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Smart Cities, Big Data and the Built Environment: What's Required?



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Report for Royal Institution of Chartered Surveyors

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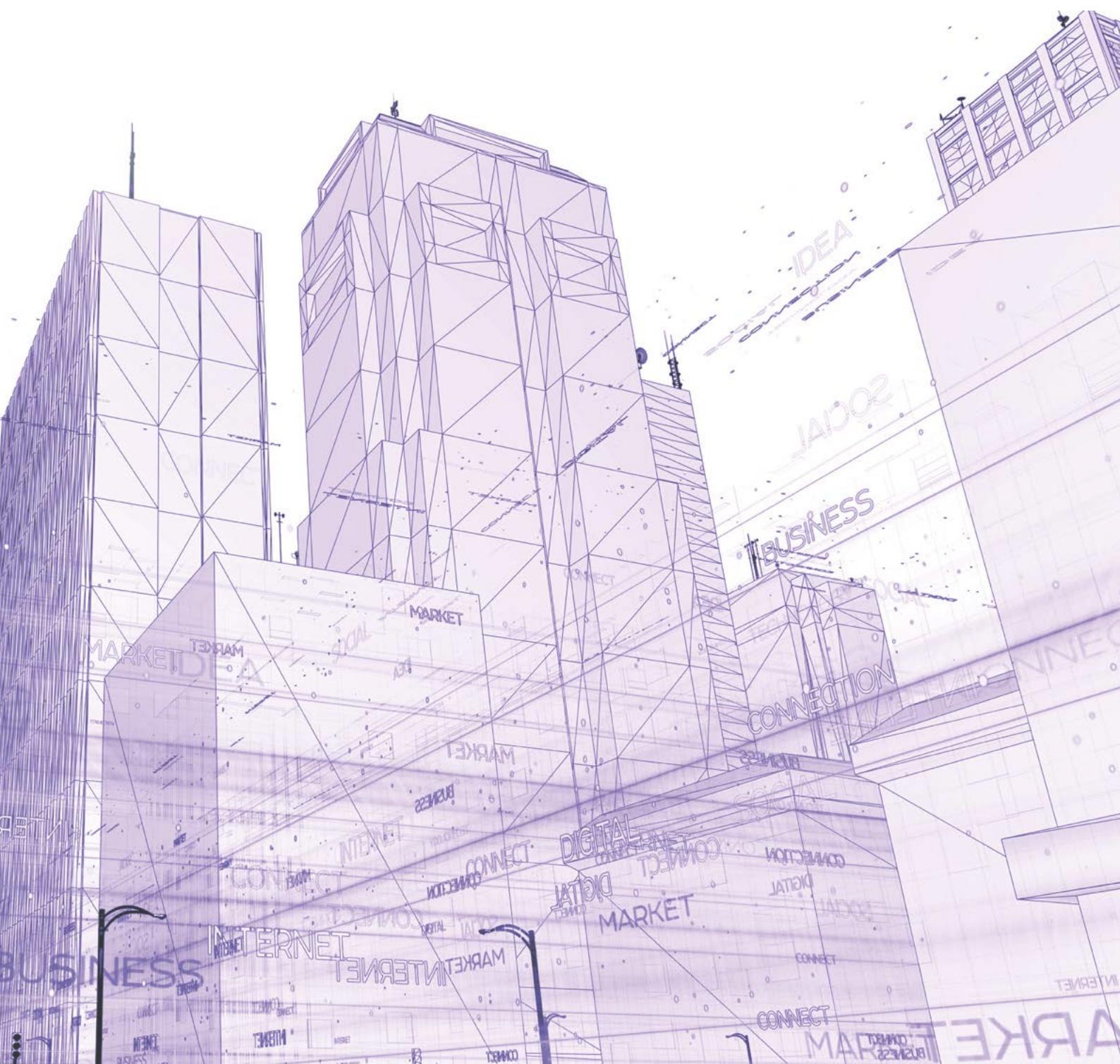
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Executive Summary

Background

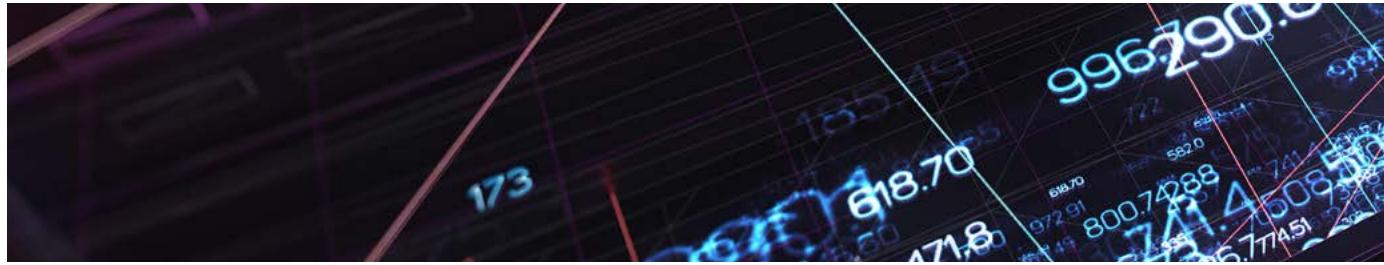
We live in an increasingly urbanised world. Currently more than 50 per cent of the world's population lives in cities, and this is set to grow to 70% by 2050 (UN, 2014). Recently we have seen a greater focus on information and communications technology (ICT) to argue the case for 'smart cities'. This places a strong emphasis on an ICT-led and a 'data-driven' future, which also positions the development of new products, processes, organisational methods and markets at the heart of the continued ambition for sustainable urban economic growth.

The interconnected agendas of smart cities, big data and open data, on the face of it, provide bold and exciting opportunities for the built environment professions, including RICS members. But, what in reality will those opportunities be, and what are the challenges? This research, conducted from 2015-2016, seeks to explore those questions and focuses on the city level.

The aim of this research is to examine the scope for the development of data platforms at city level in the UK and internationally and to determine how the RICS and its members (and other built environment professions, including architects, planners and engineers) can benefit from these data platforms. Focusing on 'big data' and 'open' data relating to the built environment, the research examines:

- The drivers and barriers for big data platforms at city level in the UK and internationally.
 - Key trends in the development and opening up of big data in cities.
 - The opportunities for client advice and the potential for RICS members to use big data creatively and innovatively to add value to their professional work.

Using an institutional analysis approach, the research consisted of an online scoping survey of UK smart cities; four case studies in Bristol, Milton Keynes, Amsterdam and Taipei; and a UK expert workshop.



Main findings

The big picture in UK smart cities

Only 47% of cities in the survey had an established definition for a smart city, with a majority adopting the BSI smart city definition¹. Moreover, high level planning at city level is not common: only 22% of respondents had a smart city action plan and only 22% had a smart city framework.

Similarly, only 33% of respondents stated their city had a data strategy and only 22% stated that the strategy mentioned big data. On the other hand, some 61% of respondents suggested their city had an open data platform.

Key message: *In the UK, there is an apparent lack of strategic thinking in smart cities and the current focus appears to be on open data rather than big data.*

'On the ground': what is happening in UK smart cities and internationally?

All four case studies showed a primary focus on open data, with big data playing a secondary and evolving role. The open data hubs are currently free of charge in each city and offer access to some 'built environment' data, including transport, energy land use and property etc. However, there was often scepticism expressed about the illusory nature of 'big data' by the interviewees. Although there were examples of big data built environment projects, there was also a marked lack of engagement by the built environment sector (property and construction), both in terms of (i) direct data provision to data platforms at city level and in terms of (ii) direct engagement with smart city built environment projects at city level. This generally reflected issues over data confidentiality but also the nature of the property and construction sectors in terms of their fragmented nature, different timescales to the digital sector, and issues over the interoperability of data.

Key message: *Although there is some evidence of built environment big data projects, the main focus in the smart city case studies is on open data. There is little or no evidence of the real estate and construction sectors engaging directly with the smart city agenda.*

The challenges of built environment big data

Despite the promise of big data, the research shows a number of challenges surrounding the development of big data projects in the built environment:

- **Definition and measurement:** defining what we mean by 'big data' is difficult. Different meanings and interpretations can be put on the term and distinctions in the terminology were seen as unhelpful. Our interviews also showed much scepticism around the concept of truly big data and whether it was yet available.
- **Business engagement:** moving the debate beyond simply government or local government led initiatives is proving difficult. There is evidence to suggest that the property and construction sectors are underdeveloped in terms of overall digitisation and big data applications, in comparison with other industry sectors. Part of the solution might be a market-based data exchange at city level (Milton Keynes), or the development of different data platforms for cities (Amsterdam).
- **Interoperability:** the ability of different ICT systems to work with a variety of datasets is also a critical issue to bear in mind. The proliferation of data standards and general fragmentation in the built environment sector (actors working to their own specific objectives without seeing the value of leaving their operational 'silos') is not helpful.
- **Top-down approach:** in the UK workshop, it was felt that the smart city agenda is very much 'top down', with much of the impetus provided by software and hardware vendors, whereas in fact what was needed was a 'bottom up' demand focused approach, provided through a more BIM-led, asset management focus.

¹ "Smart city" refers to 'effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens' [BSI, 2014].



Policy and practice implications: what's required?

Overcoming the barriers and enabling the built environment sector to engage in smart cities, big and open data requires a more detailed appraisal of two key issues:

- Understanding the use and supply of built environment big data.
- Recognising the changing roles of stakeholders.

Use and supply of built environment big data

There needs to be a primary focus on **procurement and digital assets**. Firstly, there is a need to understand the requirements of the built environment sector in terms of data. The identification of these requirements needs to be embedded within the procurement process and aligned with the delivery and operation of built environment assets. Secondly, the future use of data needs to be tackled by embedding interoperability in the built environment sector, and focusing on how the data will be used in the context of the smart city.

Engagement at the right time and with the right stakeholders

stakeholders is important. The contractors and delivery partners in projects need to discuss options for data gathering, sharing and analysis with their clients at the procurement stage. This requires organisations to be 'data savvy'; to identify where big and open data can help inform and improve the operation of their own organisations, as well as those of their clients. Citizen engagement is also vital; people must be able to understand data gathering and sharing in the development process, as well as understanding the benefits and drawbacks of data sharing.

Creating trust and brand is important in the built environment sector. This begins with agreement upon common data standards and a common language for data. The real estate and construction sectors can learn from other industries such as technology, retail and the aircraft industry, where trust and brand are paramount.

Dealing with **liability and regulation** will also be increasingly important to consider. For example, what happens when projects fail, or decision-making is based on incorrect data? What needs to be done about liability and regulation in this difficult field? Data quality, provenance, validation and security are therefore all important issues to consider in the built environment sector.

Recognising the changing roles of stakeholders

Cities need to develop clear **smart city strategies** and data strategies (covering big data and open data) which provide greater certainty for all stakeholders. There need to be **improved incentives** for companies to provide open data and big data, through the development of viable commercial business models.

Professional bodies within the built environment sector (including RICS and RIBA) need to determine what role they and their members should have in relation to data (open and big) in the context of smart cities.

Promoting the agenda through **champions for change** in the professional bodies is vital and collaboration across the built environment professions is a critical issue to address.

Data skills and smart city skills (relating to data analytics and data management, for example) are cross-cutting skills which need to be embedded within, for example, professional competencies. Built environment professionals need to be able to gain a much better understanding of the data needs and requirements of their clients, as well as the potential impacts of big and open data on professional advice in this area.

It will also be important for the professional bodies to be more **closely aligned** with tech companies, city authorities and other stakeholders in the smart city agenda. This will help provide further impetus to enable all stakeholders to work together to deliver **improved services for citizens**.

Key message: *This research has examined both open data and big data through the lens of the smart city. It has highlighted many issues for consideration by built environment professionals and their professional bodies, especially regarding how best to engage with the smart city and BIM built environment agendas.*

There is evidence to suggest that the real estate and construction sectors (and related professional services) do hold big data and are using it internally for client services and other activities. A key challenge is to find out whether, and how, this data could be used in a smart city context, and in other potentially collaborative ways. Further research is therefore needed to examine what data is held by such organisations and how it could help underpin and drive both the smart city and BIM built environment agendas in an integrated way.

1.0 Background and context

1.1 Introduction and research focus

The interconnected agendas of smart cities, big data and open data, on the face of it, provide bold and exciting opportunities for the built environment professions including RICS members (RICS, 2015). However, what in reality will those opportunities be, and what are the challenges to realise those opportunities?

The research focus is on smart city programmes, set in the context of specific smart city built environment projects and their relationship with open data, some of which may also be big data. The research aims to examine the scope for the development of data platforms at the city level in the UK and internationally and to highlight the potential benefits of these data platforms for the built environment professions².

The following section examines the emergence and meaning of the term 'smart city', before discussing the parallel emergence of 'open data' and 'big data' in the context of the 'built environment'. The emerging opportunities for the real estate and construction sectors are then examined in relation to big data and open data, in the context of smart cities in the built environment. This is followed by a review of the key research questions which the current research addresses

1.2 Smart cities: definitions and origins

There are many definitions for the concept of 'smart city'. These not only reflect the differing origins of the concept, but also the varying disciplinary and institutional lenses through which a city can be viewed (Moir et al, 2014; Kitchin, 2015; Glasmeier and Christopherson, 2015; Albino et al, 2015). Appendix 1 provides some examples of smart city definitions which vary according to the groups (government, academia, consultants and industry standard bodies) which provide them.

Kitchin (2014, 2015) identifies two distinct understandings of 'smart' cities. Firstly, the term is often used to describe the increasing extent to which cities are composed of pervasive and ubiquitous information and communications technology (ICT). This ICT is embedded in the urban fabric through fixed and wireless telecoms networks, sensor and camera networks, and building management systems (Townsend, 2013). Secondly, the term has also been used to refer to the wider benefits to the economy and to innovation that can be gained by developing and

enhancing the knowledge economy in a city region. In this perspective ICT is seen as a platform for bringing together ideas and innovations, especially with regard to the professional services (Logan and Molotch, 1987).

The smart city movement is not without its critics, however. For example, Adam Greenfield's (2013) work suggests that we should be wary of the influence of a neo-liberal ideology, which can be seen as mixing technocratic governance with mass surveillance. Townsend (2013) argues for a more socially inclusive notion of a smart city, where greater importance is attached to bottom up innovation (innovation driven by citizens themselves), rather than what many perceive as a 'one size fits all' top-down approach (driven by technology companies and consultants). NESTA (2015) also highlights 'practical flaws' with the smart city concept:

- A tendency to start with technological solutions rather than urban challenges.
- An insufficient amount of evidence to suggest that smart city solutions help cities address 'real world' problems.
- Limited transfer of learning between smart city projects.
- Few opportunities for citizens to engage directly in the design and deployment of new technologies. This is supported by recent research in the UK by YouGov and Arqiva (Arqiva, 2016) which suggests 96% of people are unaware of smart city initiatives in their own city.

1.3 Smart cities in practice: a global phenomenon?

Smart city projects come in a range of types and sizes and have a variety of different characteristics (Cosgrave et al, 2014). Some projects relate to new cities and others to existing cities. Zegras et al (2015) state that for some of the biggest cities in the world, such as Dhaka in Bangladesh, something as simple as a transit map is not available. What is 'smart' for one city may already be widely available in other cities therefore (Glameier and Christopherson, 2015).

Although the number of smart city projects is growing globally, they differ within their individual and national contexts and reflect complex and subtle variations in national policy and regulatory structures. According to Lee et al (2014) there were 143 ongoing or completed self-designated 'smart city' projects globally in 2012, divided between Europe (47 projects); North America (35 projects); Asia (40 projects); South America (11 projects); and Middle East/Africa (10 projects). Recent research within the EU-28 (Directorate General for Internal

2 For a definition of the key terms used in this report see section 2.1.

Policies, 2014) identified 240 cities with significant and verifiable smart city activity (i.e. with evidence of active smart city projects) with particular hotspots in the UK, Spain and Italy.

There has been a particular emphasis on developing smart cities in the BRIC countries in recent years.

According to the Chinese Smart Cities Forum (Liu and Peng, 2013) 6 provinces and 51 cities have included an explicit emphasis on smart cities in their plans, with 36 under construction. These projects are primarily technology focused, with relatively less attention given to environmental and social issues. A number of south-east Asian cities, such as Singapore, South Korea, Taiwan and Hong Kong are following a similar path, promoting 'economic growth' through smart city programmes (Albino et al, 2015). These include Singapore's IT2000 plan to create an 'intelligent island' and Taoyuan's E-Taoyuan and U-Taoyuan projects³.

The UK government is currently using a 'market-making' approach to smart cities by trying to create conditions conducive to business growth (Centre for Cities, 2014). The government therefore acts as a 'co-ordinator' through initiatives such as the Smart Cities Forum (through the former Department of Business Innovation and Skills (BIS)) and the Future Cities Catapult (which has supported projects in a number of cities including Aberdeen, Bristol, Birmingham, Leeds, London and Milton Keynes)⁴. In the UK, the picture is one of experimentation at the city level. In many cases the concept of a 'sustainable city' is integrated with that of a smart city and its agendas and projects (Caprotti et al, 2016). Additional funding for smart city projects in the UK has also come from the EU (although the latter may be limited in the future, following Brexit (Hoare, 2016). However, a recent survey by Zodion (2016) found that a lack of budget, leadership and capability are holding back the rollout of smart city projects across the UK.



³ In India, there are plans to create 100 smart cities at a cost of £445b. Several of these projects have already begun, including Kochi Smart City and Naya Raipur smart city [UKTI, 2015]. The Indian government plans to develop these as satellite towns of larger cities and by retrofitting existing medium-sized cities so that both will act as magnets for investment and development. ⁴ The government has also acted as a 'funder' through Innovate UK, and as a 'regulator' by working with such bodies as the British Standards Institute. The All Party Parliamentary Group [APPG] on Smart Cities also brings together a range of key stakeholders.

1.4 City data, open data and big data: definitions

Data lies at the heart of the smart city concept. This is because city governments and businesses require data and information to be able to provide appropriate and timely services and products to their citizens and customers. In this section, the terms 'city data', 'open data' and 'big data' are defined.

1.4.1 City Data

City data can be defined as (EIP SCC, 2015: 5):

'Data that is held by any organisation – government, public sector, private sector, or not for profit – which is providing a service or utility, or is occupying part of the city in a way that can be said to have a bearing on the local populations and the functioning of that place'.

In a general sense 'city data' can be divided into three main categories of data (OECD, 2016):

- **Flows** of resources, products, people and information across cities, measured by sensors.
- **States** of urban spaces and environments, which measures, for example, density of people and environmental factors through sensors, satellite imagery or continuous observation.
- **Activities** of people, machines and devices, and the measurement of transaction, consumption and communication patterns.

A recent survey of 30 cities (UK and international) found that data was being collected by city authorities on more than 14 categories ranging from infrastructure through to health and technology (Figure 1.1) (BSI/OS, 2015). The research found that there was a particular need for data to support projects in:

- Social and community.
- Transport and mobility.
- Infrastructure.
- Technology.

Figure 1.1

Required data to support city projects [relative importance as percentage]

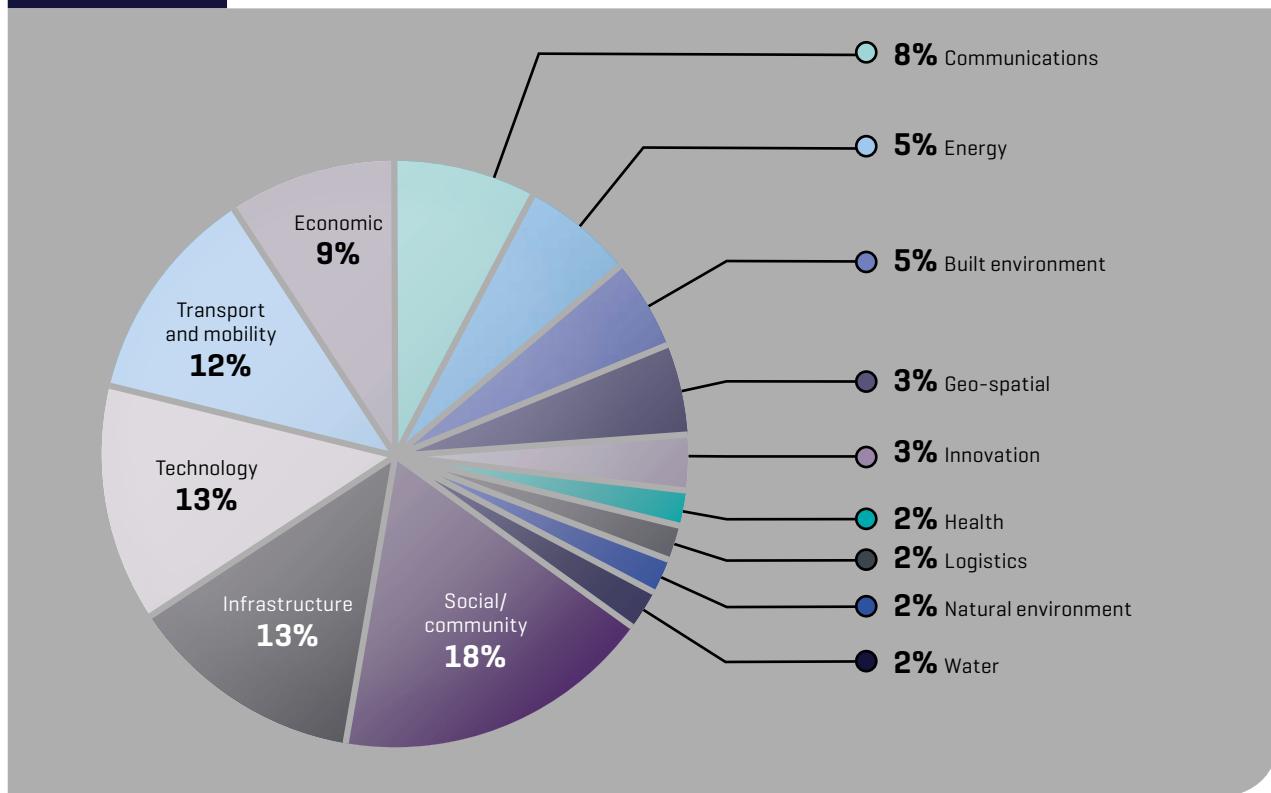


Figure source: BSI/OS, 2015

Despite this demand for certain types of data to support city projects, a number of barriers to data collection, curation and dissemination exist:

- 1. Data on cities is fragmented or scarce.** Different types of city data have traditionally been sourced through a combination of official government surveys and small, non-continuous data sets created by local government, business and academia.
- 2. Data regulation and protection are underdeveloped.** While new developments have meant that data sets are increasingly complemented by data that is produced by sensors and crowdsourcing (Batty et al., 2012), this has raised concerns over ownership and privacy.
- 3. Organisational silos discourage data inter-operability and can create unintended duplication.** The presence of data silos operating across local authorities and public sector organisations can lead to data duplication. This can also create differing views and perspectives on data sharing between organisations and their interpretations of data protection legislation. There may also be a lack of appropriate data skills to curate and develop city data (Policy Exchange, 2016).

City data (which includes data on the built environment) can be 'open data' or it can be 'big data', and these terms are now defined.

1.4.2 Open data

Open data can be seen as accessible, public data that people, companies and organisations can use to develop new ideas, analyse patterns and trends, make decisions and solve problems (Gurin, 2014). The move towards an open data model is part of a wider online shift towards the democratisation of data and software. Although definitions vary, the Open Data Institute (2016) defines open data as 'data that anyone can access, use or share'. The UK Government (HM Government 2012: 8) suggests that open data needs to meet the following criteria:

- Accessible (ideally via the internet) and at no more than the cost of reproduction, and without limitations based on user identity or intent.
- Digital, machine readable format.
- Free of restriction on use or redistribution.

In the UK, the move towards open data is being led by central and local government. In 2010, the UK Government created the Open Government Licence (HM Government, 2014a), under which public bodies can now opt to publish their Crown Copyright material. The Open Government License ensures data is available under a free, perpetual licence without restrictions beyond attribution. Since February 2015 local authorities are also required to publish open data as specified in the revised Local Government Transparency Code.

The provision of data in an open format on open data platforms has provided opportunities for improved service provision through:

- Better planning and predictive analysis.
- More efficient construction and better asset management in cities.
- Improved citizen engagement.
- Revealing hidden and important relationships between data (Future Cities Catapult/Arup, 2014; OECD, 2016).

1.4.3 Big data

Big data refers to data that can no longer be captured, stored, managed and analysed using conventional methods. In the UK, the government has classified big data as one of 'Eight Great Technologies' and defines big data as:

'...both large volumes of data with high level of complexity and the analytical methods applied to them which require more advanced techniques and technologies in order to derive meaningful information and insights in real time' (HM Government, 2014b).

Given these definitions of big data, big data analytics are becoming increasingly important as a means to draw out new meanings, insights and value from bringing together big datasets. Big data can also be characterised by the following five features (ISO/IEC, 2014a; Gandomi and Haider, 2015):

- Large volume or magnitude of data.
- Wide variety or structural heterogeneity in datasets.
- High velocity or rate at which data are generated.
- Very variable or variation in the data flow rates.
- High degree of veracity or reliability inherent in data sources.

Gandomi and Haider (2015) discuss additional features which can be associated with big data, namely its complexity (because of its variety of sources) and value (it contains relatively low information value in relation to its volume).

Big data analytics can be characterised by their advanced data storage requirements, data management, analysis and visualisation technologies, which traditional business analytics are not able to offer (Janssen, Matheus & Zuiderwijk, 2015). The creation of big datasets (generated primarily by the decentralised nature of computing) and the ability to connect and analyse the huge amounts of data, created through pervasive and ubiquitous ICT and mobile networks has created powerful possibilities (and challenges) for cities and other stakeholders and actors in the smart city agenda (GLA, 2015). ISO/IEC (2014b) identify new sources of economic value, fresh insights into science and the ability to hold governments to account as some of the benefits that big data analysis can yield.

Figure 1.2 shows the relationship between big data, open data and open government (or the doctrine which promotes the use of transparent and open data relating to central and local government activities). The figure indicates that, for example, some big data may not be publicly available in the commercial sector (section 1 of the figure). The figure also shows that data does not have to be 'big' to be 'important'. Open data from local government on transport and mobility (section 4) can help people by providing information to them directly, or by providing the basis for new and innovative smart applications at a city level (for example, transport or mobility applications for use on smartphones). Big data can also come from other sectors such as scientific research and social media. It is unclear, however, if there are currently many examples where the open data and big data domains overlap directly and, if they do, much can also depend on how both are defined.

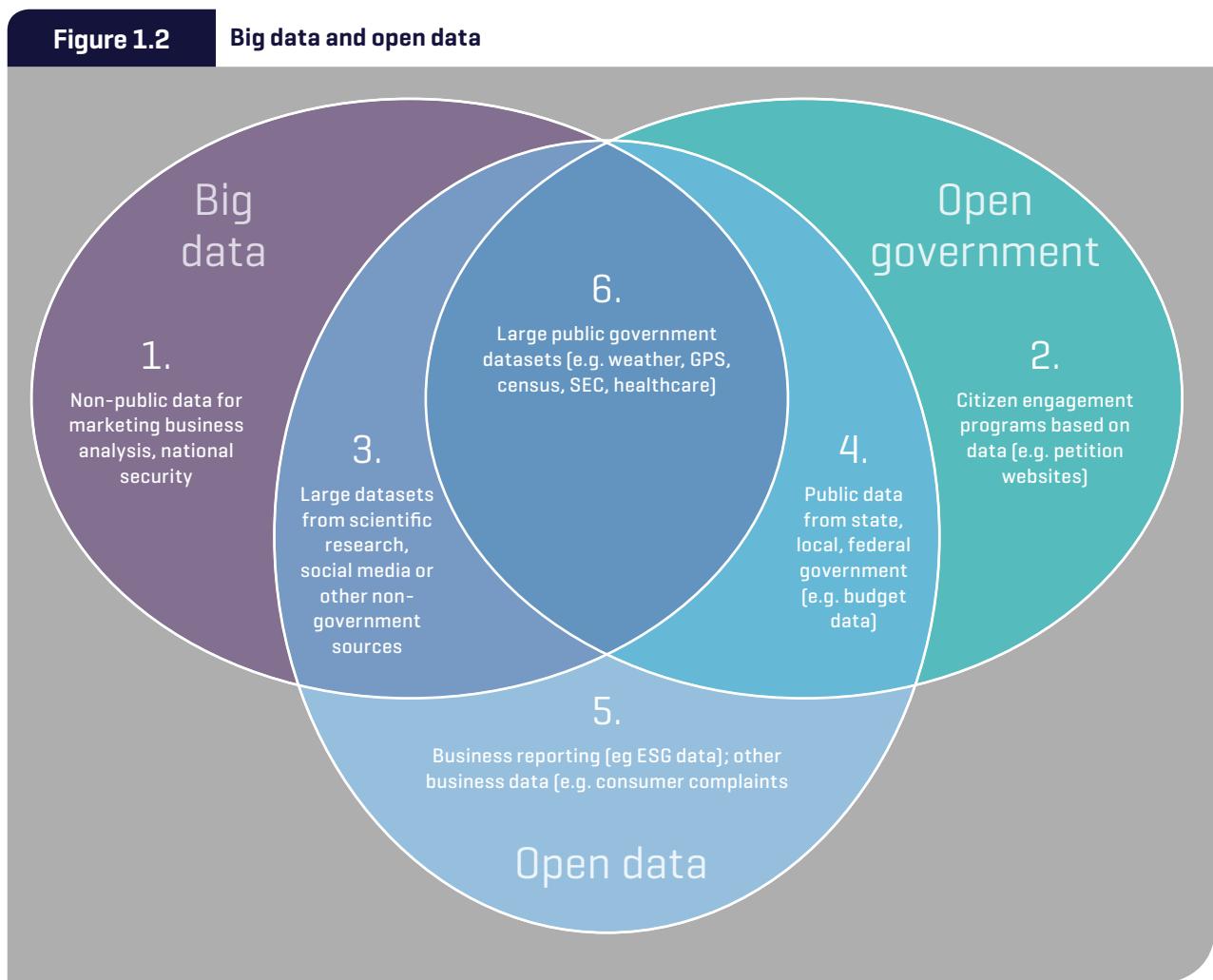


Figure source: Gurin, 2014

1.5 Policy and practice challenges for open data and big data in smart cities

In many of the smart city projects we see today, city data is seen as fundamental to success. However, there are a number of complex challenges to using both open data and big data in a smart city context (OECD, 2016). These include:

- **Interoperability and common standards.**

An important prerequisite for integrating urban systems and for developing open data and big data platforms is interoperability across different systems and components at different levels. International standards, such as those developed for smart cities (BSI, 2014; ISO/IEC, 2014b) and city data (City Data Standard, ISO 37120) for the sustainable development of communities (WCCD, 2014) are therefore seen as vital in scaling up the implementation of these projects⁵.

- **Opening access to data.**

Open access to data can be complex because of transaction costs and contractual and legal issues which can arise from data collection. Sensitive issues such as privacy and confidentiality may also need to be addressed when it comes to what data should be collected and what can be made freely available. Also, commercial interest or regulation may impede private companies from using their proprietary data for uses which will benefit the public. Conversely, regulation may impede the use of public data by companies for their private benefit.

- **Security and privacy.** The more connected ICT, energy, transport and other critical urban infrastructure become, the more a city ‘system-of-systems’ becomes vulnerable to internal and external threats including cybersecurity and natural disaster. For example, Hurricane Sandy in New York City caused a power blackout which impacted on urban infrastructures such as transport and health. The use and interlinkage of big datasets, including personal data, for service delivery or other kinds of smart city activity (such as cloud computing functions), also raises issues over privacy and ownership.

1.6 Open data and big data: smart city built environment use cases

In this section, some of the examples of smart city projects using big or open data that has been developed within the built environment context are described. A sectoral focus is adopted in the first part of this section in order to address the specific experiences of the real estate and construction sectors. The section then discusses impact of open data and big data on the built environment professions.

1.6.1 Open data and data hubs

Some city data may be open data and market estimates as to the value of this are substantial. The direct market size of the combined real estate and construction sector’s use of open data in the EU 28+ is estimated at 11.7 bn EUR for 2020 (21% of the total market) (European Union, 2015).

A number of cities have developed open data ‘hubs’ or ‘urban platforms’ (Barbosa et al, 2014; EIP SCC, 2015) in parallel with smart city programmes. An urban platform has been defined as:

‘a logical architecture/content/design that brings together data flows within and across city systems and exploits modern technologies (sensors, cloud services, mobile devices, analytics, social media etc.)’ (EIP SCC, 2015: 5).

In the UK, examples of open data hubs include the London City Datastore; Leeds Data Mill; Bristol is Open; and Milton Keynes Smart Data Hub. Elsewhere, New York’s Mayor’s Office of Data Analytics and Copenhagen’s City Data Exchange (promoted as the World’s first city to create a city data ‘marketplace’) offer similar examples of city level open data and analytical platforms. These platforms differ in their nature and extent: some may be more open (accessible to the general public), while others may contain big datasets which are not necessarily fully ‘open’.

The growth of open data in a smart city context is opening up possibilities for new business models to be developed which relate to the use and supply of open data (Janssen and Zuiderwijk, 2014). In this respect, Carrara et al (2015) suggest that there are four types of open data ‘re-users’:

- **Enablers:** organisations that supply open data, which comprise mainly the public sector.
- **Enrichers:** larger organisations that use open data to enhance existing products and services.
- **Developers:** organisations that design, build and sell smart applications. Some cities, for example, have provided Application Programming Interface (API) portals to enable applications (or ‘apps’) by developers to link and use open data for a range of uses in energy, transport and health.
- **Aggregators:** organisations that collect and aggregate open data.

⁵ See also the Hypercat standard which lies behind the Internet of Things [Hypercat, 2017].

1.6.2 Potential uses of big data in the real estate and construction sectors

In the context of smart cities, 'big data' can potentially provide new opportunities and models for business in such areas as energy performance analysis in buildings, applications in financial markets, real estate transactions, predictive asset management and Building Information Modelling (BIM) (RAE/IET, 2015; RICS, 2015; Sawhney, 2015).

In the real estate sector, there is potential to use big data for buildings (in relation to design, operations and management), in the provision of buildings services and in improving market understanding (Catella, 2015). Very large datasets which change rapidly may have the potential to provide new analytical insights or new ways of visualising data, for example:

- Large portfolio owners or companies providing property services may have very large datasets providing details on land and buildings (e.g. floor space and layout or energy consumption) (JLL, 2014).
- Big data analytics can improve understandings of energy consumption in retail stores in a large property portfolio, leading to potentially better informed decisions by energy managers (Janda et al., 2015).
- The ability to analyse and transform large data sets can also help the real estate sector provide a better understanding of customer profiles and customer services (Catella, 2015).
- In property finance and investment markets, big data strategies can produce insights that help in risk assessment and taking investment decisions (Catella, 2015).

In the construction sector, the use of big data from BIM provides considerable potential for optimising the use of resources and waste, generative design, performance prediction, visual analytics and energy management (Bilal et al, 2016). The UK government's Digital Built Britain report (HM Government, 2015) states that, in particular, the agendas of BIM and smart cities are closely aligned. For example, by providing BIM data and information, it is possible to model the impact of new buildings on transport demands, healthcare, air quality and also to inform decision-making on the best location, linking BIM data on the buildings with wider, city data (BSI/OS, 2015). BIM recognises that whole lifecycle information needs to be made available and shared with a range of actors, including asset owners, financiers, developers, architects, residents and local council (*ibid*).

Despite there being a substantial potential for the use of big data in both the real estate and construction sectors, there is some evidence to suggest that both sectors are currently relatively underdeveloped in terms of overall digitisation and big data applications, in comparison with other sectors (PwC, 2012; Gandhi et al., 2016). These differences may reflect the fact that both sectors are relatively labour intensive. In particular, construction is a highly fragmented industry with a variety of stakeholders where much of the data, although voluminous, may still not be stored electronically (McKinsey (2011). Construction data is also often produced using a variety of formats and standards, making 'interoperability' a key issue between different sub-sectors within the industry such as architectural, structural and energy (Bilal et al., 2016).

A study conducted in the US by McKinsey (2011) suggests that both construction and, to a lesser extent, real estate service companies lag other industries in terms of their big data potential and big data ease of capture. This is attributed to low data productivity (see also Brown et al, 2011). Byfors (2014) attributes the relatively limited potential for developing big data in the construction sector to its fragmented nature, relatively weak learning, strong institutional norms, rules and procedures and lack of digitisation.

Despite these challenges, new start up 'realtech' or 'proptech' companies are emerging, which are focusing on big data applications and uses. Much of the investment in venture capital in this sector is in the USA (CB Insights, 2016) Examples include Compstak (Compstak, 2017), where real estate professionals can share commercial lease information anonymously, and SmartZip (SmartZip, 2017), which uses algorithms to analyse big data on properties and identify those which are most likely to sell within a certain period. Examples in the UK include 'Deal X'; a commercial property listing system and the 'Building Data Exchange'; an open data platform which contains building performance data on more than 100 Innovate UK projects (Deal X, 2017; Building Data Exchange, 2017; RICS, 2017; Metaprop, 2017). The emergence of BIM is expected to help develop digitisation and big data use in the construction sector (HM Government, 2015). There is also an emerging construction tech startup market focused primarily on the collaboration between the software and data analytics sub-sectors (CB Insights, 2016), with an increasing use of Artificial Intelligence (AI) in the real estate sector.

⁶ The Digital Built Britain report [HM Government, 2015], suggests that there are three predominant datasets which are core to BIM. These hold data from the operational, delivery and performance management phases of a portfolio, programme or project.

1.7 Open data and big data applications in the built environment professions: an overview

The potential for increasing the availability of open data and big data in the built environment could create market opportunities for built environment professionals in the use or supply of data and as intermediaries in the data supply chain (RAE/IET, 2015; RIBA/Arup, 2015; IET, 2015; RICS, 2015). As the RICS Futures Report (2015: 33) also suggests:

"Our own sector collects data on valuations, building condition, construction costs, leases, maintenance programmes and operational costs. If we start to take data from public sources in any other country – such as data on land, property value, occupier information, utilities and more – and combine that with local data, our sector holds enormous potential to change how we work".

The big data and open data that can support built environment professionals in a more specific smart city and 'built environment' context relate to such areas as land, buildings, planning information, transport and energy (Table 1.1). The defined users (and producers) of city data may therefore include built environment professionals from property (or real estate), construction, architecture and planning (RIBA/Arup, 2015).

The emergence of smart cities and big data, particularly with a focus on big data analytics, has also opened up opportunities for urban planners (Batty et al, 2012; Bettencourt, 2013; Tharukiah et al, 2015). Big data analytics provides the potential to bring together large datasets on transport, land-use, buildings and health, which can be used to support decision making and long term planning through better analysis of urban planning problems.

1.8 Summary and current research focus

The data which are becoming available in the context of smart cities offers various opportunities for built environment professionals and property and construction companies. These opportunities include:

1. Using data from smart city projects supplement and enrich advice provided to clients.
2. Partnering with city authorities and others to develop mobile applications.
3. Contributing (and being seen to contribute) to the development of open data platforms at the city level.

There are important questions to consider about the opportunities that the development and opening up of open and big 'built environment' data in smart cities could create for professionals in the built environment (including RICS members) who wish to add value to their professional work. For example, what is driving and inhibiting the trend to open and big built environment data at smart city level? Which smart cities are particularly successful at working with the built environment sector in an open data and big data context?

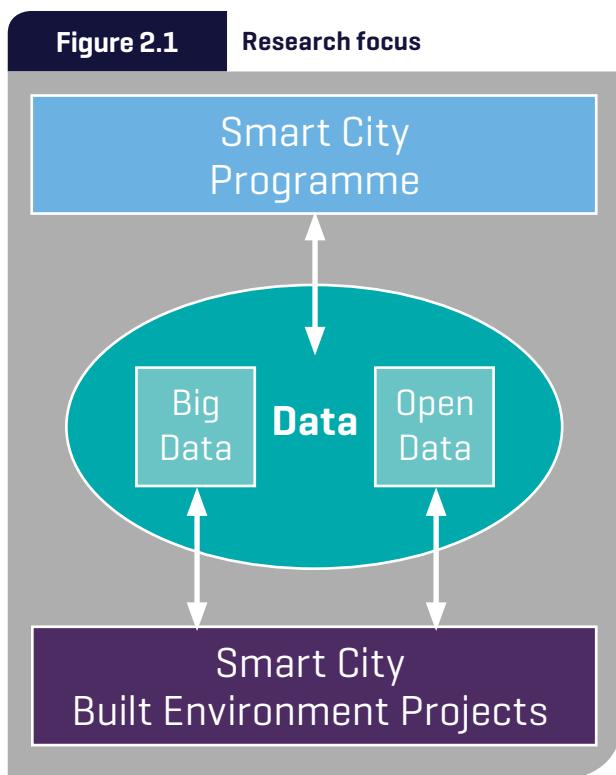
The research aims to examine the scope for the development of data platforms at the city level in the UK and internationally and to highlight the potential benefits of these data platforms for the built environment professions. Focusing on big data and open data in the built environment, the objectives are to:

1. Examine the drivers and barriers for big data platforms at city level in the UK and internationally;
2. Examine key trends in the development and opening up of big data in cities;
3. Examine the opportunities for client advice, and the potential for RICS members to use big data creatively and innovatively to add value to their professional work.

Table 1.1

Smart cities, big data and open data: potential areas of application in the built environment professions

Real estate and property	Construction	Architecture	Planning
<ul style="list-style-type: none"> ▪ Marketing and sales ▪ Facilities management ▪ Corporate real estate ▪ Mapping ▪ Research and analytics 	<ul style="list-style-type: none"> ▪ BIM ▪ Mapping ▪ Asset management ▪ Research and analytics 	<ul style="list-style-type: none"> ▪ BIM ▪ Design ▪ Public engagement ▪ Interactive mapping and visualisation 	<ul style="list-style-type: none"> ▪ Long term urban planning: land use and transport ▪ Consultation ▪ Interactive mapping and visualisation ▪ Research and analytics



2.0 Methodology

2.1 Introduction: research focus and definitions

Our focus in this research is on smart city programmes, set in the context of specific smart city built environment projects and their relationship with open data, some of which may be big data (Figure 2.1).

The following definitions are adopted in this research:

- Smart city programme: the overarching plan, strategy and framework that provides the context for city level smart applications and data platforms.
- Smart city built environment project: projects at city level which produce and use built environment data relating to, for example, land and buildings, energy and environment, transport and mobility and health and wellbeing.
- Smart city agenda: the motives or intentions to promote and develop smart city projects or programmes.
- The built environment: this research uses Handy et al's (2002) definition of the built environment as comprising:
'land use patterns, the distribution across space of activities and the buildings that house them; the transportation system, the physical infrastructure of roads, sidewalk, bike paths, etc., as well as the service this system provides; and urban design, the arrangement and appearance of the physical elements in a community.'
- Built environment data: data from the built environment is relevant for application in the 'domains' of land and buildings, energy and environment, transport and mobility and health and wellbeing. The city data relating to projects in these built environment domains may be big data (i.e. very large, complex and rapidly-changing datasets) and/or open data (i.e. data that can be freely used, shared and built on by anyone, anywhere, for any purpose).
- Built environment professions and professionals: includes property and construction experts, architects and planners.

2.2 Conceptual framework

Much of the previous research on smart cities has relied on document analysis rather than interview-based studies or ethnographies and genealogies (Kitchin, 2015). This research therefore seeks to directly engage with key actors (city authorities, businesses, academia and others) in order to understand the practical implications of the smart city and open and big data agendas.

The research draws on the process-based data model of Desjardins (2014), which sees open data supply and data use as a cyclical process with four main steps:

1. Data collection.
2. Data publishing.
3. Leveraging data for the city to provide economic value for citizens and business.
4. The development of platforms to connect governments and citizens.

The current work builds on the comparative study of San Francisco and Seoul Metropolitan City by Lee and Hancock (2012; Lee et al, 2014). The research also draws upon work by Neirotti et al (2014) and Chourabi et al (2015), both of which, in varying ways, sought to measure the ‘success factors’ of smart city initiatives or projects in a city, based on particular aspects or domains of a smart city. Other work by Ojo et al. (2015) has used similar smart city frameworks to analyse open data initiatives and smart city projects.

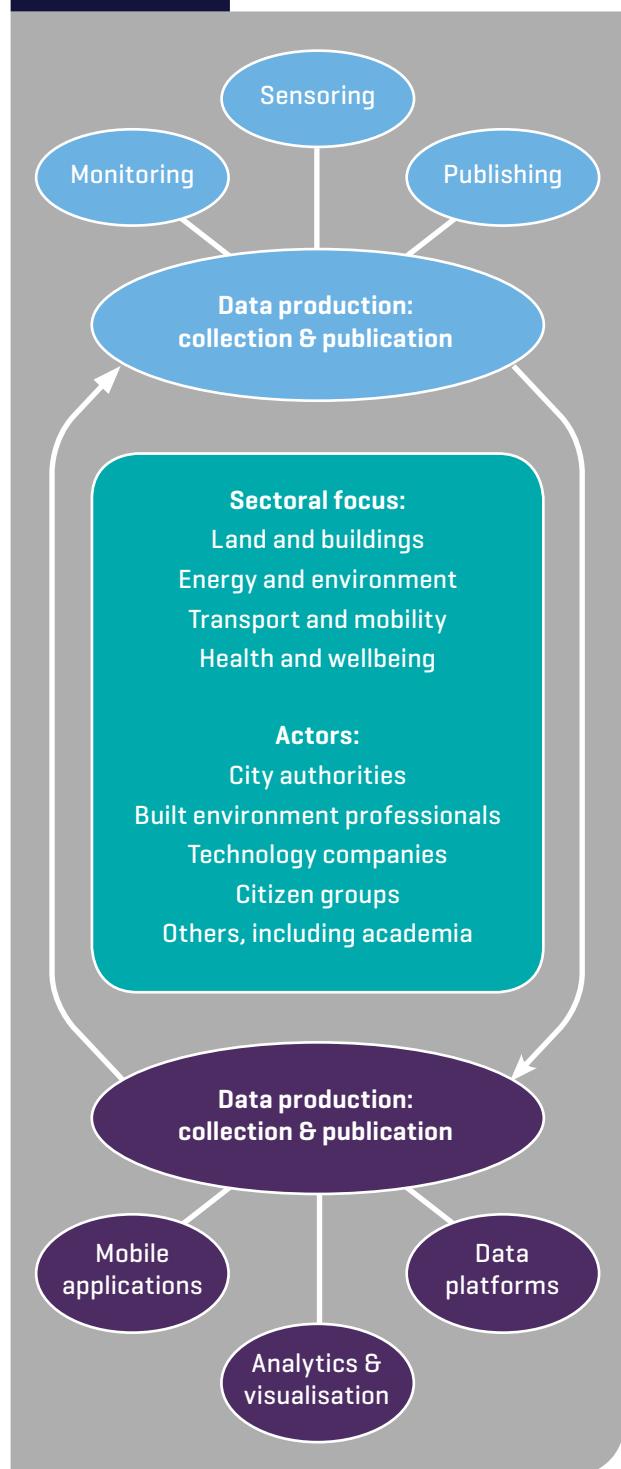
The conceptual framework adopted is shown in Figure 2.2.

The research examines smart city projects with a sectoral focus, namely, the built environment. The research examines the role of the following key actors in this process:

- **City authorities**, who manage and provide open city data and the relevant data platforms, and who play a key role in leading smart city projects.
- **Built environment professionals**, who have a potentially key role to play in smart city programmes by partnering with city authorities and others to develop mobile applications, analytics and collaborative data platforms; and to contribute to the development of open data/big data platforms at city level. They may also use big and open data to provide the basis for advice to client organisations.
- **Technology companies**, which provide software and hardware technologies for smart city programmes and built environment projects.
- **Citizen groups**, who can play an important role in helping shape smart city programmes and projects.
- **Others**, including academia, who play an important role in developing applications and thought leadership.

The focus in the research is on the relationship between data production (collection and publishing) and data use (applications, analytics and data platforms). In this sense ‘data platforms’ include the data ‘hubs’ and ‘urban platforms’ as described in section 1 of the report.

Figure 2.2 Conceptual framework





2.3 Research design

The research design incorporates three elements:

- A scoping survey of UK smart cities to understand the details of smart city programmes, related built environment big data, and open data projects.
- Case studies of four smart cities (Bristol, Milton Keynes, Amsterdam and Taipei).
- A UK workshop to engage with data providers and data users to identify:
 - (i) the opportunities and challenges for built environment open data and big data in smart cities, and
 - (ii) how to unlock potential value in open and big data for the built environment professions.

The overall approach is based on 'institutional analysis'. The research examines the institutional structures and mechanisms by which operations are organised within each of the smart city projects and the wider conceptual framework described above. This enables a detailed study to be made of the structure of organisations and the way in which those organisations operate and relate to each other (Marsh and Stoker, 2010). This is appropriate because the smart city programmes which are part of this study involve a variety of actors and stakeholders. The focus is very much therefore on the economic and public policy dimensions of these programmes and particularly how the actors listed above interact in smart city built environment big data projects.

2.3.1 Scoping survey of UK smart cities

An online survey of 19 UK cities was carried out in spring 2016 to provide a broad understanding of smart city data platforms. The cities were selected on the basis of population size and engagement with the smart city agenda.

The UK scoping survey focused on the following areas:

- Frameworks in place for smart cities (for example, definitions, strategies and action plans and what they contain).
- Overall focus and prioritisation of smart city projects.
- Data collection: what sort of data is being collected and analysed and why?
- Open data: which data is being provided through open access and why?
- Big data: which data is being collected and why?
- Barriers to data provision.
- Examples of big or open data use, by type, which have been undertaken in the 'built environment' (for example land and buildings, energy and environment, transport and mobility and health and wellbeing) and other contexts.

The respondents were all senior managers in the relevant UK city local authorities (for list of respondent cities see Appendix 2).



2.3.2 Case studies

Four case study cities were selected on the basis of their coverage within the literature reviewed. All four case studies were identified within the literature as leading examples of smart city projects:

- Bristol and Milton Keynes in the UK.
 - Amsterdam in the Netherlands.
 - Taipei in Taiwan.

The research comprises a comparative case study approach that encourages high-level comparison, with the UK case studies set as the reference point. Key stakeholders in the relevant city councils, academia, industry and other groups were interviewed for this work. A total of 35 interviews (Bristol 9; Milton Keynes, 7; Amsterdam, 7; and Taipei, 12) were conducted. The majority of these were conducted face to face, with some by telephone and Skype in the UK. For further details see Appendix 3. Interviewees for these case studies were asked the following questions:

- What built environment big and open data is produced and used in the smart city programme?
 - How is it produced and used?
 - Why is it produced and used?
 - Who produces and uses it?
 - What are the challenges involved in its production and use?
 - What are the exemplar smart city built environment projects that have developed at city level?
 - What are the institutional conditions and characteristics which stimulate or inhibit these emerging initiatives; for example, around strategy, action plan, and possible links with funded research?

2.3.3 UK Workshop

Finally, a workshop was held in the UK as a means to engage with data providers and data users and to test the validity of the research findings from the scoping survey and case studies. The workshop, which was attended by 12 delegates (all senior decision-makers and representatives from their organisations), focused on the opportunities and challenges for built environment open data and big data. The workshop participants were asked to consider and discuss the following questions:

1. Reviewing the research findings: impacts on big and open data

- To what extent do the findings of the current research resonate with your experience of built environment data at city-level?
 - What are the implications for developing built environment open data at city-level (for suppliers and users)?
 - What are the implications for developing built environment big data at city-level (for suppliers and users)?

2. Unlocking the potential value of open and big data

- What needs to be done to develop better engagement from the built environment sector at city level in (i) use and (ii) supply of open and big data?
 - How can professional built environment bodies and other stakeholders help in this process?

3.0 Main Findings

3.1 Introduction

This section presents the main findings from the three elements of our research:

- Scoping survey of UK smart cities.
- UK and international case studies.
- UK workshop.

3.2 Scoping survey of UK smart cities

3.2.1 Overall response rate

The online survey (designed in Survey Monkey) was live during March-April 2016. Respondents were senior smart city or sustainability officers in city-based local authorities. Twenty one cities were identified (on the basis of population size and their publicised engagement with the smart city agenda), and the individuals identified were contacted by email. Nineteen responses were received, representing a response rate of 90%. The cities which responded are listed in Appendix 2.

3.2.2 Smart city: programme definitions, plans and frameworks

Respondents were asked about their smart city definition, plans and framework in the context of the overall smart city programme. The findings can be summarised as follows:

- Only 47%⁷ (9 out of 19 respondents) of the cities in the survey has an established definition for 'smart city'.
- Of the 9 respondents who did have a definition, the majority (66%) suggested the closest alignment was with the BSI smart city definition.
- Only 22% (4 out of 18 respondents) indicated that they had a smart city action plan⁸. Four respondents (22%) also indicated that a plan was being developed. Cities which highlighted their plans with specific weblinks included Milton Keynes, London and Birmingham. Of those suggesting they had an action plan, the common sectors included in the plan were the built environment, economic development, energy, health, transportation and waste.

- Only 22% (4 out of 18 respondents) indicated they had used a smart city framework of some kind (e.g. RICS (Doherty, 2012), (Smart Cities Council, 2016). In these particular cases, two of the respondents mentioned EU funding as being crucial to developing the framework and subsequent integral projects. As one respondent stated:

"We were successful in getting funding ... [from the EU Lighthouse project]. Although we had a smart city ambition and programme, it was the application and implementation of a large project that led to adopting of a framework".

3.2.3 Smart city data: strategy, platforms and open/big data

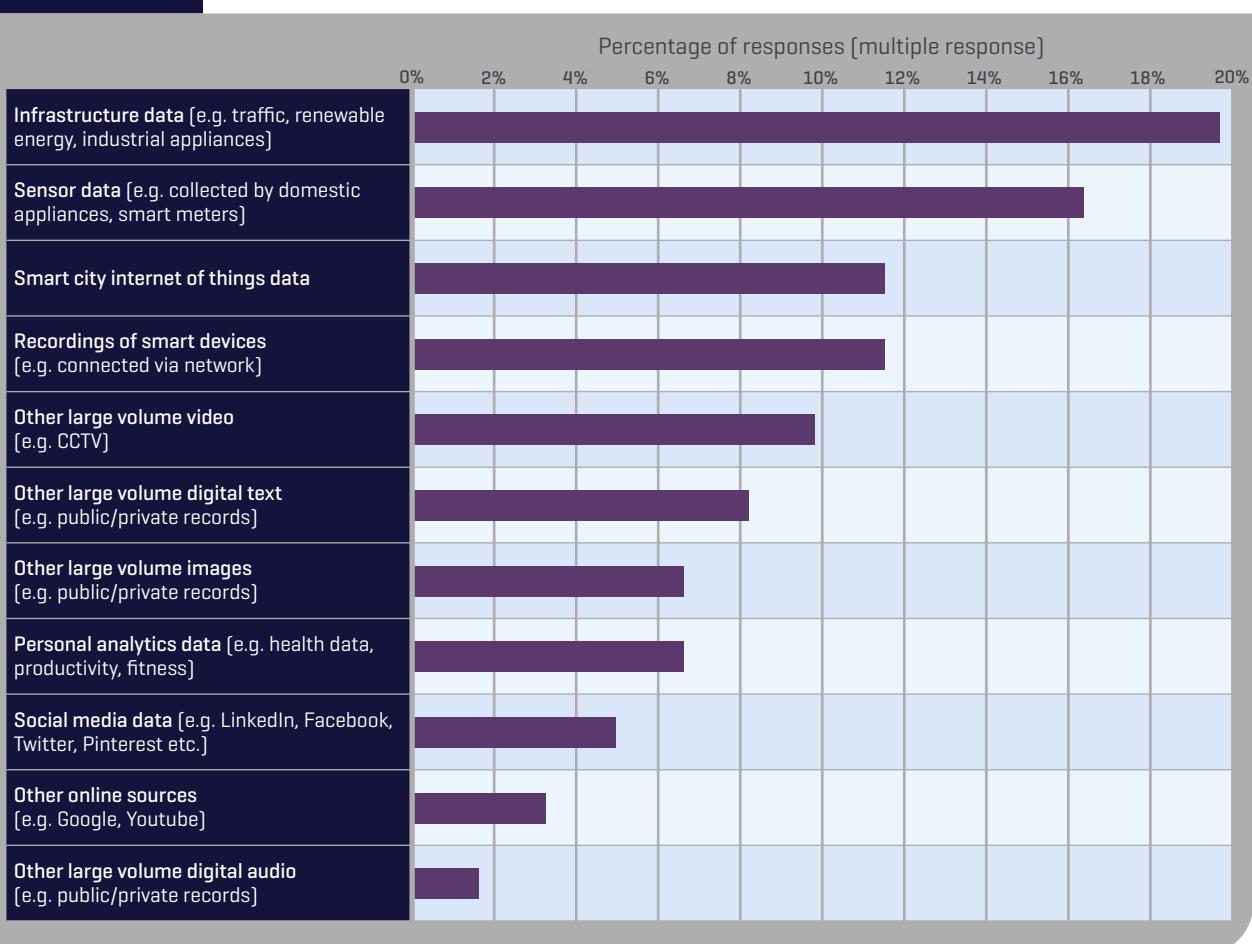
Respondents were asked about their smart city data strategy and their use of open data and big data.

- 33% (6 out of 18 respondents) suggested their city follows a smart city data strategy. 56% (10) indicated that they did not have such a strategy and 11% (2) stated that they did not know. Examples of cities which have a smart city data strategy include London, Edinburgh and Leeds.
- Only 22% (4 out of all 18 respondents) to the data strategy question indicated that the strategy mentioned big data.
- 61% (11 out of 18 respondents) indicated that their smart city had an open data platform. 17% (3) indicated that it did not, and 22% (4) indicated that they did not know. Some 61% (11) of respondents to this question indicated that their city provides data in an open data platform. Examples here include London, Milton Keynes, Glasgow, Edinburgh, Bristol, Leeds and Reading.

Although some respondents were positive about the potential for big data, some respondents also expressed scepticism or lack of awareness about big data, with one describing it as a:

"... buzzword for the amount of data that organisations have access to, which is difficult to process using traditional approaches but if utilised correctly can lead to organisations making better decisions and become more efficient".

⁷ Unless otherwise stated all percentages throughout relate to valid responses and exclude missing data. ⁸ The figure is 36% when expressed as a percentage of those answering just this question [i.e. 11 respondents].

Figure 3.1**Digital data types collected [respondents = 14].**

3.2.4 Digital data sources: where does data come from and what types are collected?

Of those respondents who answered this question (15), the majority⁹ suggested they held data from local and national public data sources (33% and 30% respectively), with private sector (19%) and members of the public (19%) less involved in supplying data.

As far as digital data types collected for the smart city initiatives are concerned, the majority of respondents to this question indicated that their smart city collected infrastructure data (19%) and sensor data (16%) (Figure 3.1). Other data included internet of things (IoT) data¹⁰, smart devices and other large volume data, including public/private records and CCTV.

3.2.5 Current and future applications for data collected in smart cities?

The most frequent current applications of smart city data occur in infrastructure data (23% of responses) (primarily energy management and transportation) and sensor data (19%), for example, including low carbon programmes, weather impacts and air quality/vehicles (Figure 3.2). IoT data, including air quality and river level data, was collected for applications less frequently (11% of responses).

In terms of future applications, personal analytics data (including health data), infrastructure data and sensor data were seen by respondents as also being important. Other future potential uses indicated by respondents here included data relating to transport, circular economy, city resilience, air control, infrastructure, and house planning, renewable energy and local power management.

⁹ Respondents were allowed to select more than one option [i.e. a 'multiple response'] in their responses to the questions discussed in sections 3.2.4 - 3.2.9. To ensure consistency the data for these responses has been 'normalised' so that the total is 100% in each figure. ¹⁰ Data relating to interconnected devices.

Figure 3.2

Current and future applications for data collected in smart cities
 [respondents = 12 and 13 respectively].

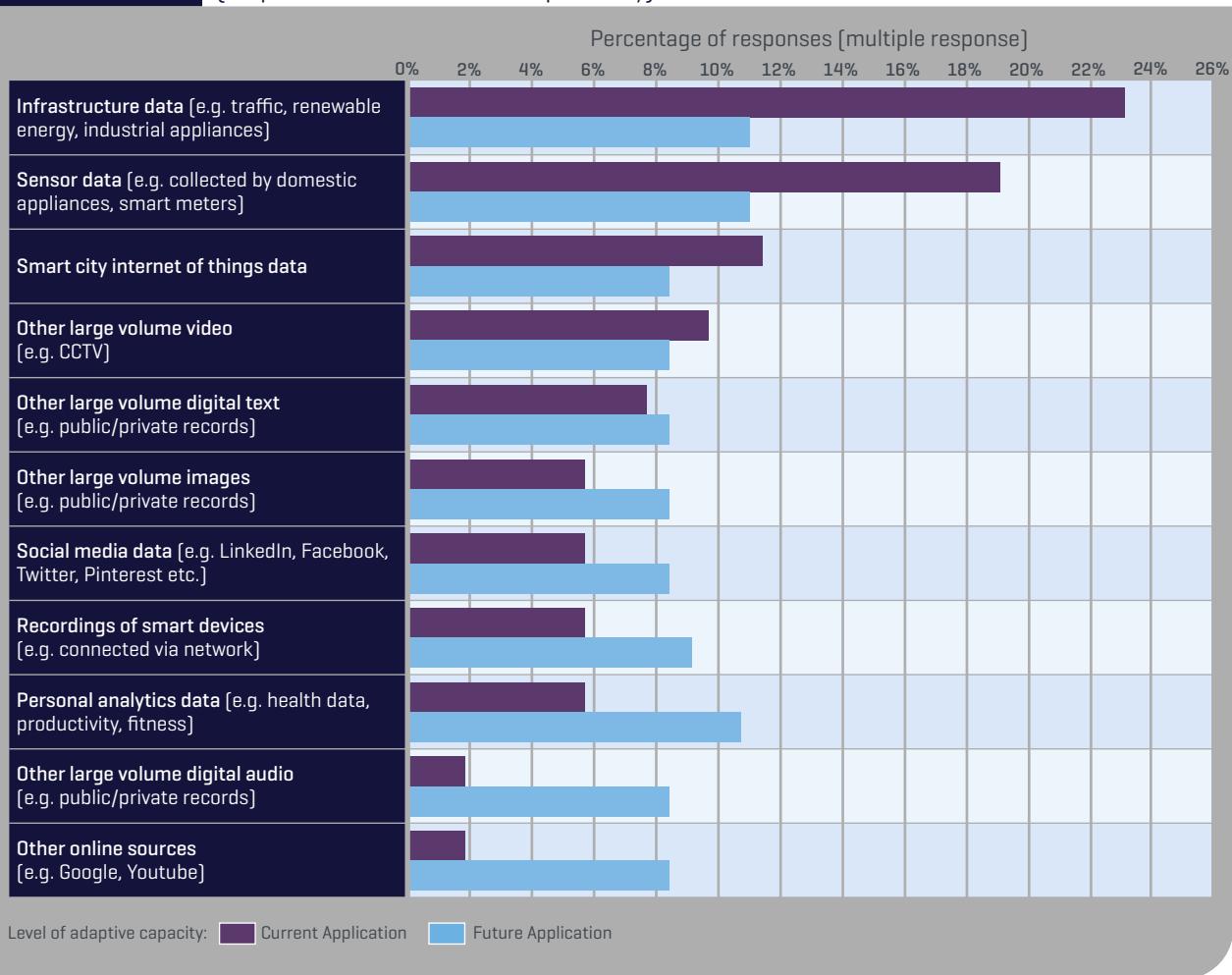


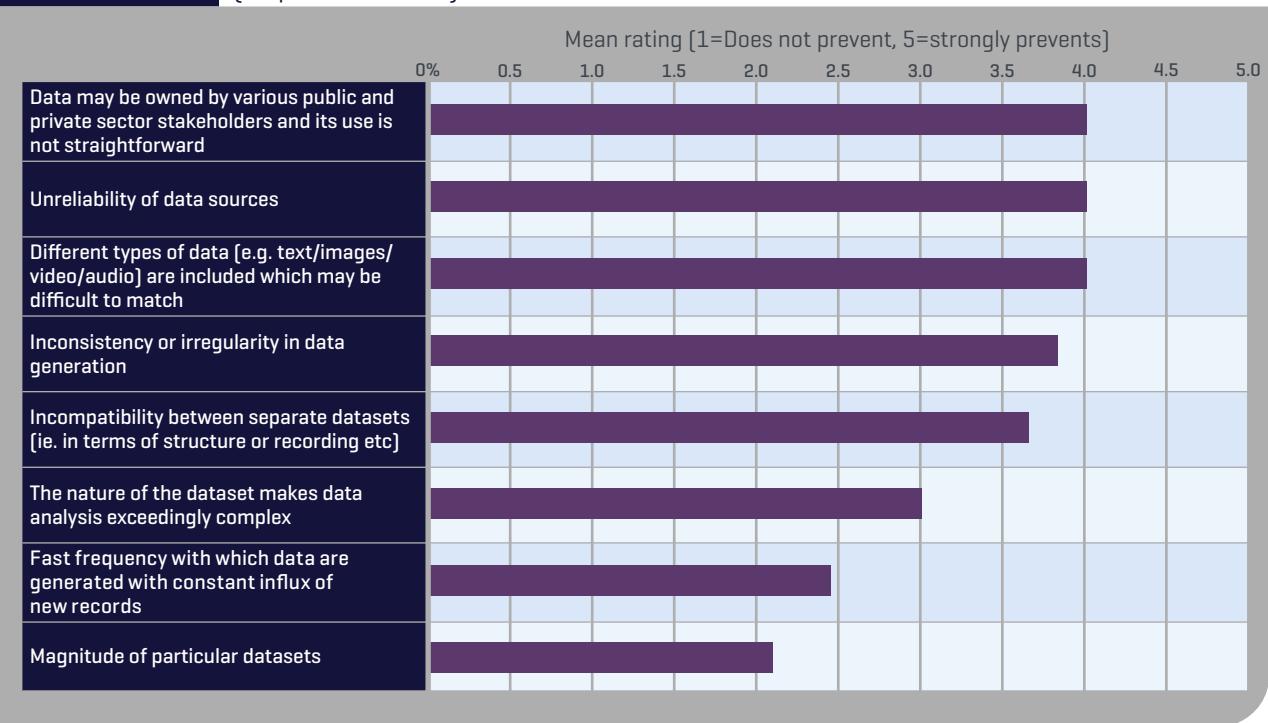
Table 3.1

Examples of smart city built environment projects

Project	City	Website	Description
Sharing cities	London	http://www.sharingcities.eu/	By fostering international collaboration between industry and cities, this EU 'lighthouse' project seeks to develop affordable smart city solutions. It aims to result in integrated commercial-scale smart city solutions with a high market potential.
Dimmer	Manchester	http://dimmer.polito.it/project/	The EU-funded DIMMER project integrates BIM and district level 3D models with real-time data from sensors and user feedback to analyse and correlate buildings utilization and provide real-time feedback about energy-related behaviours.
Bus tracker	Edinburgh	http://www.mybustracker.co.uk/	Bustracker provides easy access to real time bus information in and around Edinburgh. Its aim is to give residents, commuters and visitors access to real time information about buses across Edinburgh.
Carbon Culture	Cardiff	https://platform.carbonculture.net/communities/cardiff-council/19/	CarbonCulture is a community platform that is designed to help people use resources more efficiently.

Figure 3.3

What is inhibiting the use of large volume digital data in the smart city? [respondents = 13].



3.2.6 What is inhibiting the use of larger volume digital data in the smart city?

Respondents were asked to rank big data barriers on a scale of 1 ("does not prevent") to 5 ("strongly prevents") in the smart city. The highest ranking barriers to using big or large volume data in their current smart city initiatives were found to be fragmented ownership of the data (mean rating, 4.00), unreliability of data sources (mean rating, 4.00) and different types of data (mean rating, 4.00). Inconsistency and irregularity in data generation was ranked in second place, followed by incompatibility between separate datasets (3.67 mean rating) (Figure 3.3).

3.2.7 Examples of built environment data projects

Respondents were asked to provide examples of built environment case studies. There were 12 respondents to the case study questions, representing 63% of respondents. Respondents listed 22 smart city built environment projects. These included examples relating to energy and infrastructure (11); transport (9); integrated smart city (1); and health (1) Leading examples of these are shown in Table 3.1.

3.2.8 Data types used in built environment projects

Respondents from the smart city projects were asked to indicate which types of data they tend to use in built environment projects, some of which may be big data. As Figure 3.4 shows, infrastructure data (27% of responses), sensor data (22%) and IoT data (14%) are the most common types of data used. This replicates the findings from section 3.2.5.

3.2.9 Benefits and barriers for smart city built environment projects

When asked about benefits and barriers of smart city built environment projects (see Figure 3.5), the most common benefits of smart city built environment projects were seen to be improved sustainability (27% of responses); improved 'liveability' for citizens (18%); and better public safety (12%). Other factors, such as innovative new services (9%) and citizen engagement, tourism and saving money (all 6%) were perceived to be less important¹¹.

Figure 3.6 shows the relative importance of barriers for smart city built environment projects. Costs and funding (38% of responses); infrastructure requirements (27%) and the lack of collaboration between stakeholders (16%) were the three most important factors. Security and privacy was relatively less important (11%)¹².

¹¹ The 'other' category represented a response suggesting a shift in the modal split of transport was important. ¹² The 'other' category represented problems with availability of technology and procurement.

Figure 3.4

Digital data used in smart city built environment projects
 [number of respondents = 14].

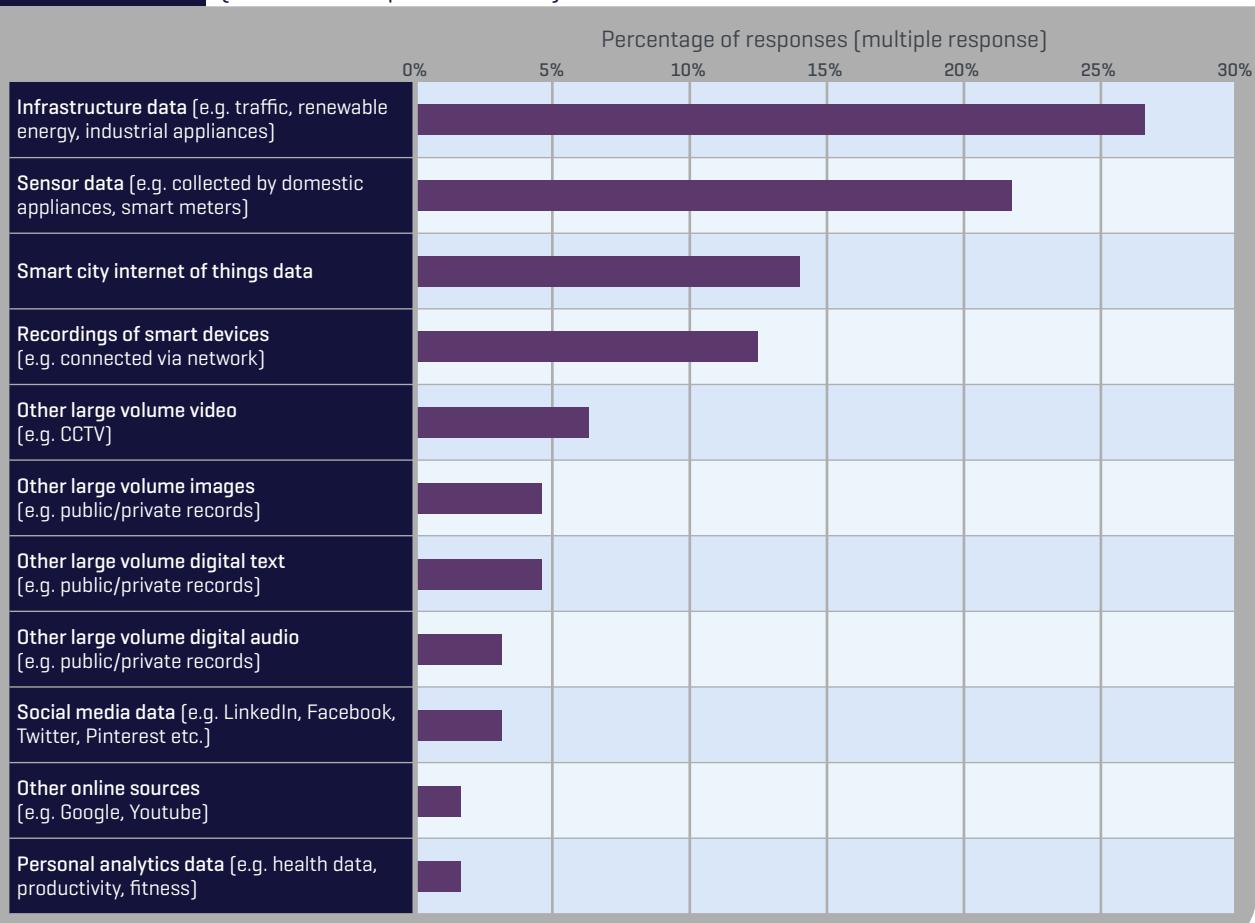


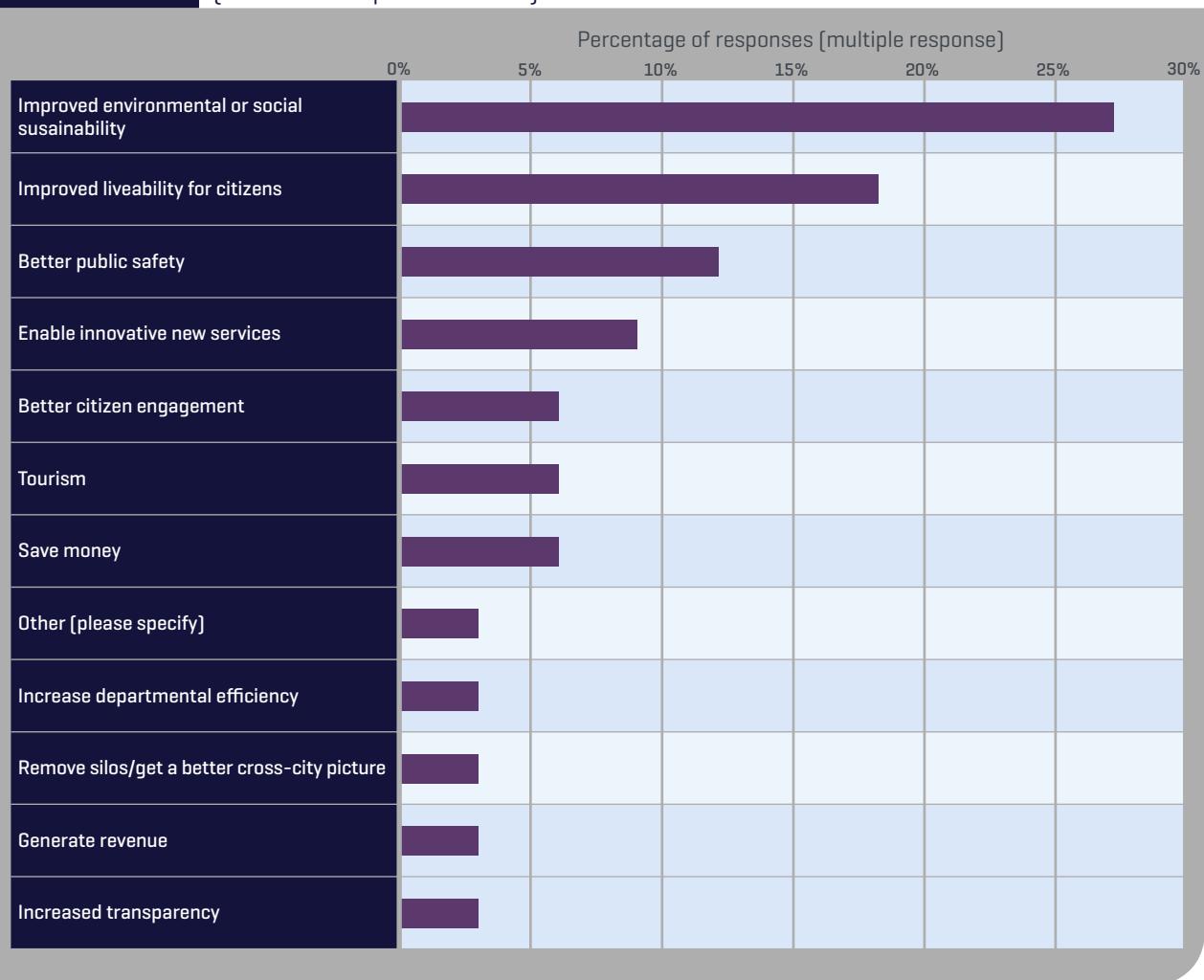
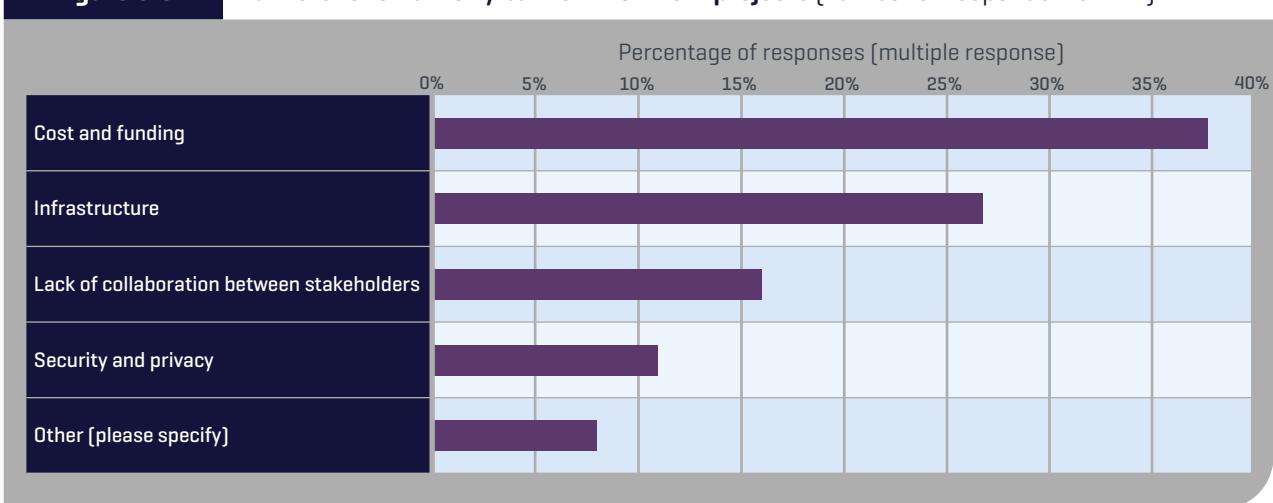
Figure 3.5
Benefits of smart city built environment projects
 [number of respondents = 11].
**Figure 3.6**
Barriers for smart city built environment projects [number of respondents = 11].




Image source: 1 – Claudio Divizia – Shutterstock.com

2 – andyparker72 – Shutterstock.com

13 See Appendix 3 for further details of interviewees etc. 14 The Wireless Mile in Bristol, based around Bristol's Harbourside and the 'Brunel Mile', will also enable innovators to test applications using a range of linked wireless devices using Wi-Fi, 3G, 4G, LTE and 5G experiments.

3.3 UK smart city case studies¹³

3.3.1 Bristol

3.3.1.1 Background and context

Bristol, the eighth largest city in the UK, is located in the south west of England with a population of about 442,000. The city, which is a hub of enterprise and a major economic centre, is projected to increase in population by 22.1% to 2037, which is higher than the projection for England of 16.2% (Bristol City Council, 2015). The council is a unitary authority, and its executive function is controlled by a directly elected mayor of Bristol. Bristol's growth and economic vibrancy (the highest GVA per head outside London (Navigant, 2016), creates housing and infrastructure pressures and environmental pressures.

3.3.1.2 Smart city programme

Bristol City Council leads the smart city strategy through the Bristol Futures Group, a dedicated team (or Directorate) based within the council, which works with other local industry, academic (University of Bristol) and civic groups on co-produced projects and programmes. The smart city programme (the 'Open Programmable City') was established in 2011, and is a collaborative programme between the council, business and citizens.

This programme includes the Bristol Future City Demonstrator (2013) which supported the development of smart city infrastructure through Innovate UK funding (preceded by the GigaBit Bristol project (2012) and funded through the Department for Culture, Media and Sport (DCMS). The programme also includes the ongoing Bristol is Open (BiO) project, which is developing an 'open programmable city region' (Figure 3.7) (Bristol City Council, 2016). This is a collaboration between the technology, media and telecommunications industry, universities, local communities and local and national government. The project is governed by a joint venture between University of Bristol and Bristol City Council, guided by an Advisory Board of partners. An important part of the BiO project is the open data platform, which brings together a range of open datasets, primarily from the public sector. The Bristol Data Dome is located in @Bristol's Planetarium and is a 3D hemispherical screen with 4K resolution (unique in the UK). It is connected to the high speed fibre network and a super computer based at University of Bristol to enable analytics and data visualization experiments. This is also used for public engagement¹⁴.

There is also a strong focus on citizen engagement in community driven digital projects through the Citizen Sensing programme. Bristol also has a range of other related funded projects, focusing on driverless vehicles and smart energy. Connecting Bristol provides an overarching framework for much of this work and is a joint partnership between Bristol City Council other public sector agencies, the private sector and the community and their representatives.

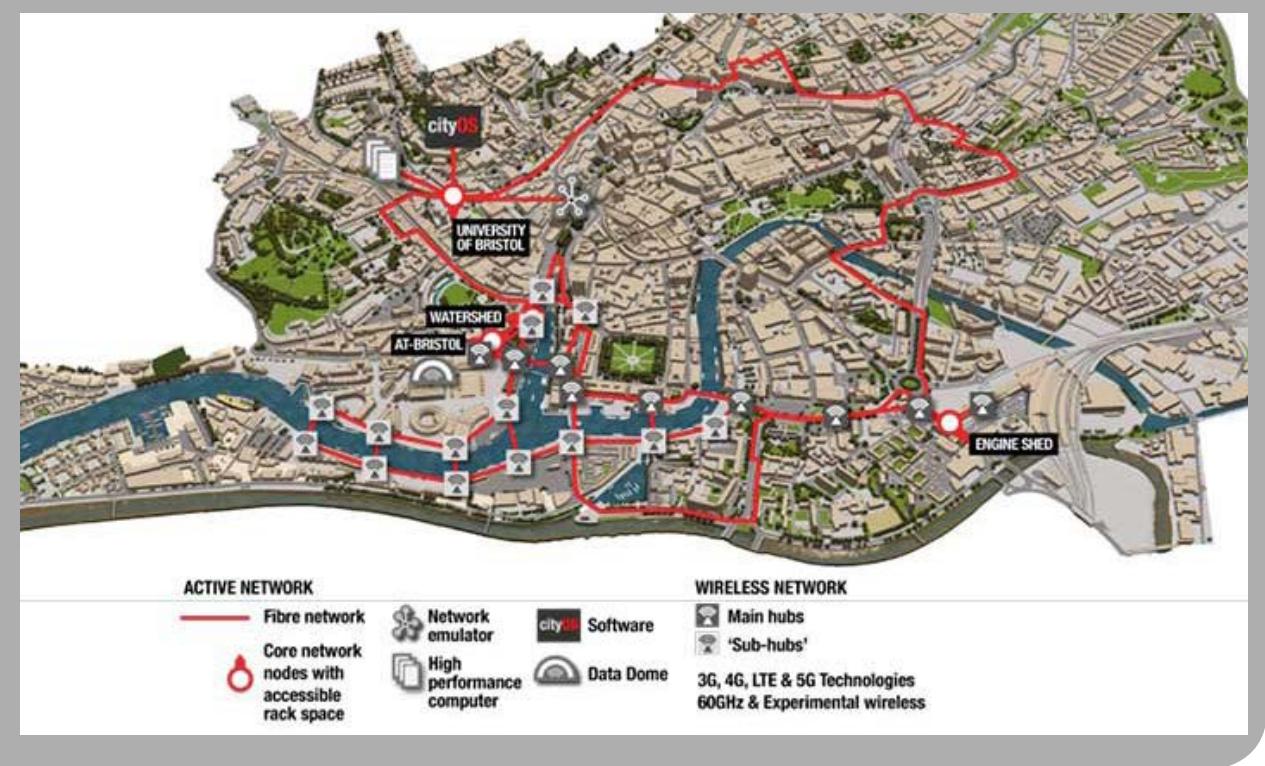
Figure 3.7**Bristol's open programmable city region infrastructure**
[Wireless connectivity: 3G, 4G, LTE & 5G Technologies]

Figure source: Bristol is Open, 2017

3.3.1.3 Open data

An important element of BiO is the open data platform which has been developed by the Council in conjunction with Socrata, a US company. This contains more than 200 datasets, including some in real time covering such areas as land use, health, energy, mobility, community, and education. There is also an API to encourage applications developers to use the data creatively for smart city applications. The city has run several open data competitions and hackathons focusing on built environment themes, such as energy transport and mobility. However, there were also major challenges in persuading business to agree to provide data for an open access platform. As a council interviewee suggested:

“... my experience of this at the moment is that I don't think there are many businesses... who want to share their data openly with the city... there's still not much of a culture or a business model that necessarily supports that... I don't see many businesses actually giving their data away at the moment”.

The BiO network provides a strong focus on infrastructure in the city centre. However, the interviewees suggested that efforts to scale up the project's coverage, particularly within the built environment, are hampered by the production of different data standards and different data formats. Although there are no plans to restrict data on the hub or create 'closed' data, the data platform may also evolve to incorporate data exchange between users.

3.3.1.4 Big data

As a local authority interviewee suggested, big data projects were still at a very early stage:

“... but outside of academia, it's quite difficult to see how you bring [this] together. So, there is still this massive opportunity of big data, but it's not that clear who can grasp it and how they can grasp it... we're just not in a state of readiness to get hold of that”.

Ambitions between organisations also differ. In the built environment sector there may be differing views on the benefits of BIM and big data, particularly at city level. Attitudes to BIM and big data are also different within professions in the built environment sector. As one interviewee from the city council suggested:

“They [built environment professionals] don't need to think about the whole city, they... just think about their building, and that gets you back to commercial imperative to use this data... that BIM story isn't... sticking, really... I think the people who see the point of this easiest are the architects, because they're used to working with software, sort of conceptually building things... you go to the construction firm and they're like, 'I don't even know what you're talking about', you get to the building manager and they don't know yet what they can have, so at every step you don't see the energy for this that I have”.

Another reason for the perceived lack of built environment sector engagement might be differing timescales for projects between the built environment and the digital sector. As one industry expert suggested:

"In digital we are all about three months... then of course in the built environment you're talking decades in terms of investment cycles and everything else. So ... they are on such radically different beats that it'll be interesting to think about how that might actually come together."

3.3.1.5 Built environment projects

There are only a limited number of smart city 'built environment' data projects in Bristol. There was also a strong sense that the property and construction industry were less engaged with this sector than others, although not exclusively so. As a city council interviewee suggested:

"The construction industry is really slow on this, and it's obviously not within the culture of construction industry, I don't think, to be using, [or] to have a digital approach to what they're doing."

The emphasis in Bristol is therefore currently on open data, although there are plans to use a new partnership with NEC to focus on big data analytics, which would link with the BIO programme infrastructure and Data Dome. Examples of the most relevant are recent and ongoing projects which have used built environment data include:

- **REPLICATE.** The REPLICATE project (Renaissance in Places with Innovative Citizenship And Technology) is a European research and development project, funded through the Horizon 2020 programme, that aims to deploy integrated energy, mobility and ICT solutions in city districts.
- **Citizen Sensing:** The Citizen Sensing Approach is a guide to delivering projects that use sensor technologies. These projects can range from gathering and sharing data in order to monitor radiation levels in the environment to using applications that augment a mobile phone.





Image source: 1 and 2 – AC Manley – Shutterstock.com

3.3.2 Milton Keynes

3.3.2.1 Background and context

Milton Keynes was developed in 1967 as part of the UK's new towns programme. The council is a unitary authority. Located in the south east of England, Milton Keynes is the fastest growing urban area in the UK. The current population of Milton Keynes is approximately 260,000 and it is also home to more than 159,000 jobs, with population growth expected to be 20% by 2026. Milton Keynes has increased in population by 40,000 (18%) over the last 10 years, and this continued growth is expected to create additional housing and infrastructure pressures in the urban area (Milton Keynes Council, 2016).

3.3.2.2 Smart city programme

The MK Future City Programme (established in 2012/13), which is led by the council, has a range of smart city projects. The overall aim of the programme is to promote continued housing and employment growth and meet key infrastructure challenges and carbon reduction commitments. The programme is a collaboration between business, universities (including the Open University and Milton Keynes) and government partners such as the UK Catapults (Caird et al, 2016).

Within the MK Future City Programme, the flagship MK:Smart project is a £16m initiative, partially funded by the Catalyst Fund of the Higher Education Funding Council for England's (HEFCE) and led by The Open University. This brings together a higher education and industry partnership with the aim of helping to secure the future economic growth of Milton Keynes¹⁵. The city also hosts the £150 million Transport City Catapult and is trialling a number of smart initiatives such as installing smart street lighting in order to reduce energy use by 40 per cent, and the deployment of low emission driverless vehicles (Centre for Cities, 2014; Navigant, 2016).

MK:Smart, which is funded through to 2017, is designed to put in place 'an integrated innovation and support programme, which will leverage large-scale city data to sustain and accelerate economic growth' (Knowledge Media Institute, 2016). At the centre of this programme is the MK Data Hub, a data acquisition and management infrastructure, which has 513 data sets across eight themes (Figure 3.8) comprising energy; transport; water; business; education; statistics; environment; and sensors. (MK:Smart, 2016)¹⁶.

Linked with the development of this programme is Our:MK, which is designed to provide a platform for engaging with people and communities in Milton Keynes to develop grant-aided 'smart and sustainable' project applications which can help tackle issues around energy, transport and water and other areas of application.

¹⁵ To further underpin the development of the smart city activities, but also to develop further long term strategy and visioning [linking with Plan:MK's focus on strategic planning], the MK Futures Commission was established in 2015.

¹⁶ Milton Keynes was one of the first UK cities to pioneer networks based on IoT technologies, and in 2013 the city was the first in the UK to establish a citywide low power wireless access network. Milton Keynes is also developing an Open Energy Map to understand energy trends across the city [Navigant, 2016].

3.3.2.3 Open data

The MK Data Hub is the central IT and data management infrastructure of the MK:Smart programme, and is designed to act as a platform enabling the supply of data from data providers, who remain in control of how data may be redistributed (through data licences), and the access permissions they want to apply. The MK Data Hub is centred on smart APIs to enable developers to re-use and reformulate the data for applications. This data could also be used for further analytics and strategic planning and decision-making at city level.

Third party open data acquisition is time consuming and complex and verifying ownership of data may be difficult. There are also issues around fragmented ownership of data, making data aggregation and assembly difficult. Although some of the data is 'open' data, the hub recognises that getting business to supply data requires

incentives. These incentives can be either through data exchange or data trading or through a volume based charge for data usage.

There have been problems with incentivising business to supply open data to the MK Smart Data Hub. This is not only because of the inherent value of business data, but also because of the perceived harm that might be done to commercial interests. As an industry interviewee said:

"I don't think that everyone is going to make their data available for free, if that's what 'open' means in that context. 'Open' meaning 'available', I agree with. I think that there will be data owners that will need ... an incentive in order to get through the pain of actually making their data available ... There is nothing in their business model internally that would drive them towards making that available to anyone else outside their business, unless there was a direct need".

Figure 3.8 MK: Smart Data Hub

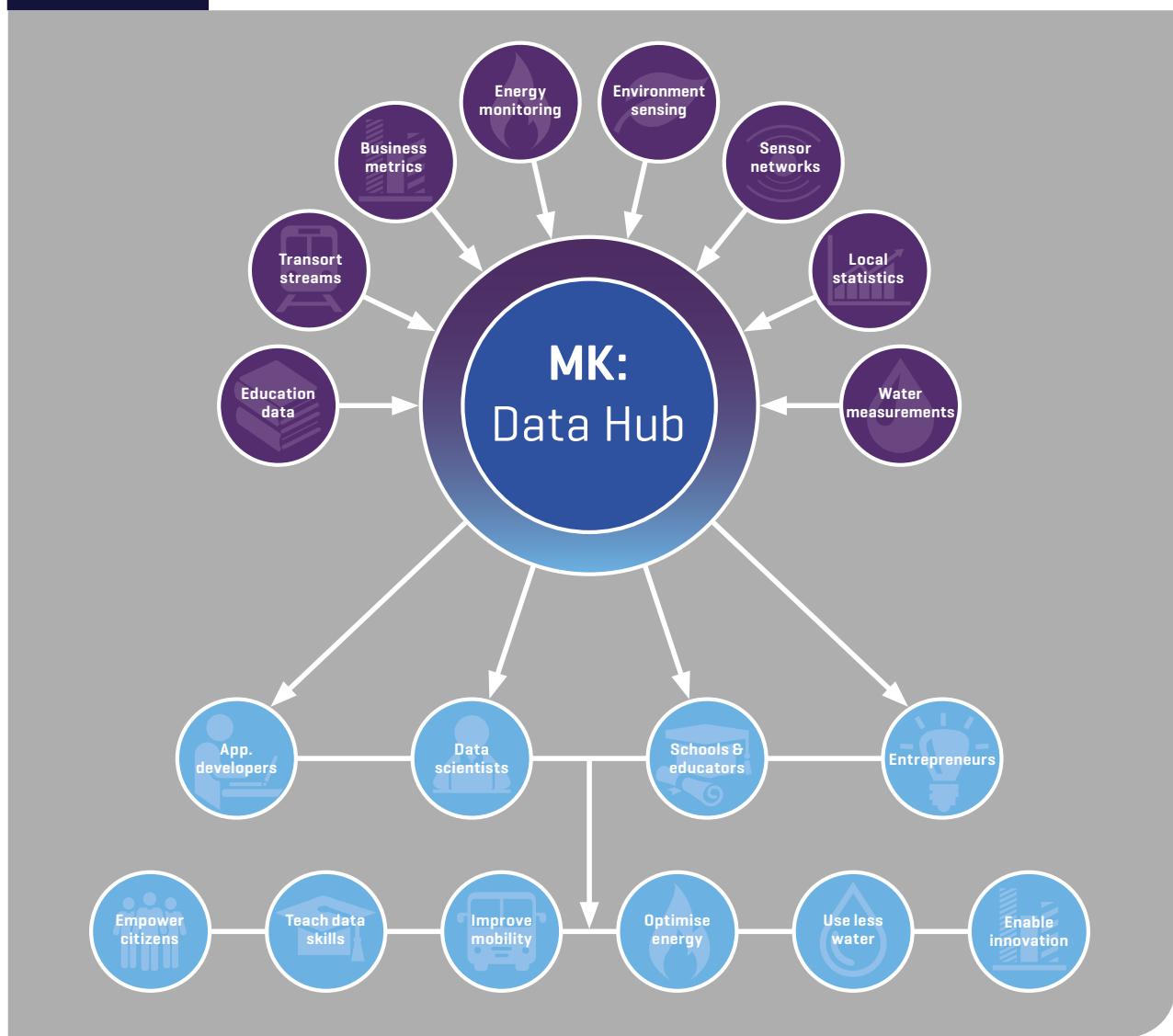


Figure source: MK Smart, 2017



3.3.2.4 Big data

Although some of the data used in the Milton Keynes projects discussed above (including those related to the built environment) includes what might be termed 'big data', there was some degree of scepticism expressed about the use of big data in the Milton Keynes context. As an industry interviewee suggested, simply because of the relatively low levels of sensor coverage:

"Depending on what you, how you define big data, my view at the moment is that the data we have in the MK:Smart Data Hub does not classify itself as 'big data'. We don't have huge volumes or huge velocities, yet. However, that will be the case if and when it is deployed out of the city scale".

An even more sceptical view was expressed by a local authority interviewee:

"I'm not sure big data is the new oil ... I think for it to truly work it will have to be at scale for it to be city wide, and we're nowhere near that at all. So that's why you're not really seeing outcomes because it's at such a micro level ... it's almost like 'The Emperor's Clothes'; it's like, well what is it?"

The primary focus in the Milton Keynes smart city project has been on assembling data in its widest sense, rather than concentrating on 'big data'. As one academic interviewee said:

"At the moment we, basically we deal with 'medium' big data, we don't deal with big, big, big data, because of this, because in order to deal with big, big, big data you really need to have the big, big, big data streams, and at the moment we don't have them ... We really need to go beyond demonstrators, have an integrated and very large scale deployment of sensor and infrastructure, and then we will have the really big, big, big data hub."

3.3.2.5 Built environment projects

In the built environment sector there is, so far, little evidence of direct engagement with the MK:Smart city programme. As one local authority interviewee noted, scaling up action across the city is required to make the MK:Smart programme successful. A variety of funding streams have been used to incrementally link additional projects to the overarching programme of work. The nature of the built environment sector, comprising many actors, each focused on achieving their own specific goals, may not be conducive to engagement with smart city programmes. An academic interviewee said:

"The key person is the person who actually owns the place, then they hire the architect... the architect, the planners, they decide, they design the place, and then somebody is actually going to build something. Now, typically none of these people cares about having a smart neighbourhood. They may have vague ideas it would be nice to be a little bit more sustainable... but the job of the landowner is to make money, and the job of the developer is to build quickly, make a lot of money, and get the hell out of there".

There are only a limited number of examples of smart city built environment data projects in Milton Keynes which are using 'big data'. Examples of the most relevant include the following ongoing projects:

- **Transport: MotionMap.** This project focuses on cloud enabled mobility to develop a city-wide transport information service, and will ultimately include embedded timetables, car parking, bus and cycleway information and estimates of congestion and crowd density in different parts of the city.
- **Energy: Community Action Platform for Energy (CAPE).** This is a spinoff project from the MK:Smart programme. The project aims to create an interactive website that will allow citizens and communities in Milton Keynes to start and run projects that will make their energy use cheaper, more effective and more sustainable.



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2 – www.hollandfoto.net – Shutterstock.com

3.4 International smart city case studies

3.4.1 Amsterdam, The Netherlands

3.4.1.1 Background and context

Amsterdam is the capital of the Netherlands. In 2016, it had a population of 834,713 (Gemeente Amsterdam – Onderzoek, 2016). The wider Amsterdam Metropolitan Area (AMA) has a population of 2.4 million, of which 1.48 million are actively in employment (AEC, 2017). Of the employed population, the majority are employed in government and commercial services and the trades sector, with a lower proportion employed in manufacturing and construction (Gemeente Amsterdam – Onderzoek, 2016).

3.4.1.2 Smart city programme

Amsterdam Smart City (ASC) is overseen by the Amsterdam Economic Board (AEB), which has the mission of sustainably enhancing prosperity and well-being across AMA¹⁷. ASC is a Public Private Partnership (PPP) between the local government, private sector organisations and knowledge institutions. ASC operates as an independent platform outside the local municipality. Once a project is started, the aim is for it to be self-steering. The role of ASC in this process is that of facilitator, not that of manager. The objectives of the ASC are to connect stakeholders, to accelerate 'doing and learning' and to strengthen the smart city fabric in the process. ASC focuses on the following themes: Infrastructure & Technology; Energy, Water & Waste; Mobility; Circular City; Governance & Education; Citizens & Living. The ASC platform works closely with the chief technology officer (CTO) office in Amsterdam to tackle these and other themes.

Smart city solutions are demonstrated in the Smart City Experience Lab, which is located in the Marineterrein area of Amsterdam. In 2016 the DataLab was opened (an initiative from the department of Onderzoek, Informatie en Statistiek (Research, Information and Statistics)). The DataLab is a physical location where people with an interest in data can come together to think about relevant data questions and come up with advice, data supply mechanisms and innovative solutions for Amsterdam.

3.4.1.3 Open data

The open data programme on data.amsterdam.nl is currently managed by the CTO office in the municipality of Amsterdam. As there has been demand to improve the way in which internal data in Amsterdam is organised and shared, it has been relatively simple to make a business case for sharing data externally through the open data programme (Soetendal & van der Lans, 2016).

¹⁷ See Amsterdam Economic Board [2017].

Figure 3.9 Data sharing in Smart Amsterdam

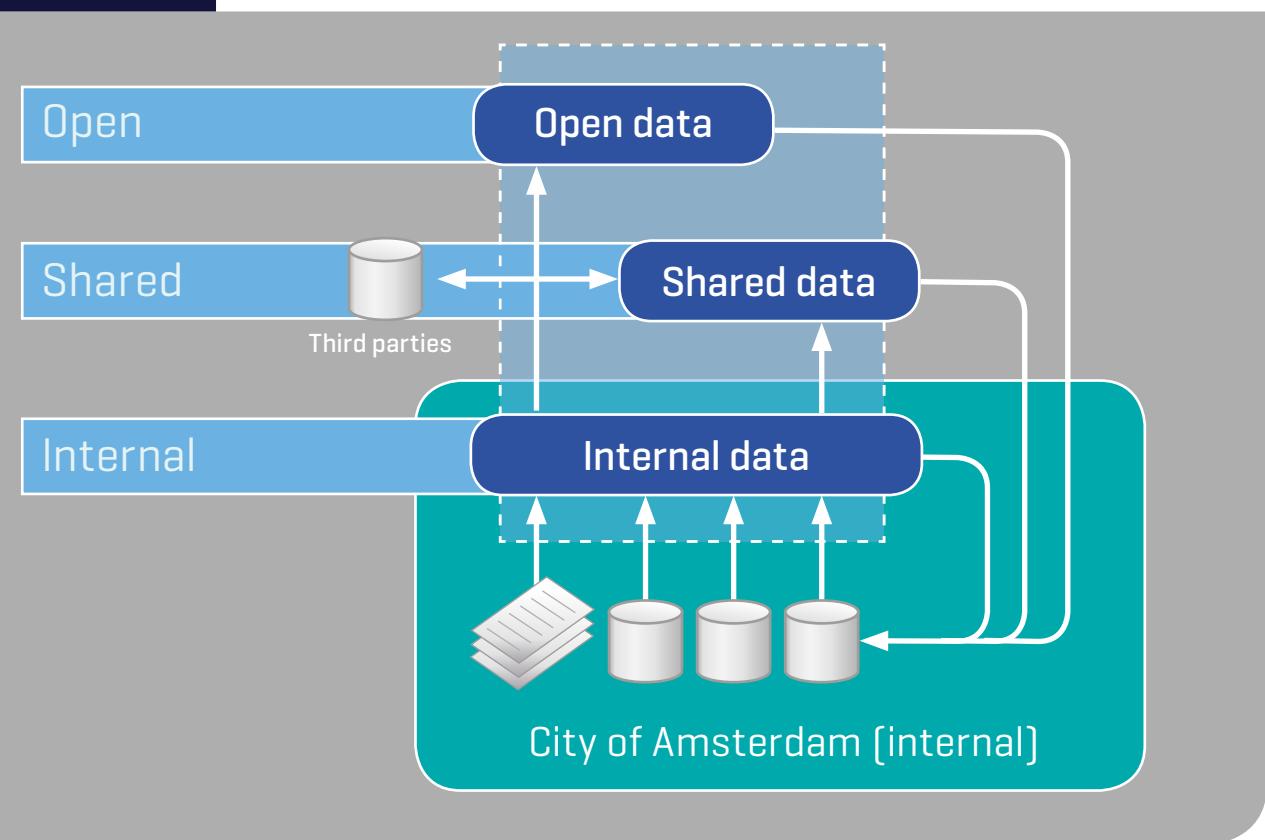


Figure source: Soetendal & van der Lans, [2016]

The system for data sharing consists of three tiers of data (Figure 3.9):

- **Open Data:** Shared with everyone, without any restrictions.
- **Shared Data ('Gedeelde data':)** Shared with external partners, under certain conditions.
- **Internal Data ('Interne data':)** Shared only within the local council.

The municipality of Amsterdam follows the Dutch national principle of: 'Open Data, tenzij...'; i.e. 'Open data, unless...'. This means that all data is open, unless there are clear legal reasons for it not to be shared, such as material that is sensitive to privacy or security issues, confidential information or data which contains business secrets.

Open data is seen as a by-product of an efficient information system within the city. This is also what will drive open data in the future. As a local authority respondent stated:

For your internal processes [...] the intelligence-led nature is important and ... the ability to take decisions based on information, about how to make the city smarter and more efficient. You need a good information provision for that and once you have that in place, open data can be a nice by-product of this."

It was acknowledged that data sets on the open data platform in Amsterdam are not suitable for real-time analysis. Data sets on the open data platform are most commonly available in historical Excel files and HTML formats. As an industry respondent suggested:

"You know, from a transparency perspective it is good that they exist. [...] I think what has happened a lot, is that people come to them with the perspective of "data is the new gold". And when you come to an open data portal it is a cold shower. Because you don't find any gold in them, you find Excel files that are three years old."

The conditions for data sharing may also need to be clarified, especially where smart city projects can be developed as a means to facilities data exchange. One industry respondent suggested that, rather than offering full access and ownership of open data in data platforms, a next step could be a data curation service. As a curator of data, the city would act as the mediator between the owner and the user of data.

3.4.1.4 Big data

Respondents highlighted a number of types of big data which are generated in Amsterdam. These primarily include data on infrastructure (such as traffic lights or sensors in the roads), energy consumption (including the electricity network), water consumption and parking. It was also suggested that big data analytics can provide new insights because of the unprecedented sample sizes and coverage. This can potentially lead to more reliable findings, which will consequently allow for more complex research questions to be asked.

The heterogeneity of big datasets and how they are brought together presented challenges in the context of the 'Smart City'. As an industry respondent suggested:

“... perhaps the challenge in the city is, how you bring more heterogeneous datasets together? [...] Because ... cities are a mess, yeah? Cities are not beautifully constructed machines where everything’s organised in the right way.”

With the current volumes of data being generated at an increasingly high frequency, it was suggested from the interviews that data collation is becoming more time-consuming. Moreover, respondents highlighted the need for a thorough understanding of the data gathering process and of big data analysis, as a way to ensure, for example, that data does not produce false positives. Understanding 'big data' better, having an infrastructure in place to collect it and educating data and research users about its use were all seen as important steps towards creating a useable system.

3.4.1.5 Built environment projects

Much of the focus in the Amsterdam Smart City is on projects that address transport and infrastructure ('mobility') and energy. Tourism and cycling are also important areas in Amsterdam. A local authority respondent suggested:

“... an important goal for, I think, for many European cities but also for Amsterdam is to use less energy and to use more renewable energy and to use the infrastructure wisely, smartly and that’s maybe where data comes in as well so these goals are, I think, common for many European cities.”

Before embarking on any smart city project, the business case and the user case needs to be made very clear. One of the industry respondents highlighted the absence of a strong business case as a barrier:

“One of the reasons ... in my opinion why it was more difficult to achieve what we wanted to achieve was that we were unable to formulate the business case from the very outset. And when you do not have a crystal-clear business case it becomes much more difficult to generate support.”

Digital connectivity was seen by one local authority respondent as a means to an end in this context. As this respondent suggested:

“... and digital connectivity, I’m very unfamiliar with that because we see digital connectivity as a means. It can be an enabler to in the end achieve all these other things. That’s how we see connectivity.”

Two examples of built environment projects in Amsterdam include:

- **City-zen:** City-zen is a project sponsored by the European Union's Seventh Programme for research, technological development and demonstration. The aims of City-zen are to scale up innovative energy solutions and open networks. In Amsterdam, these objectives are implemented through the retrofitting of existing dwellings, making the e-grid smarter and improving and expanding the heating grid. Another part of City-Zen is the 'Serious Game', which stimulates energy saving behaviour among young people.
- **CitySDK:** The CitySDK project, which is linked to Amsterdam Smart City, aims to demonstrate what can be done through the use of open data and one of its outputs has been a Linked Data API. As part of this project, the WAAG society has developed a 'Gebouwenkaart' for the whole of the Netherlands, a map which visualises the age of buildings through the use of colours on a map.



3.4.2 Taipei city, Taiwan

3.4.2.1 Background and context

Taipei city is the capital of Taiwan (Republic of China). In June 2016, Taipei had a population of around 2.7 million and covers an area of 272 km² (Department of Land & Department of Civil Affairs, 2016). There are twelve administrative districts in the Taipei city. As a result of its historical and economic development and varied topography, Taipei's population is unevenly distributed, resulting in regionally specific challenges. Taipei city was awarded by the Intelligent Community Forum as an 'Intelligent Community' in 2006 (ICF, 2015).

3.4.2.2 Smart city programme

The Taipei Smart City Programme is led by the Taipei City Government (TCG, 2017) with the strong leadership of Deputy Mayor Mr Charles Lin. As stated by Taipei's deputy mayor:

'the implementation of 'Smart City' – on top of the city's administrative agenda – will be divided into four sections, which are smart government, smart citizens, smart experiment sites, and smart infrastructure' (DOIT, 2016).

The goal of the Taipei Smart City Programme is to provide better public services and facilities for citizens by employing intelligent technologies and IoT solutions.

The 'Taipei Smart City Project Management Office' (PMO), formed in March 2015 by the TCG, is in charge of the implementation and governance of the smart city programme. The PMO are positioned as 'middle actors' in the system'; the PMO acts as an 'innovation-matching platform' to facilitate connections and collaboration and to introduce and promote innovations between the various local government levels and actors.

3.4.2.3 Open data

Taipei City Government (TCG) is the first administrative authority in Taiwan to promote open data. Its open data platform, 'Data.Taipei', went live in September 2011. The platform is funded, managed and maintained by the TCG. The platform brings together open datasets, providing a one-stop contact for inquiry services.

The platform has 2,044 datasets (as of 7th October 2016) and 18 applications, utilising data provided by 91 collaborating organisations within the TCG. The eighteen applications came from a number of innovation competitions hosted by the TCG, where developers were invited to develop applications using the city's data sets. The platform provides two types of datasets (TDEODCK, 2015):

1. Published datasets: regular and non-regular E-publications produced by the TCG and its departments, mainly in PDF format; and
2. Digital datasets (structured or un-structured) which can be downloaded from the website.

The concept of the ‘built environment’ (as understood in the UK) is not used in practice in Taiwan – rather, the experts interviewed translated the term as ‘construction industry’. A construction industry expert commented that the concept of ‘smart city’ is very broad and its impact on the construction industry is limited, stating that:

“there is no link between smart city and the construction sector, as open data tends to relate to energy or transportation, not construction.”

However, even if we adopt the wider UK meaning of ‘built environment’ data used in the context this research, there are crucial problems in Taipei. Firstly, data process control. As an ‘IT’ industry expert commented:

“data that is claimed to be ‘open’ often needs ‘membership’ to gain access to it... such as tendering documents for public works.”

Secondly, data is also often not machine readable (for example, it may be in PDF format).

3.4.2.4 Big data

There is a different articulation of the term ‘built environment’ in Taiwan among construction and non-construction practitioners (e.g. city councils, academia) from that which is used in the UK and elsewhere. It appears that construction practitioners treated ‘built environment’ big data as a more general, narrative-based view of ‘construction’ big data. This is evident in the statement by a ‘construction’ industry expert that

“in the built environment, big data includes quantity, function, cost, outsourced work packages, and preliminary construction.”

Both construction-related experts further indicate that the construction ‘big data’ that is available on-line is not always up-to-date. Furthermore, there is scepticism towards the reliability of data.

3.4.2.5 Built environment projects

There are a number of built environment/construction ‘big’ and ‘open’ data projects spread all over the city. However, there is a strong view that there is an urgent need to integrate these projects. Furthermore, the success of these projects led by the TCG appears to be driven through two approaches: government-led or citizen-led. Firstly, the government-led approach tends to be driven by government initiatives. The following are two government-led examples:

- **Air Box programme** (community PM2.5 air quality monitoring) is a collaboration project between TCG, Academia Sinica, Realtek, Asus and residents to work together in response to air pollution prevention and control. Residents can access the internet or use an application to view environmental data.
- **Taipei Smart City Community Project** for public (social) housing focuses on energy efficiency, remote care and electronical car rental system. It includes a total of 6,000 units of six Smart Public Housing projects.

Secondly, the citizen-led approach tends to come into play when a disaster has struck. For example, the gas pipeline explosions in Kaohsiung in 2014, in conjunction with the delays caused by hidden pipes during the removal of bridges surrounding Taipei’s North Gate, led to the establishment of Taipei City Road and Piping Information Center which was established by the TCG in July 2015 to promote citizens access to information about open road maintenance and management.



3.5 UK workshop

3.5.1 Delegates

The workshop was attended by 12 delegates who were senior decision-makers and representatives from their organisations (Table 3.2) in July 2016. Although the focus was on smart cities, BIM was also part of the workshop discussions and the workshop was preceded by presentations on (i) initial research findings and (ii) the UK smart cities and BIM agendas. In the workshop presentation, it was stressed by an industry expert that smart cities needed to be understood within a wider context of BIM and data provision.

Project	City
Private sector companies	4
Government/NGOs	4
Surveying practices	2
Local authority	1
Academic	1

3.5.2 Key issues from workshop

3.5.2.1 Barriers to smart cities, big data and BIM

One of the key barriers to achieving integration and a joined-up approach to smart cities and BIM are problems around measurement. An industry expert pointed out that a lot of the data available is either ‘bad’ or not fit for purpose, that there is no strategy and calibration and that there is a lack of agreed standards. Moreover, there are doubts as to whether the data at the core of BIM and smart cities is really best described as ‘big’. As the same workshop attendee suggested:

“My argument probably is, is this really ‘big data’ yet? It’s quite big. Is it really big? I don’t think so. I think we’ve just got quite large lumps of data, not yet really big data.”

A further barrier is getting industry engagement beyond government-led responses. So far the response from the market in terms of data provision has been very fragmented, and the construction sector is unlikely to catalyse market transformation. An industry expert commented:

“There’s no Boeing or Rolls-Royce or Airbus coming along and say actually we’re going to solve this problem, get on with it ... I suspect if there was going

to be a big market transformer it’s not going to come from construction. It’s going to come from digital and manufacturing sector, so probably a Siemens or a Bosch or Huawei ...”

Moreover, unrestricted competition in the development of applications could create duplicated effort. There is also a need for smart clients. For example, understanding how a client needs to produce and use data is at the heart of the definition of a smart client. As an industry expert commented:

“If you haven’t got a smart local authority you haven’t got a smart city, so one of the things we’ve got to look at is how we increase the capability of our smart clients. These represent big, key decisions that the client needs to make”.

A key enabler is getting greater consolidation within the market by getting greater buy-in from the construction industry and from large FM companies and companies with large property portfolios. Retailing and airlines are examples of innovative industries from which construction can learn.

3.5.2.2 Top down or bottom up: a failed market?

It was felt that the smart city agenda as it currently stands is very much ‘top down’, with much of the impetus provided by software and hardware vendors, whereas in fact what was needed from a data perspective was a bottom up approach, provided through a more BIM-led, asset management focus. In that way, provided the individual assets were co-ordinated, it is easier to control sensor installation, calibration and measurement.

The barriers found in the RICS research and the barriers explored in the workshop also led one industry expert to suggest that the smart city market was in danger of failure:

“[It’s] pretty much a failed market, which is why there’s less money going into that sector for various reasons. It’s, the vendors have created a failed market. We need to unravel it and re-ravel it into a new strategy”.

3.5.2.3 Data, applications and the role of stakeholders

It was felt that there is a distinction between (i) the provision of open data and big data and (ii) the subsequent development of applications. These are two very different processes. For example, in the world of BIM the focus is very much on data to enable service provision, whereas smart city applications are usually developed to help deliver services based on the available data.

Although commercial sensitivity needs to be applied to the provision of data within a smart city model, government and local government were actually in a good position to help drive the smart city and BIM agendas. This is because of their ownership and close relationship with sources of healthcare and transport data, for example. However, the discussions also highlighted that local authorities are

at different stages and have different capabilities and resources to be able to do this.

It was also suggested that a 'smart city guide', based on a maturity model concept¹⁸, could also help city authorities better understand the steps required from data provision through to service delivery. This would also help cities and stakeholders plan more clearly so that data gaps do not arise.

'Interoperability', or the ability of different ICT systems to work with a variety of datasets, was also discussed as a critical issue to bear in mind. The proliferation of data standards and general fragmentation in the built environment industry was perceived as counterproductive. Moreover, it was suggested that local authorities focused too exclusively on the 'nice' or attractive side of smart cities (i.e. transport, healthcare and environment) instead of looking at other applications for big and open data such as crime and security. However, these kinds of social outcomes were seen by respondents as being particularly hard to measure, because, realistically, they cannot be assessed simply in terms of financial benefit or payback. There were also regional differences in approach, so cities needed to be understood within different contexts.

In some cities, such as Milton Keynes, there have been projects which have sought to create a 'trading environment' for data, where data is traded as a commodity. One industry expert commented that, even in the case of healthcare data, it was not feasible to rely simply on government data as representative of the full spectrum of data. While pharmaceutical companies, logistics companies and others would probably only share their data for a price, their data was still very important to embrace. Nonetheless, city authorities have a clear role to play as 'brokers' for data, using a 'curation' model similar to Amsterdam and Milton Keynes. In such models, data can be shared or protected depending on supplier and user requirements. The potential catalyst for this change was seen by respondents to be local authorities and central government. By providing their data openly, businesses looking for a first mover advantage could then build on this impetus. There were also signs from the discussions that some UK businesses were starting to put a direct asset value on their data in their balance sheets.

Workshop participants felt it was important to acknowledge the role of other stakeholders in the smart city agenda. For example, contractors and their clients were seen as unlikely to provide primary leadership alone, but utility companies (energy and water for example) had a key role to play. It was also suggested in the workshop that there was a need to engage with utility companies for direct data provision, as well as Local Economic Partnerships (LEPs), the police and transport agencies. Participants also discussed the need for shared data from citizens; from their phones and other devices.

However, they also discussed the need to acknowledge the varying roles of the different actors and stakeholders.

Local authorities were identified as being under pressure in the UK in an era of austerity, and often lacking the right skills and resources to drive change:

"... and things like big data, I think ... is probably a bit of a distraction at the moment when ... local authorities have difficulty enough at the moment handling effectively smaller datasets, let alone deciding what we're going to do about large datasets".

Often the distinctions in terminology were seen as unhelpful. Indeed, one industry expert suggested:

"I think for the sake of this debate, actually, I think the words 'open' and 'big', 'model' and 'BIM' should be deleted from our taxonomy because they really don't help. Yeah, it's just 'data'... The market and how we fund, and how we create these changes, is actually the real challenge."

3.5.3 Unlocking potential value in open and big built environment data

It was agreed in the workshop that there needs to be a primary focus by the built environment professions and professionals on data procurement and digital assets. Firstly, there is a need to understand the data requirements of the built environment sector as this is poorly understood at present. This understanding needs to be embedded within the procurement process, which needs to be aligned with the delivery and operation of built environment assets (with a primary focus on Totex¹⁹). Secondly, the future use of the data needs to be tackled by embedding interoperability in the built environment sector, and focusing from the outset on how the data will be used in the context of the smart city.

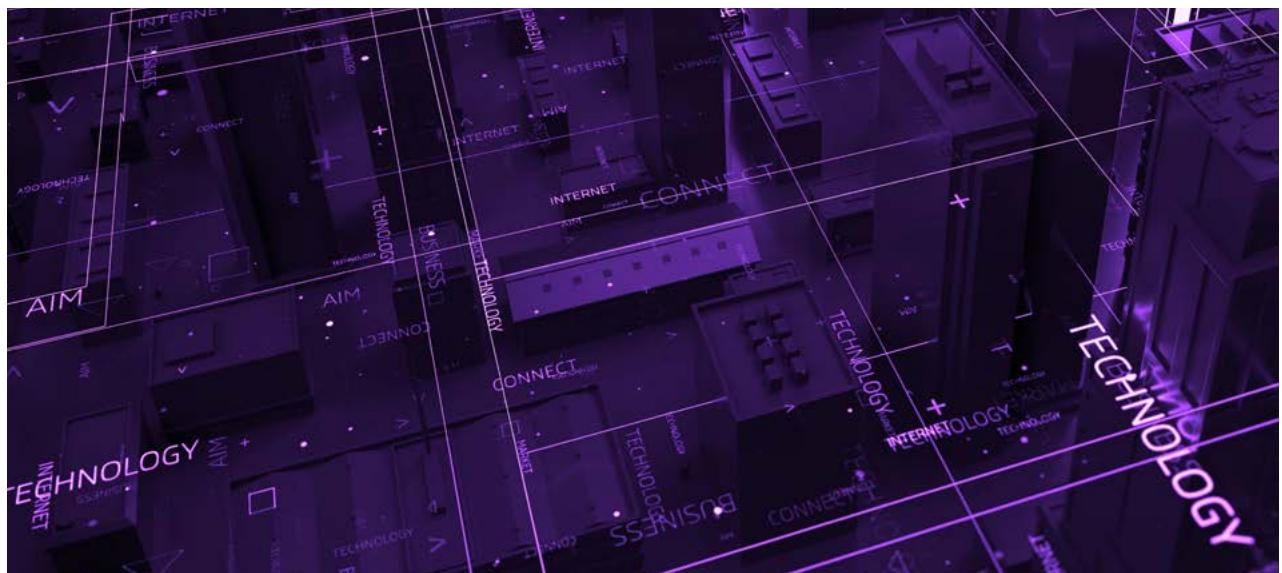
Engagement at the right time and with the right stakeholders was identified as important. The contractors and delivery partners in projects also need to influence their clients with respect to data at the procurement stage.

Creating trust and brand was also discussed as important in the built environment sector. This begins with standards, as a means to agree on a common language for data. The construction industry can learn from other industries such as technology, retail and the aircraft industry, where trust and brand are paramount.

The workshop discussion also suggested that dealing with liability and regulation will be increasingly important in the future. For example, actors and stakeholders need to agree what happens when projects fail, or when decision-making is found to be based on incorrect data. Liability and regulation were identified as key topics for urgent consideration.

¹⁸ The maturity model concept is used to assess how an organisation can potentially perform in its ability for continuous improvement in a defined activity or stakeholders' activities. ¹⁹ Totex, or Total Expenditure, is a concept used within regulated industries which are heavily dependent on infrastructure assets [in contrast to Opex (operating costs) and Capex (capital expenditure)].

4.0 Conclusions



4.1 Introduction

This chapter of the report provides conclusions to the research, drawing out the main findings to highlight:

1. The 'big picture' in UK smart cities.
2. 'On the ground': what is happening in UK smart cities and internationally?
3. The promise and the challenges of built environment big data.
4. Policy and practice implications: what's required?

4.2 The 'big picture' in UK smart cities

4.2.1 Definitions, plans and strategies

As the literature review showed, there is no overall consensus as to what is meant by a 'smart city'. Cities differ in their approaches, and the way in which they develop and manage smart city projects. The UK scoping survey in this research found that only 47% (9 out of 19) of cities in the survey had an established definition for smart city (with a majority adopting the BSI smart city definition). Moreover, high level planning at city level is not common. Only 22% (4 out of 18) of respondents had a smart city action plan and only 22% a smart city framework.

Similarly, only 33% (6 out of 18) of respondents suggested their city had a data strategy and only 22% (4 out of 18) suggested that the strategy mentioned big data. On the other hand, some 61% (11 out of 18) of respondents suggested their city had an open data platform.

The majority of data collected for these platforms is sourced from the public sector and frequently focuses on infrastructure data and sensor data. When asked about benefits and barriers of smart city built environment projects were seen to be improved sustainability (27% of responses); improved liveability (including health and wellbeing) for citizens (18%); and better public safety (12%).

In the UK, therefore, it is clear that there is a lack of strategic thinking in smart cities and that the current focus is on open data rather than big data.

4.2.2 Big data barriers

Although there are clearly potential future applications for the use of both open data and big data in UK smart cities (for example, personal analytics, infrastructure and sensor-based data), a number of important big data barriers were identified at city level. These included:

- Fragmented ownership of the data.
- Unreliability of data sources.
- Different types of data being held in different formats.
- Inconsistency and irregularity in data generation.

4.2.3 Built environment data projects

Although there were examples of built environment smart city projects in a number of cities (including London, Manchester, Edinburgh and Cardiff), costs and funding issues and infrastructure requirements were all seen as important barriers which were preventing progress.

Table 4.1 Comparison of smart city case studies

	Bristol	Milton Keynes	Amsterdam	Taipei
Smart city programme leadership	Led by Bristol City Council in partnership with Bristol University and other partners.	Led by the Open University in partnership with Milton Keynes Borough Council and other partners.	Facilitated by Amsterdam Economic Board, with input from local government, private sector and knowledge institutions.	Led by Taipei City government with input from research institutions, private sectors, NGOs.
Smart city programme focus	Low carbon and resilience. An emphasis on 'experimentation' and a 'playful city'.	Sustainable economic growth. The city is seen as a 'testbed'.	Connect stakeholders, accelerate doing and learning and strengthen the smart city fabric.	Smart government, smart citizens, smart experiment sites, and smart infrastructure.
Open data: importance	Primary focus in smart city.	Primary focus in smart city.	Primary focus in smart city.	Primary focus in smart city.
Business model for open data hub	No cost currently.	No cost currently, but data exchange/marketplace also being developed.	No cost for use of platform. Other platforms exist to share data internally and externally.	No cost for use of platform. Some specialist data is chargeable.
Big data: importance	Secondary focus and evolving in smart city.	Secondary focus and evolving in smart city.	Secondary focus and evolving in smart city.	Secondary focus and evolving in smart city.
Built environment 'big data' projects	<ul style="list-style-type: none"> • REPLICATE • Citizen Sensing 	<ul style="list-style-type: none"> • MotionMap • CAPE 	<ul style="list-style-type: none"> • City-zen • CitySDK 	<ul style="list-style-type: none"> • Air Box programme • Taipei Smart City Community Project for public housing
Level of built environment sector engagement with smart city projects	Low level	Low level	Low level	Low level

4.3 'On the ground': what is happening in UK smart cities and internationally?

Although smart cities differ in their approaches, the research case studies showed a number of similarities in terms of their characteristics. Firstly, in terms of leadership, Universities played a more important role in the UK than in the international case studies. As Table 4.1 shows, for example, the universities in Bristol and Milton Keynes are an integral part of the leadership, whereas in Amsterdam, the Amsterdam Economic Board facilitates but leads with partners and in Taipei, the city government leads. Secondly, in the UK, historically the smart city agenda has been overlaid onto existing sustainable city programmes (Bristol) or policies which focus on sustainable economic growth (Milton Keynes). In Amsterdam and Taipei there is a much stronger focus on the imperative of the smart city for its own sake.

Despite these differences, all four case studies focus on open data, with big data playing a secondary and evolving role. The open data hubs are currently free of charge in each city (with some specialist data such as public works tendering information subject to charge in Taiwan). These hubs all offer access to some 'built environment' data (although there is some uncertainty over the use of this term in Taipei), including transport, energy, land use and property etc. However, there was often scepticism expressed about the illusory nature of 'big data' by the interviewees. Although there were examples of big data built environment projects, there was also a marked lack of engagement by the built environment sector (property and construction), both in terms of direct data provision to data platforms at city level and in terms of direct engagement with smart city built environment projects at city level. This generally reflected issues over data confidentiality, but also the nature of the property and construction sector in terms of its fragmented nature, different timescales to the digital sector and issues over interoperability of data.

4.4 The promise and the challenges of built environment big data

Much of the smart city literature has highlighted the promise and appeal of big data and big data analytics. Big data (and open data), available within the smart city framework are seen by their advocates as an opportunity to create a ‘market place’ for data, encouraging urban innovation and helping create economic benefits and jobs growth for cities in the UK. The growth of interest in big data is also being fuelled by (i) the increasing prevalence of sensors in buildings and the wider physical built environment of cities and (ii) the greater connectivity between a variety of devices and sensors (the ‘Internet of Things’). This increased connectivity makes it much easier to produce real time data feeds for subsequent analysis, for example, of traffic, pollution levels and energy use (IET, 2015). Moreover, the UK Government’s Digital Built Britain programme (HM Government, 2015) sees a strong interconnectivity between the digital data, which could be made available (and open) through BIM and asset management functions and the broader smart city model.

The primary research (case study interviews and workshops) has revealed a number of challenges surrounding the development of big data projects in the built environment:

- **Definition and measurement:** defining what is meant by ‘big data’ is difficult as different meanings and interpretations can be put on the term. Distinctions in the terminology between ‘open’ and ‘big’ data, as well as ‘model’ and ‘BIM’ were seen as unhelpful by respondents. The interviews also showed much scepticism around the concept of truly big data and whether it was yet available.
- **Business engagement:** Moving the debate beyond government or local government led initiatives is proving difficult. The property and construction industries lag in terms of digitisation and innovation levels continue to lag other sectors. However, this problem of business engagement is not unique: commercial confidentiality issues and commercial interests continue to hamper the development of data hubs which could potentially use commercially provided data. Proving the business case and end use case were therefore seen by respondents as vital to success. Part of the solution might be a market-based data exchange at city level (Milton Keynes), or the further development of a curation role for cities (Amsterdam).
- **Interoperability:** the ability of different ICT systems to work with a variety of datasets is also a critical issue to bear in mind. The proliferation of data standards and general fragmentation in the built environment sector is not helpful.

- **Top-down approach:** in the UK workshop, it was felt that the smart city agenda is very much ‘top down’, with much of the impetus provided by software and hardware vendors, whereas in fact what was needed was a ‘bottom up’ approach, provided through a more BIM-led, asset management focus. In that way, provided the individual assets were co-ordinated, it would be easier to control sensor installation, calibration and measurement. Unless this was tackled, the smart city market was in danger of ‘failure’, although clearly many cities were facing budget constraints because of austerity measures.

4.5 Policy and practice implications: what’s required?

Addressing these barriers and enabling the built environment sector to engage in smart cities, big and open data requires an honest appraisal of the role of key actors and stakeholders in the smart city agenda, both in the UK and internationally. Based on our findings from the workshop and other interviews, this appraisal revolves around two main issues:

- Understanding the use and supply of built environment big data.
- Recognising the changing roles of stakeholders.

4.5.1 Understanding the use and supply of built environment big data

There needs to be a **primary focus on procurement and digital assets**. Firstly, there is a need to understand the requirements of the built environment sector in terms of data, as this is poorly understood at present. This understanding needs to be embedded within the procurement process, which needs to be aligned with the delivery and operation of built environment assets (with a primary focus on Totex). Secondly, the future use of built environment data needs to be tackled by embedding interoperability in the built environment sector and by focusing on how the data will be used in the context of the smart city. However, it is important to understand that existing built environment projects also need to be tackled in terms of data provision. A focus on digital assets (i.e. buildings and infrastructure, for example) and putting an asset value on data itself in company balance sheets can help provide impetus for this.

Engagement at the right time and with the right stakeholders is important. The contractors and delivery partners in projects need to discuss options for data gathering, sharing and analysis with their clients at the procurement stage. This requires organisations to be ‘data savvy’: to identify where big and open data can help inform and improve the operation of their own organisations, as well as those of their clients.

Citizen engagement is also vital; people must be able to understand data gathering and sharing the development process, as well as understanding the benefits and drawbacks of data sharing to the wider city.

Creating trust and brand is important in the built environment sector. This begins with agreement upon common data standards and a common language for data. The construction industry can learn from other industries such as tech, retail and the aircraft industry, where trust and brand are paramount.

Dealing with liability and regulation will be increasingly important and needs to be addressed with smart city programme strategies. For example, what happens when projects fail, or decision-making is based on incorrect data? What needs to be done about liability and regulation in this difficult field? The quality and the provenance, validation and security of data are all important issues to consider in the built environment sector. Big data sets also create issues in terms of screening, verification and the appropriate use of human and/or machine-based processes for checking data quality.

4.5.2 Recognising the changing roles of stakeholders

Cities need to develop clear **smart city strategies and data strategies** (covering big data and open data) which provide greater certainty for all stakeholders. A 'smart city guide', or 'digital masterplan' based on a maturity model concept, could also help city authorities better understand the steps required from data provision through to service delivery. This would also help cities and all stakeholders plan more clearly so that data gaps did not arise. There needs to be improved incentives for companies to provide open data and big data, through the development of viable commercial business models.

Professional bodies within the built environment sector (including RICS and RIBA) need to determine what role they and their members should have in relation to data (open and big) in the context of smart cities. This means understanding how to supply and broker relevant data for particular requirements. There is a first mover advantage here for organisations which needs to be highlighted as an opportunity by professional bodies.

Promoting the agenda through 'champions for change' in the professional bodies is vital and collaboration across the built environment professions is a critical issue to address. The development of case studies using big and open data from the built environment will help promote better understanding of how such data can be utilised. However, built environment professionals and businesses may currently lack the people with the right data management and analysis skills. There also needs to be a better understanding of liability so that the 'fear' of sharing data can be reduced and data trading becomes easier.

Data skills and smart city skills (relating to data analytics and data management, for example) are cross-cutting skills which need to be embedded within professional competencies (including those of the RICS). Built environment professionals need to be able to gain a much better understand the data needs and requirements of their clients, as well as the potential impacts of big and open data on professional advice in this area.

It will also be important for the professional bodies to be more closely aligned with tech companies, city authorities and other stakeholders in the smart city agenda. This will help provide further impetus to enable all stakeholders to work together to deliver improved services for citizens.

This research has examined both open data and big data through the lens of the smart city. It has highlighted many issues for consideration by built environment professionals and professional bodies, especially regarding how best to engage with the smart city and BIM built environment agendas.

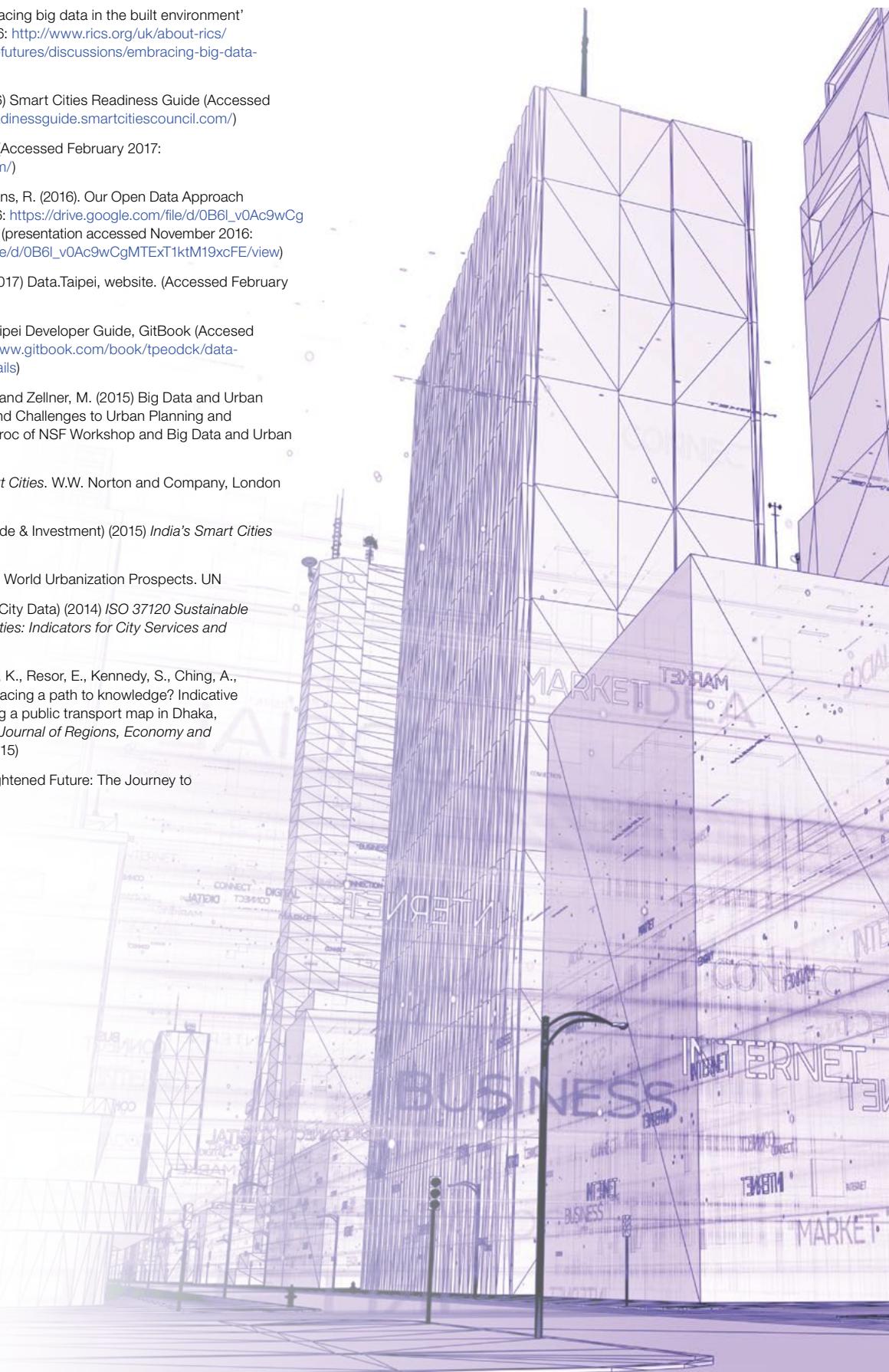
There is evidence to suggest that the real estate and construction sectors (and related professional services) do hold big data and are using it internally for client services and other activities. A key challenge is to find out whether, and how, this data could be used in a smart city context and in other potentially collaborative ways. Further research is therefore needed to examine what data is held by such organisations and how it could help underpin and drive both the smart city and BIM built environment agendas in an integrated way.

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Appendix 1: Examples of smart city definitions

Type	Definition	Source	Reference
Academic	'Smart cities will take advantage of communications and sensor capabilities sewn into the cities' infrastructures to optimize electrical, transportation, and other logistical operations supporting daily life, thereby improving the quality of life for everyone'.	Chen (2010)	Chen, 2010
	'Smart cities have high productivity as they have a relatively high share of highly educated people, knowledge-intensive jobs, output-oriented planning systems, creative activities and sustainability-oriented initiatives.'	Kourtit et al, 2012	Kourtit et al, 2012
Government	'... the concept is not static: there is no absolute definition of a smart city, no end point, but rather a process, or series of steps, by which cities become more 'liveable' and resilient and, hence, able to respond quicker to new challenges. Thus, a Smart City should enable every citizen to engage with all the services on offer, public as well as private, in a way best suited to his or her needs. It brings together hard infrastructure, social capital including local skills and community institutions, and [digital] technologies to fuel sustainable economic development and provide an attractive environment for all'.	BIS	BIS, 2013: 2
	'A smart city is a place where the traditional networks and services are made more efficient with the use of digital and telecommunication technologies, for the benefit of its inhabitants and businesses'.	EU	EU, 2016
Technology companies	'A smarter city uses technology to transform its core systems and optimize finite resources. At the highest levels of maturity, a smarter city is a knowledge-based system that provides real-time insights to stakeholders, as well as enabling decision-makers to proactively manage the city's subsystems. Effective information management is at the heart of this capability, and integration and analytics are the key enablers'.	IBM	IBM, 2013
	'The "smart city" concept includes digital city and wireless city. In a nutshell, a smart city describes the integrated management of information that creates value by applying advanced technologies to search, access, transfer, and process information. A smart city encompasses e-home, e-office, e-government, e-health, e-education and e-traffic'.	Huawei	IBM, 2013
Industry standards	'Smart Cities: a new concept and a new model, which applies the new generation of information technologies, such as the IoT, cloud computing, big data and space/geographical information integration, to facilitate the planning, construction, management and smart services of cities. Developing Smart Cities can benefit synchronized development, industrialization, informationization, urbanization and agricultural modernization and sustainability of cities development. The main target for developing Smart Cities is to pursue:	ISO	Huawei, 2016
	<ul style="list-style-type: none"> ▪ Convenience of the public services; ▪ Delicacy of city management; ▪ Liveability of living environment; ▪ Smartness of infrastructures; ▪ Long-term effectiveness of network security'. 		
	'Smart cities is a term denoting the effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens'.	BSI	ISO/IEC, 2014b: 2
	'A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects'.	ITU	ITU, 2014: 1

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Appendix 2: List of respondent cities in UK online survey

Belfast City Council
Birmingham City Council
Bristol City Council
Cambridgeshire County Council (for Cambridge)
Cardiff City Council
Coventry City Council
Edinburgh City Council
Glasgow City Council
Greater London Authority
Leeds City Council
Liverpool City Council
Manchester City Council
Milton Keynes Council
Peterborough City Council
Reading Borough Council
Southampton City Council
Southend Borough Council
Sunderland City Council
Unspecified city council

Appendix 3: Smart city case studies – further information

Bristol

Key Websites

Website	Weblink
Bristol is Open	http://www.bristolisopen.com/
Open Data Bristol	https://opendata.bristol.gov.uk/
Connecting Bristol	http://www.connectingbristol.org/
Citizen Sensing	http://kwmc.org.uk/projects/bristolapproach/
Replicate	http://replicate-project.eu/

Interviewees

Academic	1
Industry	1
Local authority	7
Total	9

Milton Keynes

Key Websites

Website	Weblink
MK:Smart	http://www.mksmart.org/
MK:Data Hub	http://www.mksmart.org/data/
Our:MK	https://ourmk.org/
Plan: MK	https://www.milton-keynes.gov.uk/planning-and-building/planning-policy/plan-mk
MK Futures Commission	http://www.mkfutures2050.com/
MotionMap	http://www.mksmart.org/transport/
CAPE	https://capeproject.co.uk/

Interviewees

Academic	3
NGO	1
Industry	1
Local authority	2
Total	7

Taipei

Key Websites

Website	Weblink
Taipei Smart City	https://smartcity.taipei/?locale=en
Taipei City Open Data Platform	http://data.taipei/
Taiwan Smart City Solution Alliance	http://smartcity.org.tw/info_en.php
Taipei City Road and Piping Information Center	http://dig.nco.taipei/Tpdig2/Default.asp
Taipei Smart City Community Project for public housing	http://www.housing.taipei.gov.tw/ph-ae/smарт-community

Interviewees

Academic	2
Construction NGO	1
Industry	3
Taipei City Government	6
Total	12

Amsterdam

Key Websites

Website	Weblink
Amsterdam Smart City	https://amsterdamsmartcity.com/
Open Data Amsterdam	https://data.amsterdam.nl/
City Zen Energy renovations	http://www.cityzen-smartcity.eu/demonstration-sites/amsterdam/
City Zen Serious Game	https://amsterdamsmartcity.com/projects/city-zen-serious-game
CitySDK Linked Data API	http://citysdk.waag.org/
'Gebouwenkaart' Age map of Dutch Buildings	http://code.waag.org/buildings/
Energy label atlas	http://www.energielabelatlas.nl/

Interviewees

Industry	3
Local authority	4
Total	7



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With offices covering the major political and financial centres of the world, our market presence means we are ideally placed to influence policy and embed professional standards. We work at a cross-governmental level, delivering international standards that will support a safe and vibrant marketplace in land, real estate, construction and infrastructure, for the benefit of all.

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