qlikview, Google Analytics and, when dealing with geo-data, esri and Google Maps. Google, Esri and Sense-OS not only provide data and analytics services, they also provide tools for developers to build new apps. Esri, for instance, works with 2CoolMonkeys who build open data tools on top of Esri platforms, for use by governmental agencies.

Another challenge for cities is to build the needed capacity and skills for collecting, storing and analyzing data at unprecedented depth and scale, as well as to acquire 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's Mayor's Office of Data Analytics and the Center of Innovation through Data Intelligence, the Mayor's Office of New Urban Mechanics in Boston and Philadelphia, or Chief Information Officers Chicago and Asheville, US. 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 too. With respect to infrastructure and computing power, many cities will not have the financial means and 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.

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 of whether or not to collect and publish specific data (Kitchin, 2013). The University of Rotterdam, Netherlands, has developed a decision model to help urban policy makers whether and how a dataset should be published for reuse (Gemeente Rotterdam, n.d.). More generally, the *OECD Privacy Guideline*s should be considered for guidance also at the city level. However more specific discussions are needed, for example on the usefulness of minimum requirements for city open data portals or on what data is appropriate or not to be public.

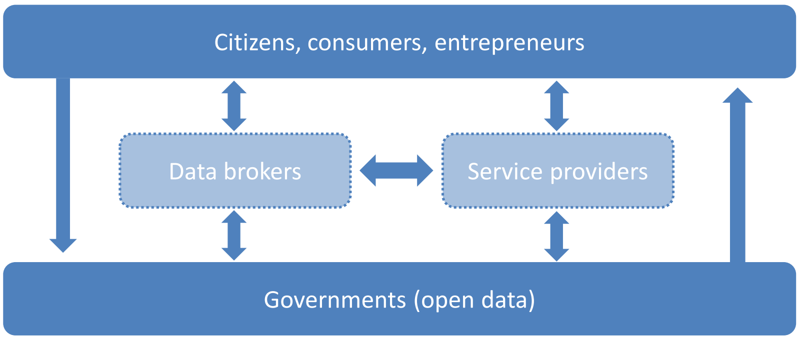
*Source* : Open Cities, 2013; OKNF, 2014; Koonin, 2014; Kitchin, 2013; Lane, 2014; TNO; Gemeente Rotterdam, n.d.; Datacatalogs, 2014; EC, n.d.

39. Private data providers including data brokers make additional data available, but they lack incentives and rules for using private data publically (see Chapter 4). Commercial data platforms like Esri or Sense-OS collect and (re)package open data, make it 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 finding data and provides interaction between its users. Data brokers like Experian, Factual and GfK collect open and proprietary data and provide market intelligence; however, they do not necessarily facilitate interaction and data sharing among various interested players, mainly due to commercial interest. 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 between the actors engaged in producing, collecting, handling and using proprietary and open data (Figure 10.2).

40. 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 and when, as well as to opt out of data collection and production. Only few private companies that collect data from individuals enable data portability. Data portability would allow individuals, latest at the point of ending a contract with a firm, to access their data in order to keep it or use it in another context (Hemerly, 2013).

**Figure 10.2. Actors handling proprietary and open data in cities**




*Source*: OECD

41. Some public initiatives are aiming to offer services to improve data portability. 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 *via* which consumers can access their financial, communication, health, insurance and energy data that are being held by businesses. The precursor of both platforms is *ProjectVRM*, a US initiate that provides a model for Vendor Relationship Management, launched in 2006. Private sector initiatives also include start-ups like *Handshake* that promises to keep individuals' data private, and allows them to hand data out deliberately for a reasonable price; or Green Button, which allows electricity consumers to have access to all data from their smart meters.

42. New guidelines may be needed to promote better access to data across the economy and to help overcome existing barriers to data access, linkage and re-use. 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 between public policies related to data access, linkage and re-use. This would also include the OECD Council Recommendations promoting better access to data, including in particular the *Recommendation of the Council for Enhanced Access and More Effective Use of Public Sector Information* of 30 April 2008 [C(2008)36], and the *Recommendation of the Council concerning Access to Research Data from Public Funding* of 14 December 2006 – [C(2006)184][1], both being currently under review.

***Implementing privacy principles***

43. Many of the opportunities and practices discussed in this chapter have implications for the protection of personal data and demand the implementation of privacy principles. The framework for privacy protection in the context of data-driven innovation is elaborated in Chapter 6 of this report and applies to cities as well. National and sub-national policy makers should focus on implementing the *OECD Recommendation concerning Guidelines Governing the Protection of Privacy and Transborder Flows of Personal Data* [C(2013)79]. Most principles in this Recommendation also apply in the context of data collection and use in cities. For example, in the case of predictive analytics, practiced by city police departments, using and linking large data sets, some of which include personal data, to inform anticipatory decision making raises privacy concerns that need to be addressed (White House, 2014). Cities are also likely to make increasing use of cloud computing and to outsource storage and computing outside the city's jurisdiction and possibly abroad. General privacy concerns related to cloud computing are therefore relevant for cities as well. In sum, policy makers, also at subnational and city level, need to step up to protect personal data and implement existing privacy principles in the evolving context of data-driven innovation.

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