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March 2018

Big data, smart cities, intelligent buildings – surveying in a digital world

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Report for Royal Institution of Chartered Surveyors

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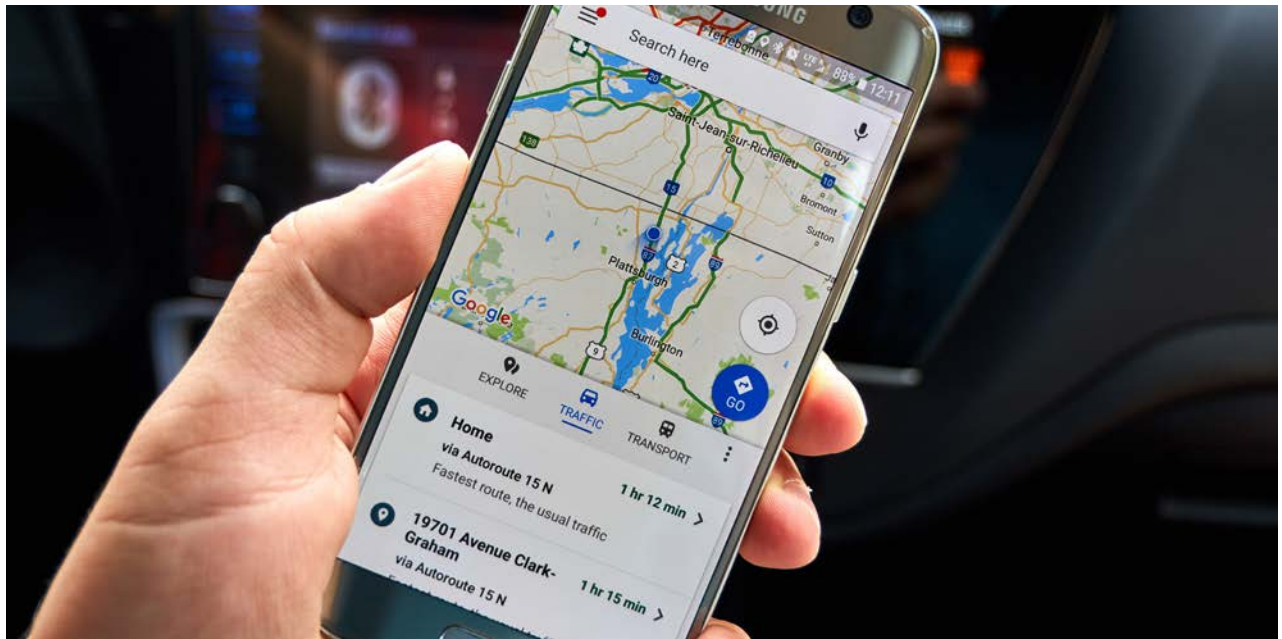tmulhall@rics.org

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Foreword

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For centuries, map making was the preserve of national institutions producing maps of their country's territory at a variety of scales. These maps, created by surveyors, provided the modern basis for recording land rights, establishing boundaries and the supporting documentation for a host of transactions in land, property and construction.

In 2004, Google Maps did not exist. By 2018, it is the default resource for consumers looking for locational information on a global basis. All of this was made possible in such a short space of time by the arrival of big data and the supporting infrastructures around it. While the rapid development of new entrants in the geospatial market may seem like a threat to the traditional agencies, on the contrary, organisations that have fully embraced the digital world have developed new, better and more accessible services responding to client needs in formats previously unimaginable.

This insight paper considers the potential disruptive impact of big data and digital technologies on traditional surveying practice. Some of our professionals are directly engaged with the area on a day-to-day basis as data generators. Their industries have always had a strong technical basis and have been closely involved in the sector's technological developments. Others rely on large databases and big data as users of other people's content, and so approach this world from a different perspective. Some professionals may seem to be less directly impacted, nevertheless their sectors are steadily being transformed, even as their private practice appears to remain the same.

It is fair to say that no part of surveying practice will remain untouched by the impact of big data and digital technologies. This will be either through proactive adoption of new digitally based approaches to our work; being led by client demand to deliver these services; or being forced by digitally enabled competition from existing providers and new entrants.

This paper recognises that there will be a great deal of variability among professionals in knowledge, understanding and expertise in this area. Internationally, it is evident that different countries are at different stages of development in the adoption of digital technologies. Generationally, it is also clear that many in the profession will have been converting from analogue to digital. But there will be a whole new group of young people entering the profession from now on who will only have known a digital environment. Yet, they too will not be immune from the accelerating pace of innovation.

These professionals will be working alongside each other, exchanging information, collaborating and competing to provide clients with the best possible service. Our intention is to ensure that all are aware of the transformational changes taking place and understand the implications for our diverse areas of practice.

John Hughes FRICS
RICS President (2017–2018)

1.0 Introduction

Big data is a term used to refer to large, complex data sets that cannot be analysed using traditional data analysis techniques. The use of big data is becoming a key basis of competition and growth for professional firms, and it is already affecting every area of business activity including real estate, construction and the built environment.

Spatially-referenced big data is impacting every aspect of the surveying profession, and chartered surveyors need to understand what big data is, and to engage with its implications. These range from smart cities and intelligent buildings, through to property information relating to construction costs, property markets, land use and valuation data.

Some big data applications are already ubiquitous and they are changing the way the profession works. Yet some real estate professionals may be behind the curve when it comes to this trend and may be poorly equipped by training and experience to capitalise on this pervasive technology.

Nowadays, the majority of data is born digital and the flow of new data is constant with more data being created and at an ever-increasing rate. The pace of this data growth is difficult to imagine. The British Standards Institute (BSI) observes that more information was generated in the last two years than in the entire history of humankind (see PD 8101:2014 *Smart cities. Guide to the role of the planning and development process).*

Big data represents both an opportunity and a threat. Many commercial organisations are intent on monetising big data, either through the provision of professional services, through the ownership and augmentation of the data, or through the development of innovative new services.

A recent RICS Research Trust project identified the challenges of built environment big data, ranging from problems of definition, to the changing role of stakeholders and the need for new and different skills from the traditional skills of chartered surveyors (Dixon, et al., 2016).

Given the size of the data being captured and stored, it is easy to see why the term big data has arisen, but there is more to big data than the problem of size. There is a socio-technical dimension that is overlooked by engineers, computer specialists and data analysts who often treat data as being technically neutral and objective in nature. Data does not exist independently of the ideas, practices, and contexts used to manage it; nor does it exist independently of instruments used to generate it (these ideas are explored in greater detail by Kitchen, 2014).

Then there are the multiple narratives from the different stakeholders who promulgate big data, and it is fair to say that there is a boosterism associated with the commercial opportunity that big data represents.

Beyond the technical problems, big data raises ethical questions around privacy, and privacy trade-offs, data-sharing, anonymity, security and consent.

To understand the implications that big data has for the built environment, it is first necessary to understand characteristics of big data and how it is defined.

2.0 Characterising big data

Any consideration of big data starts with contemplation of data size and a look at some definitions and characteristics of big data. Given the rapid evolution of the concept, big data is a poorly defined term, used with varying degrees of precision and capable of multiple definitions.

On the one hand, definitions may be techno-centric, focusing solely on the tools used for the gathering and analysis of data. Such definitions tend to compartmentalise the field and narrow the spectrum of occupations and skills to a tightly-knit group of specialists, primarily scientists, mathematicians and computer specialists. This technology focus centres on how big data can be manipulated to inform technical solutions to problems without considering the context of the solution. This is where the domain knowledge of the chartered surveyor comes into play and where the profession can both influence the ways in which big data is used and tap into the opportunity that it represents.

Other definitions of big data consider the social aspect of big data applications, providing important wider perspectives on how big data can be applied, and also on the governance of big data development. The Oxford English Dictionary defines big data as:

'Extremely large data sets that may be analysed computationally to reveal patterns and trends and associations especially relating to human behaviour and interactions.'

This definition encompasses the wider socio-technical issues relating to the human dimension and hints at problems of privacy, anonymity and consent while the US National Institute of Standards and Technology provides a more technical definition:

'Big Data consists of extensive datasets – primarily in the characteristics of volume, variety, velocity, and/or variability – that require a scalable architecture for efficient storage, manipulation, and analysis.'

This includes reference to the most widely accepted 'three Vs' of big data: volume, velocity and variety. These characteristics epitomise the standard depiction of big data, often known as the 3V model, as shown in Figure 1.

Figure 1: The characterisation of big data
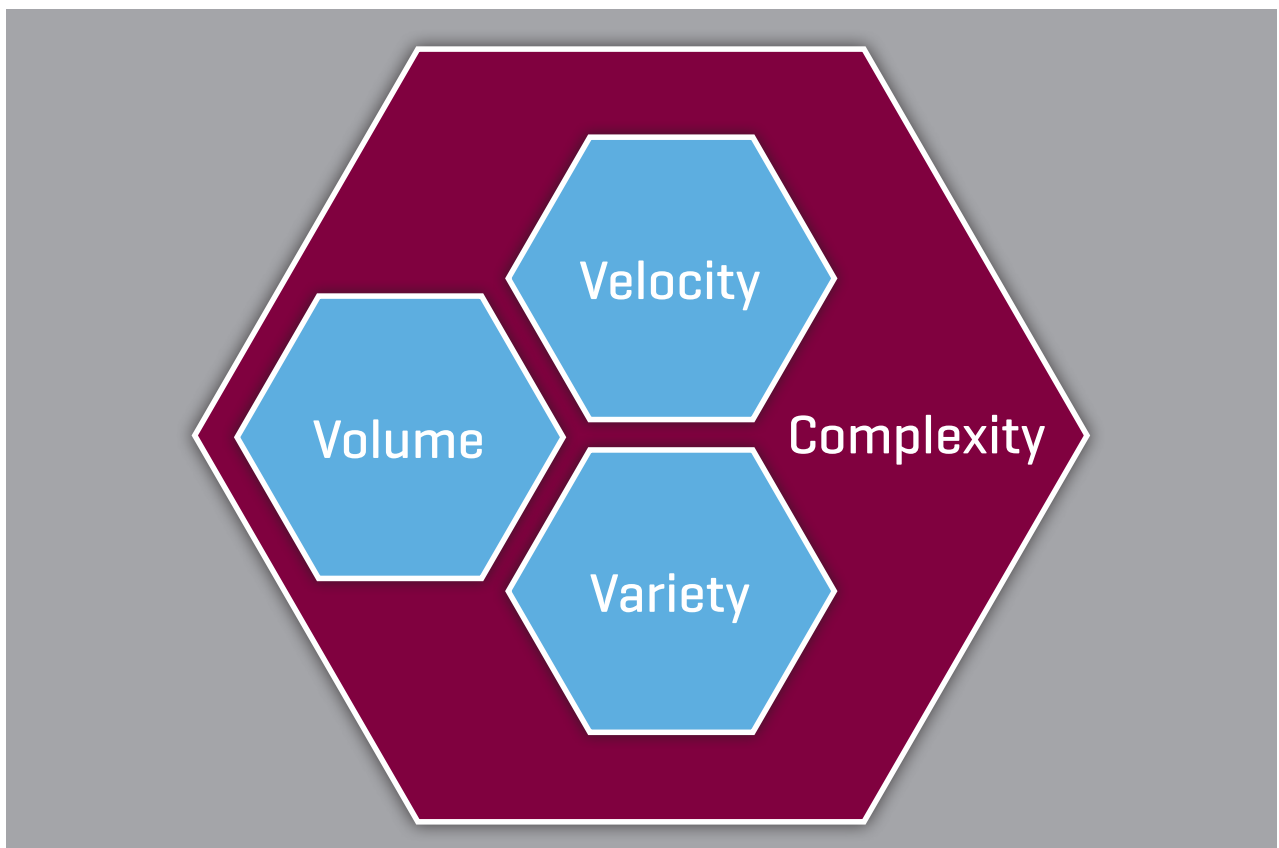
We must first consider the red bounding hexagon, labelled **Complexity**. This is to alert readers to the fact that the science of big data is complex, and it has complexity present at more than one level, from the underlying technology right through to the analytical models that must be deployed. These depart from conventional scientific methods and have been labelled the fourth paradigm (Hey et al., 2009).

The blue hexagons in Figure 1 are the three Vs that make up the widely accepted big data model, representing:

- High **volume**, measured in terabytes, petabytes or even exabytes of information. This is a huge volume of data: an exabyte is equivalent to 10 billion copies of The Economist. A big data assembly is many orders of magnitude greater than a large record set in a conventional database, which might itself contain hundreds of millions of records.

- High **velocity**, with some data being continuously generated in real time or near-real time. Data are streamed from sensors that create data constantly. Velocity refers to speed of creation but it can also refer to speed of analysis needed.

- High **variety**, as big data are drawn from a number of different data sources, including structured and unstructured data. The data may be temporally and spatially referenced. One example of this would be combining data on traffic flows with tweets providing commentary on travel conditions or commuter experiences.

In addition to these three fundamental characteristics, other aspects relating to the collation and use of big data are worth noting, and these include **variability** (noted earlier in the NIST definition), **veracity** and **visualisation**. The latter reminds us that big data isn't all about inputs and data collection: it is also about outputs.

A final V, which could be added to the representation, is for **value**. For chartered surveyors, the concept of value is as deeply ingrained as valuation and measurement are core skills for RICS professionals.

3.0 The knowledge hierarchy

Value in a data assembly comes from the processing of raw data and the knowledge hierarchy is a visual representation of how value can be added to data, often known by the letters DIKU. See Figure 2.

The knowledge hierarchy was popularised by Russell Ackoff (1989). Some versions of the model use the letters DIKW, where W stands for wisdom, in place of understanding.

In the hierarchy:

Data have no meaning or value because they are without context and interpretation. In this representation we see the data coming from multiple data sets. The data sources are shown on the left, represented as multiple data sources.

Information is formatted data that have been given meaning and context.

Knowledge is information combined with understanding and capability.

Understanding is the highest level of abstraction. It is knowledge with the addition of vision, foresight and the ability to see beyond the horizon.

Another way to characterise the levels is to describe **information** as 'know what', **knowledge** as 'know how' and **understanding** as 'know why'.

With this initial understanding of the characteristics of big data, attention is now given to the skills and expertise that are needed to navigate the big data landscape.

Figure 2: The knowledge hierarchy
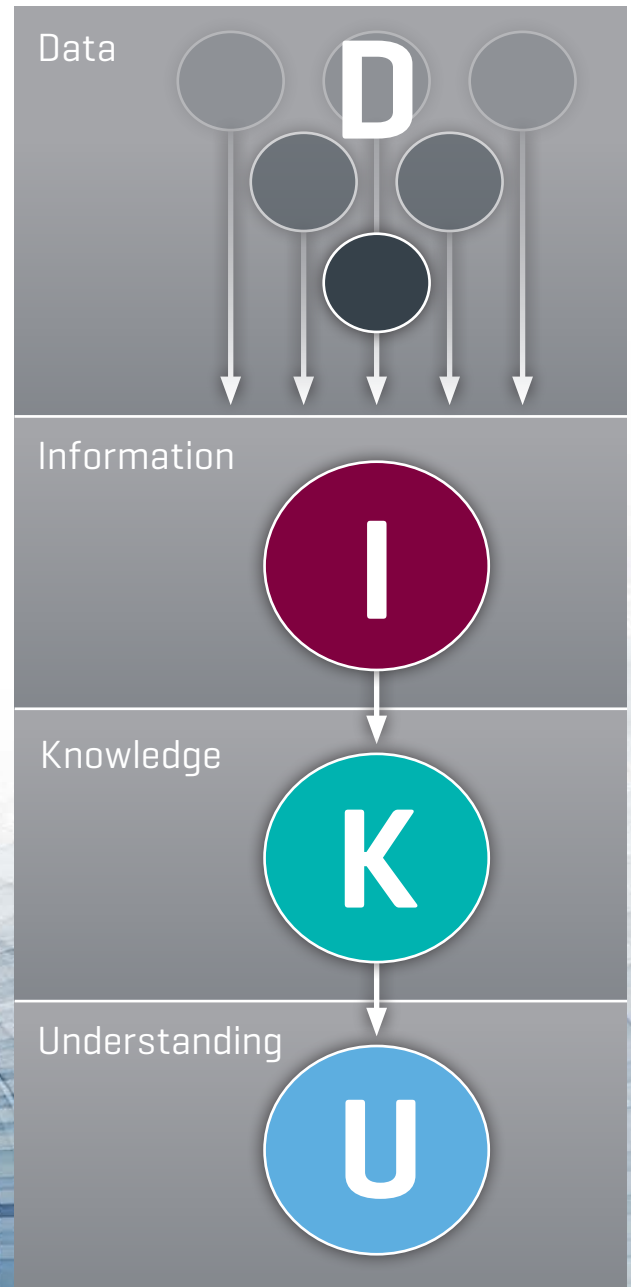
4.0 Jobs and skills

Professional firms, property owners and others concerned with the management and development of the built environment and natural resources need to address a number of challenges if they want to capture the maximum benefits from big data.

These are not just technology based. IT companies typically concentrate less on the I for information and more on the T for technology (Kitchen, 2014). Yet it is the information that is of value and the technology that provides the tools to capture, store and process the data. Even today, human input for process definition, management and interpretation remains essential.

Managing and analysing big data is expensive. It requires specialised hardware and software and specialist expertise. A talent gap also exists that will affect the ability of firms, organisations and governments to maximise the potential of big data (Hoskins, 2014). Interdisciplinary skills are needed and this makes the assembly of effective teams more difficult. Three kinds of specialist expertise are needed: domain, data and analytical. The work of Williford and Henry (2012) identifies project management as a fourth type of expertise, but this is not considered further in this insight paper. Each area has different dimensions and these are shown in Figure 3.

RICS professionals are the domain experts. To be effective, domain experts need to understand the new data structures, as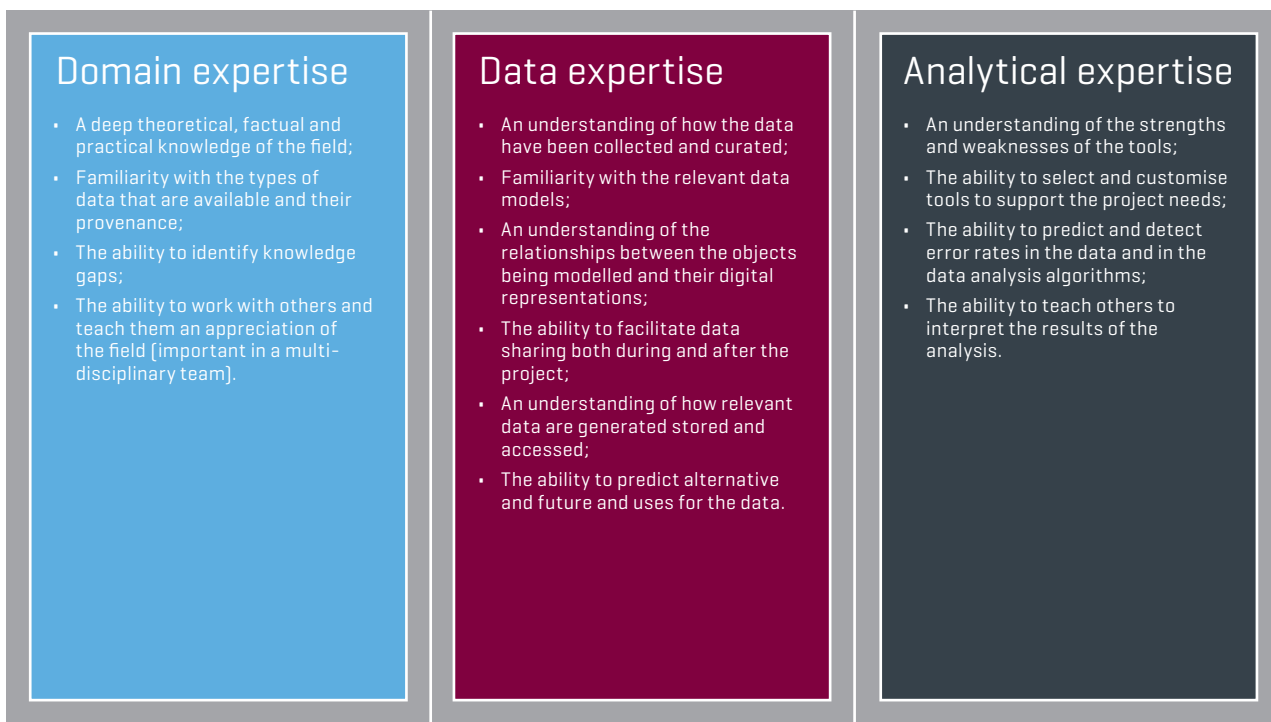 well as the changes and opportunities that arise from big data (Kitchin, 2014) but many chartered surveyors were trained in an age where data were a scarce commodity.

Having a team member with inter-disciplinary expertise is of particular value in a big data project and has been seen as critical to project success but 'people with these skills are very hard to find' (Edelstein, 2012, quoted in Williford and Henry, 2012).

According to Mckinsey (Mckinsey Global Institute, 2011) the shortage of 'analytical and managerial talent necessary to make the most of big data is a significant and pressing challenge.' They identify a shortage of nearly 200,000 people with the necessary analytical skills and a further 1.5 million 'data-savvy' managers are needed to take full advantage. Mckinsey believe that the talent shortage is just beginning.

To address these shortages, universities are starting to offer degree programmes for data scientists and this is an area of growth for many institutions. These qualifications tend to fall into two broad categories: programmes in computer science departments that are technically focussed, and those in different domain areas that attempt to blend technical skills with discipline-specific expertise, seeking to develop inter-disciplinary skill sets. Programmes are now available for spatial big data, typically at Master's level and these address the broad range of skills needed by a spatial data scientist, but this is probably at the expense of the core curriculum that might be expected of a traditional RICS accredited programme. RICS is also addressing this challenge with new technical competencies planned for the APC in 2018.

Figure 3: The skill sets needed to implement and manage big data

Domain expertise

- A deep theoretical, factual and practical knowledge of the field;
- Familiarity with the types of data that are available and their provenance;
- The ability to identify knowledge gaps;
- The ability to work with others and teach them an appreciation of the field (important in a multi-disciplinary team).

Data expertise

- An understanding of how the data have been collected and curated;
- Familiarity with the relevant data models;
- An understanding of the relationships between the objects being modelled and their digital representations;
- The ability to facilitate data sharing both during and after the project;
- An understanding of how relevant data are generated stored and accessed;
- The ability to predict alternative and future and uses for the data.

Analytical expertise

- An understanding of the strengths and weaknesses of the tools;
- The ability to select and customise tools to support the project needs;
- The ability to predict and detect error rates in the data and in the data analysis algorithms;
- The ability to teach others to interpret the results of the analysis.

It is predicted that some skills will be replaced through computerisation and the advent of big data. Researchers at the University of Oxford (Frey and Osborne, 2013) examined nearly 700 occupations and identified which were most susceptible to computerisation. Some occupations were classified as being at high risk of unemployment, based on their potential to be automated over the next decade or two. The research found that those jobs most susceptible to computerisation were generally (not exclusively) those with lower wages and lower educational requirements. A list of jobs that fall under the broad RICS umbrella and their estimated probability of automation can be found in Table 1. This list is ordered from the highest likelihood to the lowest.

Many occupations relating to the built environment are under threat from big data applications and computerisation (See Thompson and Waller, 2017 for an up-to-date analysis of this problem in a surveying context.). Jobs with a high degree of specialisation in an area that lends itself to computerisation are at greatest risk (Harkness, 2016, chapter 3). Those with higher levels of qualification seem more immune to computerisation, but it has also been suggested that the fields least under threat are those that require more creative intelligence.

Data scientists themselves, while not a specific category in the study have a very low likelihood of being computerised

and this applies to all professional engineering and science occupations. (Computer systems analysts, software developers and database administrators shown in the study are taken as proxies for data scientists.) This is largely due to the level of creative intelligence required for these occupations. Likewise, urban and regional planners have a comparatively low likelihood of having their jobs computerised. On the other hand, surveyors have an intermediate level of risk, while cost estimators and real estate managers have a higher risk. Technician-level activities are generally at a higher risk of computerisation than professional-level occupations. Estate agents and brokers are at the highest risk.

One of the central aspects of big data applications derives from the fact that computer systems can access and comb through large volumes of data to answer specific queries. Data that have formed a key part of a chartered surveyor's professional expertise for many years is increasingly moving into the public domain. The publication of property transaction prices makes this information machine searchable and allows machine-learning algorithms to process the data and automate processes that were once the preserve of qualified professionals. Even if an individual professional process cannot be fully automated, it is possible that parts of the task will be automated, thereby reducing the number of qualified professionals required.

Table 1: Extract from Frey and Osborne (2013)

Occupation	Rank on list	Likelihood of automation
Real estate brokers	40	0.97
Surveying and mapping technicians	68	0.96
Operating engineers and other operators of construction equipment	86	0.95
Appraisers and assessors of real estate	162	0.9
Cartographers and photogrammetrists	188	0.88
Real estate sales agents	206	0.86
Property, real estate, and community association managers	257	0.81
Environmental science and protection technicians, including health	284	0.77
Civil engineering technicians	290	0.75
Construction and building inspectors	349	0.63
Geoscientists	357	0.63
Cost estimators	382	0.57
Surveyors	441	0.38
Geographers	478	0.25
Environmental engineering technicians	481	0.25
Urban and regional planners	519	0.13
Landscape architects	570	0.045
Civil engineers	619	0.019
Hydrologists	643	0.014

5.0 Speed of big data adoption

The term big data can be used to refer to the data themselves (the origin of the term), or to a collection of digital technologies that support the capture, storage and analysis of big data. These technologies have enjoyed a fast path to technological maturity, which is the result of several factors. Big data refers to a collection of technologies that together enable the assembly, storage and analysis of very large data sets. This group of technologies is an example of combinatorial innovation, and this results in a technology wave that has far reaching implications for business and society as a whole. Previous examples include the petrol engine in the early 1900s, electronics in the 1920s, integrated circuits in the 1970s and the internet since the 1990s (Varian, 2010).

Another related factor is the convergence of the big data technologies with open data movements and the emergence of ubiquitous mobile computing. Open data movements seek to make big data publicly available for use by wider society rather than only the individuals or organisations that have collected data. Mobile computing, especially the development of handheld devices such as smart phones, has made it possible to collect data in real- or near-real time and much of these data are held by telecommunications companies and app developers.

Many technologies combine to facilitate big data. They include early internet technologies such as search engines, as well as more recent fields like machine-learning and distributed computing.

Big data technologies underpin a number of trends that are emerging in the built environment. One of the biggest changes is the development of intelligent buildings and building modelling.

How do surveyors distinguish between technologies that are likely to be adopted and add value and ones that will fall by the wayside and result in unnecessary cost? What is the implication for the commissioning and management of property assets, which may now need to accommodate some of these new capabilities? How do we assess the value of property assets that have new beneficial capabilities and those that don't?

6.0 Convergence of technologies

If big data is being adopted quickly, it is partly due to its underpinning role that has enabled the development of a new generation of disruptive technologies (Christensen, 2017). The result can be seen in new tech companies that come from nowhere to revolutionise an industry segment. These digital technologies tap into the emerging shared economy and success is often based on the development and ownership of a platform (Parker, Van Alstyne and Choudary, 2017) (e.g. Airbnb, Rightmove, Uber, Walulel). Writing about the future of real estate, Andrew Baum terms this area as 'PropTech 3.0' (Baum, 2017), and he explains that these new technologies will have a radical impact on property, a slow-moving asset class, in a conservative industry.

The convergence of big data, blockchain and the Internet of Things (IoT) is of particular relevance for the future of real estate. See Greengard (2015) for an introduction to the Internet of Things. The IoT is the networked world of connected devices, objects, and people. Blockchain is a decentralised network of digital records (sometimes termed 'ledgers') that link to a particular asset. Together with big data they form part of a trinity that will transform the urban realm and the outlook for the property profession over the next decade.

Blockchain is the technology that underpins digital currencies such as bitcoin but it can be used for any asset, be it physical or virtual. Blockchain keeps track of every transaction made in relation to that asset and the accuracy of the records is guaranteed by the architecture of blockchain itself. It allows for asset transfers and transactions to be recorded without the use of a third-party or central exchange and the reliability and validity of the data is assured. Information on the history of ownership and financial transactions can be recorded using blockchain. This is a technology with the potential for upheaval and dislocation for established industries (Tapscott and Tapscott, 2016, page 58). Blockchain will be used ubiquitously across industries, from tracking food provenance in the global supply chain, through to financial services where improved speed, lower costs and high data reliability are already making an impact.

Blockchain allows disintermediation – the removal of intermediaries – which could impact the structure of the property profession, and '… distributed ledgers represent a risk because new services and applications can appear from nowhere to threaten the market's architecture' (Baum, 2017, page 72). Here we see the disruptive dimension of blockchain. Baum (Baum, 2017, page 73) identifies the following benefits in the context of the property market:

- information available instantaneously
- less error, less duplication
- improved efficiency
- lower costs
- greater transparency
- reduced transaction times
- improved market liquidity.

These represent market opportunities but they can also be seen as threats to the professional status quo.

One important aspect is the need for effective cybersecurity, which represents a serious threat to the adoption of many digital technologies. For blockchain, there are security challenges to overcome, but the distributed architecture means that there is no central honeypot of data to be targeted.

The enabling nature of big data, when combined with other technologies, such as blockchain and the IoT, is a potent admix, resulting in PropTech that is already disrupting the real estate industry.

7.0 Building information modelling

RICS professionals are already specifying and adopting building information modelling (BIM).

BIM is a data-driven holistic modelling system that is based on 3D CAD. There are different BIM levels, and BIM Level 2 anticipates the exchange of data and collaboration between all parties in a construction project. (Note that individually BIM data is not big data in the sense considered in this insight paper. BIM Level 2 has been mandatory on all UK public sector construction projects since April 2016.) These data are essentially the specifications and drawings that make up the building model and they are confidential proprietary data, owned by the creator or the building owner. (British Standards Institute PAS 1192-2)

The next level of BIM, known as Level 3 or Open BIM, seeks to create and store the BIM data in a central repository, in its most advanced form with a single reference model. This differs from Level 2, which is based on data interchange, with the project parties maintaining their own BIM models. Aside from the improved efficiency of a single reference model, there are many unresolved issues around professional liability and copyright.

One of the narratives of those promoting big data is the promise of shared and publicly available data, but despite the name Open BIM, there is no proposal to open the data for access beyond authorised members of a project team. In fact, there is no obvious reason why private data of this kind should be put into the public domain, and here we see the dichotomy between the growing pool of open data (discussed in chapter 9 Open urban data) and the equally fast-growing islands of private data generated by the use of BIM and other building level data sources. Increasingly, these data are held in a digital form, and in the case of BIM modelling data, they are held in a standard format that could be shared and used by others.

The reluctance to share BIM data openly could be detrimental to efforts to increase the accuracy of BIM models in predicting the effects of building design through the use of artificial intelligence. This is because machines require sets of input data that produce known outputs in order to train themselves and thus produce predictions of how systems are likely to operate in the real-world (Ford, 2015 at chapter 4). BIM models can be enriched by the use of data that allows the modelling, not just of a building, but also how the building interacts with its local environment.

Further datasets may be included based on the type of occupant and occupancy patterns to provide a fuller picture of how a building will perform operationally. Once a building is occupied, high velocity data collection can help to verify the accuracy of the BIM modelling process, and establish whether a building is performing as intended under different occupancy, climatic or environmental conditions.

Existing BIM data combined with building performance outcomes under occupancy have great value in producing more accurate models. However, the open publishing of such data may share valuable company assets that can then be leveraged by competitors. As data increases via BIM models and FM sensing equipment, making sense of it and classifying it will become increasingly important. Artificial intelligence (AI) will enable data mining and analysis to be carried out on a much larger scale, with important implications on whole life design and build optimisation.

Data standards are important for chartered surveyors as technologies like BIM evolve. RICS is engaged with a number of international coalitions developing international measurement standards in construction and property (*International Construction Measurement Standards*, *International Property Measurement Standards*).
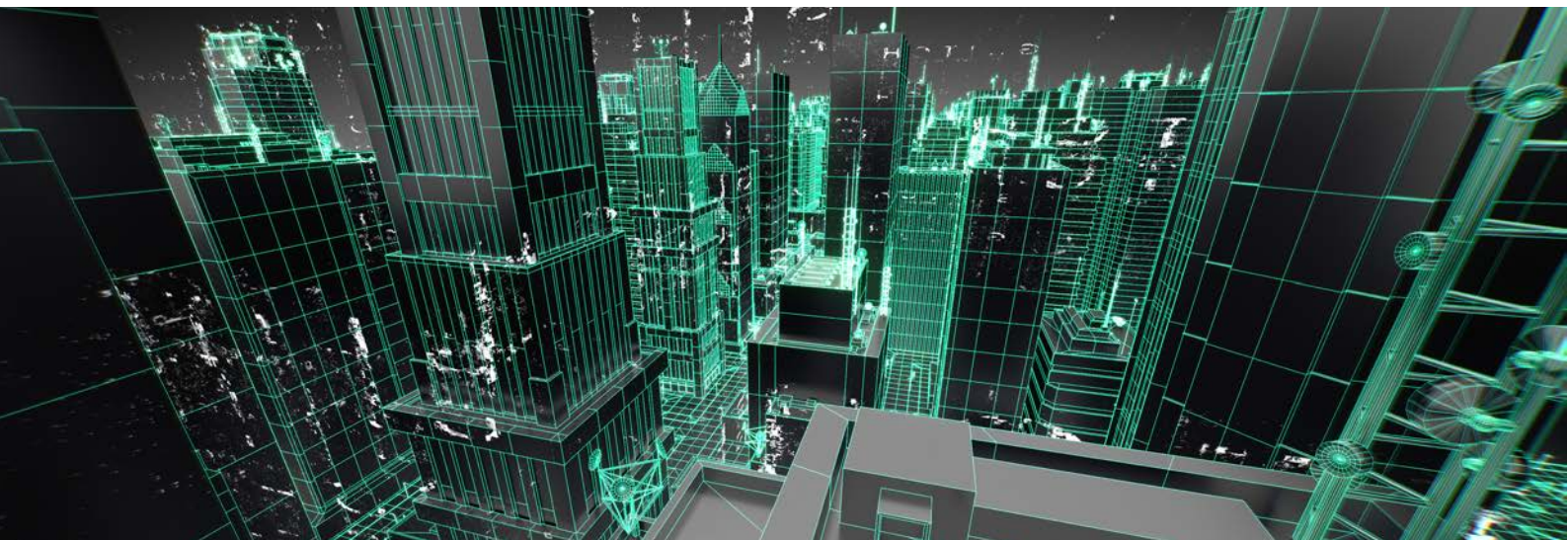
8.0 Intelligent buildings

Beyond BIM, there is also a considerable amount of other private data used by chartered surveyors and other property professionals to manage buildings over their life cycle. Modern building management systems generate large quantities of digital data from sensors and these are stored and analysed using big data technologies.

Again, this information is not publicly available, and like BIM data, there is no reason why it should be made public. In both cases there may be good public policy reasons against it. Publishing every detail of the design and management of a building, including the building services, increases the risk of crime. Building management systems are themselves vulnerable to compromise and attack by cyber criminals.

While there is a mass of private data in this area about buildings, their design, construction and management, as others, the old model of complete privacy is slow to change. Land use and planning records have long been open to public scrutiny, but over the past decade, transaction data have also been made publicly available. This is an erosion of the privacy for property owners (and a threat to professional property services that have traditionally been based on market knowledge of private transactions).

Intelligent buildings

Existing property portfolios are often caught in a financial paradox with the need to improve customer experience, lower operational costs and become more sustainable – without spending substantial capital. The desire to address this is to seek low cost, high value solutions that focus on technology and human behaviour.

- French refurb: The green refurbishment of a 1930s building, with a cost of approximately one-third of the initial building value, enabled the investor to nearly double the initial value of its asset. In addition, it led to a 10% value premium compared to the conventional refurbishment scenario. These results highlight that traditional payback calculations accounting only for energy savings can be misleading as they do not account for the long-term asset value.

- UK retrofit: Retrofitting a five storey 1980s suburban commercial building. Upgrades included: connection to district heating and power; energy-efficient lighting; improved ventilation and energy management systems; a solar photovoltaic array to generate renewable energy on site; water-efficient plumbing fixtures and fittings; The building is predicted to use 56% less energy than before the refurbishment, and 55% less water than standard. The cost of the green interventions is expected to be recovered in 13 years through energy savings alone.

- New builds: Big data has practical applications for new buildings, allowing the formation of detailed BIM models that predict how a building will perform in its specific local environment. The accuracy of standard models for predicting energy consumption can be substantially improved by gathering data on the way that occupants use a building. Understanding how buildings are actually used will also enable more powerful building management systems, capable of buffering the effects of occupant behaviour and the local external environment on energy consumption.

Implications for surveyors

Changes in the intelligent buildings sector have been occurring faster than many of the traditional real estate support structures of consultants and contractors can keep up with. Modern-day controls systems in heating ventilation, air conditioning, lighting and metering, are run by computer servers, networks and remote access. Yet many organisations have not integrated ICT into design, construction and operations. That creates risks that the generational skills gaps will result in greater capital expenses and then lead further to rising operational and maintenance costs. There are also increasing electronic security risks that are better addressed during development. Properly addressed, the current generation of core building systems can be leveraged to create advantages through data driven decision-making, higher asset utilisation, reduced capital and operational cost structure.

As one of the globally recognised professions in constructing, managing and valuing real estate, understanding this new operating environment is vital to surveyors who are providing informed advice to commissioners, occupiers, investors and lenders. The rapid developments in building design, management and maintenance, all of which are drawn together through the BIM enabled procurement process, creates the opportunity for surveyors to provide enhanced client services.

Big data is central to the creation of advanced building management systems, which prioritise the efficient use of resources by a building, controlling costs while still providing a high-quality internal environment. Data taken from a variety of sources are fed to the building management system, which then determines the best course of action, for example, managing an HVAC system in response to changes in ambient external environmental conditions.

The most advanced systems go beyond simple reactive measures, and include data streams, such as short-term weather forecasts and data on a building's thermal properties to improve the energy efficiency of building operation, which has become an increasingly important consideration within built environment professions over the last two decades.

9.0 Open urban data

The desire for transparency in governance has led to calls for open data that is freely available to everyone for the public good. In May 2013, Barack Obama signed an executive order making open machine-readable data the default for all US Government information. Open data is the concept that data should be freely available for use, reuse, and redistribution by anyone, including members of the public, academics, and commercial groups. Open data is another part of the convergence that is big data and there is a growing trend for data, especially government data, to be made available in an open and accessible way.

All levels of government have used data for centuries and in one sense big data is nothing new to government, but digital big data is different and there is a drive to improve public administration, save costs and improve operational efficiency. Over the years, as much digital data have been generated by government and others, but access has been limited as a result of licensing, fees, or caveats for use, or technical barriers (Kitchin, 2014). To be open, these data must be machine-readable, allowing for automation in data analysis, and they should be delivered in a raw format that does not require proprietary software to access it (proprietary software includes common tools like Microsoft Excel and more complex systems such as Oracle). Open data should be available, and preferably discoverable, by anyone with internet access, as well as being able to be linked to other relevant data in order to provide context (Berners-Lee, 2009).

The Open Data Institute (ODI), co-founded by Tim Berners-Lee, is an advocate for open data and this approach has meant the release of a great deal of data. There has been genuine innovation in the use of big data, and both the US and EU have embraced this notion. For RICS professionals there are many public data sets, ranging from land use information through to property sale transactions and building ownership information. This has already transformed some areas of professional practice, and has created opportunities for tech-savvy organisations to exploit this information for commercial gain.

OECD countries lead the way on open data initiatives, with the UK at number 1 in the ODI Open Data Barometer and the US at number 2. The removal of barriers to data access and the opening of public data is becoming commonplace with over 55% of countries surveyed by the ODI having an open data initiative in place representing a shift towards openness and transparency in government, as well as promoting participation and good governance (ODI, 2016).

Open data presents a view of service-oriented governments, who instead of trying to control the citizens are seeking to empower them. However, the open data initiative can also be seen as a transfer of publicly-owned data into private hands for use by private interests to generate profit from a subsidised public source. It could be argued that access to this data is of greater value to business interests, who are likely to have the funding and resources to exploit open data in a way that is unattainable for individuals or researchers. The same level of transparency does not seem to have been demanded of businesses who have been contracted to digitise public data, but who then restrict access by claiming intellectual property rights on the data produced (Bates, 2012).

Once issues of privacy and data ownership can be adequately addressed, open urban data has great potential: it may be used for the active management of city operations, for big data applications, to improve the experience of living in cities, and many other aspects of managing the built environment.

RICS, through its membership of the International Land Measurement Standards Coalition (ILMSC), is participating in developing a land reporting standard that will, in part, rely on these open urban data.

10.0 Smart cities

Smart cities are where big data comes into its own. There are rich sources of data being continually generated; and the BSI identifies **building the foundation for widespread exploitation of data** as one of the key areas to support smart city aspirations (see PD 8101:2014 *Smart cities. Guide to the role of the planning and development process*). The BSI smart cities vocabulary document describes the goal of a smart city as being **to deliver a sustainable, prosperous and inclusive future for its citizens**, but the term smart cities has many different meanings and, like big data itself, the smart city concept has suffered from boosterism by interested parties with their own story to tell (see PAS 180:2014 *Smart cities. Vocabulary*).

New smart cities

Purpose-built smart cities have been conceptualised and constructed as new self-contained developments. This has been estimated as a $3 trillion global business market over the next 20 years. Depending on their locations and their primary sponsors, these cities prioritise different aspects of smart enabling systems. Some focus on the technologies themselves, while others focus on energy conservation or green city concepts. Promoted under the 'smart city' banner, they still largely emerge as real estate enterprises. Smart city initiatives demonstrating varying degrees of success in meeting their original objectives include:

- **Songdo, South Korea** was described in 2014 by its US developers as the largest real estate investment ($40 bn) in the world. The Songdo International Business District, as it is now marketed, is constructed on the Incheon waterfront. Occupying 1,500 acres of reclaimed land and intended to accommodate 22,000 dwellings, as well as extensive commercial space, it was built as part of the drive to promote low-carbon and sustainable growth as the principal avenue for development in South Korea. Nevertheless, coinciding with the financial crash and despite considerable tax incentives, initial occupation has been slow. Started in 2003, work is not expected to be completed until the end of this decade. The city houses 40,000 people today and a further 50,000 commute to it from the surrounding area.

- **Masdar City**, was conceived by the Abu Dhabi government in 2006 as part of a much greater project to transform the country from its oil based economy to one based on knowledge and innovation. Intending to be carbon neutral and emission free, the $22 bn project was envisaged as being largely solar powered. Its original completion date was 2010, but the financial crisis and reformulated objectives have now pushed the completion date out to 2020/25. As designed, the city is intended to house around 40,000 people, but a weak market demand has slowed the project significantly.

- **Living PlanIT, Portugal** was an initiative to create a smart city through models operating in the software industry not the real estate business. A collaboration between Living PlanIT, a software company, Cisco and the municipality of Paredes in Portugal, the intention was to provide an alternative to existing real estate models regarded as endemically wasteful. Living PlanIT's model was to create an ecosystem of large and small company partners focused on creating products and services for sustainable urbanisation. In the aftermath of the financial crisis the lack of 'real estate' finance was one of the main causes of delay.

Implications for surveyors

Stand-alone smart cities for all their technological and environmental specifications are still fundamentally property investment undertakings. They are also major construction projects extending over a long period of time. Despite their sometimes global projection, they are still very much tied into their regional occupational and investment markets. Successfully satisfying these markets requires all of the conventional expertise property professionals provide together with the added knowledge of the innovation being offered in these projects. The expertise of land construction and property professionals is central to the success of these smart city' ventures. The role of the surveyor in these new environments is to understand each city's uniqueness and its market implications.

In the city, data comes from many sources. Big data technologies, used successfully, allow the city government to capture, store, analyse and act on big data for the good of citizens and other stakeholders. The focus is not on the individual buildings that make up the city, but on three classes of urban system: people, infrastructure, and environment (see Koonin and Holland, 2014).

11.0 People

Cities are built by people for people, and big data can be used to glean greater knowledge of how cities function for their residents. Interactions between government and citizens, interactions between citizens and the interaction of individuals with organisations, such as employers, healthcare systems and educational institutions are all part of the life of a city.

Increasingly, big data is recording these spatial interactions, sometimes overlaid with temporal referencing, and there are many systems that record how people interact with the infrastructure and the environment.

12.0 Geolocation, geolocation, geolocation

Geolocation is now a part of everyday life for people in cities and the data gathered are most useful to the smart city when they are put into the context of location. This provides data on where a person (or more strictly a digital device) is located on the surface of the earth. Where GPS provides a set of geographic co-ordinates, geolocation adds context. It is a convergence technology, using GPS or other co-ordinate data, and adding context for the person using it, known as geolocation data.

Geolocation applications do not depend on GPS to function. The location engine can use data from the cellular wireless network or the wifi positioning system to provide location data and the accuracy of these engines is increasing as the use of geolocation technologies become ubiquitous.

From apps on a smartphone, through to building management systems, the use of geolocation is now widespread. It can deliver information on what products and services are located nearby, it can provide real-time traffic information, or live updates of the status of a delivery. Geolocation has already changed the way people move through the built environment. An example of the effects that geolocation services has had on transport include map applications such as Google Maps and services such as Uber. Map and transport applications can provide a range of potential routes available for multiple modes of transport, approximate journey times, and information on public transport timetables. Research from Singapore suggests that the availability of such information improved the perceived pleasure of commuting, even though it did not alter the mode of transport that was chosen to make a journey (Vanky, 2014).

Intelligent transportation systems, based on the application of big data, add new layers of utility to basic geolocation

services (Leontiadis et al., 2011). Analysis of traffic updates obtained through a mix of methods, including social media, automated traffic sensors and direct surveillance, provide real-time re-routing for drivers using satellite navigation services. This improves the efficiency of the transport network by speeding up journeys and letting individuals avoid traffic blackspots as they develop, while also relieving pressure on congested areas.

Big data applications can employ geolocation and mapping technologies to improve efficiency of public services such as waste collection. In this example, sensors in waste compactor bins can detect when waste requires collecting. These data are then relayed to a control centre that can optimise waste collection routes, and reducing inefficiency by improved fuel use and reduced carbon emissions (Kitchin, 2016).

Geolocation is not without its critics. Most geolocation software apps allow the system to record the user's location, which raises questions of privacy through the misuse of user location data by vendors. Ride matching service, Uber, is reliant on geolocation and is no stranger to privacy problems over the use of rider location data. These have ranged from questions about the level of tracking that is justified to deliver the service, through to actual misuse of the tracking data by an Uber employee in 2015, and a data breach that allowed unauthorised third-party access to the data in 2014. A unilateral change to the Uber privacy policy in July 2016 gives the company permission to use far more information than is necessary to deliver the service, and it includes the right to access the user's location even when they have shut down the Uber software on their mobile device.

National smart city policies around the world

Most countries have been developing national policies on the adoption of smart technologies to inform public and private investment. These strategies are seen as catalysts to use modern science and technology to make cities, their buildings and infrastructure work better for their inhabitants. Some respond to climate change and combine smarter with greener policies. The programmes also envisage capacity building among citizens as an important measure to enhance participation in what cities have to offer. One Asian city's slogan 'smart cities need smart citizens' suggests that ultimately it is smart behaviour on the part of citizens that really makes a city a smart place to live.

- In **China**, smart cities are viewed as a significant way to accelerate the process of industrialisation, urbanisation and improving agriculture. Two hundred smart cities have been identified for inclusion under a national pilot scheme. The goal is to integrate various information resources, improve urban management and service level provision, as well as promote industrial transformation.

- The **Indian** government has a vision of a 'Digital India', and has put forward a plan to integrate smart city processes into 100 cities across the country. The expectation is that future cities will be built based on availability of optical fibre networks and next-generation infrastructure.

- In the **UK**, the government envisages smart technologies as a key driver of economic growth. In addition to promoting their adoption, government has mandated the use of BIM for all its newly procured public buildings providing an impetus to develop technical skills as well as the creation of a more collaborative culture in this area.

- As part of its Federal programme, the **United States** Department of Transport has awarded $40 million to Columbus, Ohio. This was the result of a competitive bid to help it define what it means to be a smart city. Columbus aspires to become the country's first fully-integrated city harnessing the power and potential of data, technology, and creativity to reimagine how people and goods move throughout their city.

Implications for surveyors

The perception of governments around the world is that smart technologies have the potential to create jobs and wealth and achieve competitive advantage in global markets. The expectation is that professionals providing advice and services in these markets will also understand and be employing these technologies to enhance the sector. The adoption of smart technologies to deliver buildings and infrastructure will have a transforming effect on our sector, which will favour professionals who have developed this expertise.

13.0 Infrastructure

Questions about infrastructure focus on its extent, its condition and its performance under different use scenarios. We need to know the condition of the built infrastructure, and respond to maintenance needs or occasionally to more pressing demands, as well as understanding the effects that such work has on the wider system of infrastructure.

Big data can enhance knowledge and understanding of urban infrastructure, helping to develop efficient maintenance protocols or even to indicate the likelihood of catastrophic failure, such as a bridge collapse, allowing pre-emptive measures to be put into place. Sensors are at the heart of big data and its impacts on the management of infrastructure. Cities are gaining sentience, or the ability to 'feel' and 'perceive' as sensors become more integrated into the fabric of the city, and automation software gives systems the ability to analyse the data and react to events. Sensor technologies lie at an intersection between civic life and security (Thrift, 2014) , and they assist cities to react to, or even pre-empt undesirable events based on analysis of sensor data. One example would be the use of sensors on the infrastructure to warn of excessive stress on or deterioration of materials used in construction. The unexpected closure of the Forth Road Bridge following the visual observation of a structural fault in December 2015 led to increased economic costs due to the sudden closure of the bridge with little time to develop contingency plans. The kinds of infrastructure and maintenance protocols allowed by big data facilitate more carefully planned preventative maintenance, which can be carried out at less disruptive times, and before infrastructure reaches a dangerous state of disrepair.

14.0 Environment

Every city is set in its own unique location, and knowledge about changes to the natural environment are as important as the monitoring of the physical infrastructure. Pollution and carbon emissions, noise, and aircraft movements could all have heath impacts for citizens. Recreational land uses need to be understood for their impacts on the natural resources, while land use planning needs to take account of the impacts on eco-system services.

Big data can enhance the understanding of the interplay between infrastructure, human activities, and the broader urban environment. This can then be managed to produce a better-quality environment for inhabitants, creating happier and healthier citizens (Pineo and Rydin, 2018).

Big data has additional roles to play in the management of urban behaviours, such as resource consumption or pollution generation. Intelligent machines can identify repetitive patterns that would seem random to the human observer (Ford, 2015). Machines with access to streams of continuous data are able to draw correlations between variables and behaviour, such as increased emissions or water consumption that may be associated with variations in environmental conditions or human behaviour patterns. As a machine analyses big data, its role can move beyond reactive urban management towards anticipatory urban management, and this anticipatory function can help improve urban sustainability and the provision of better quality urban environments.
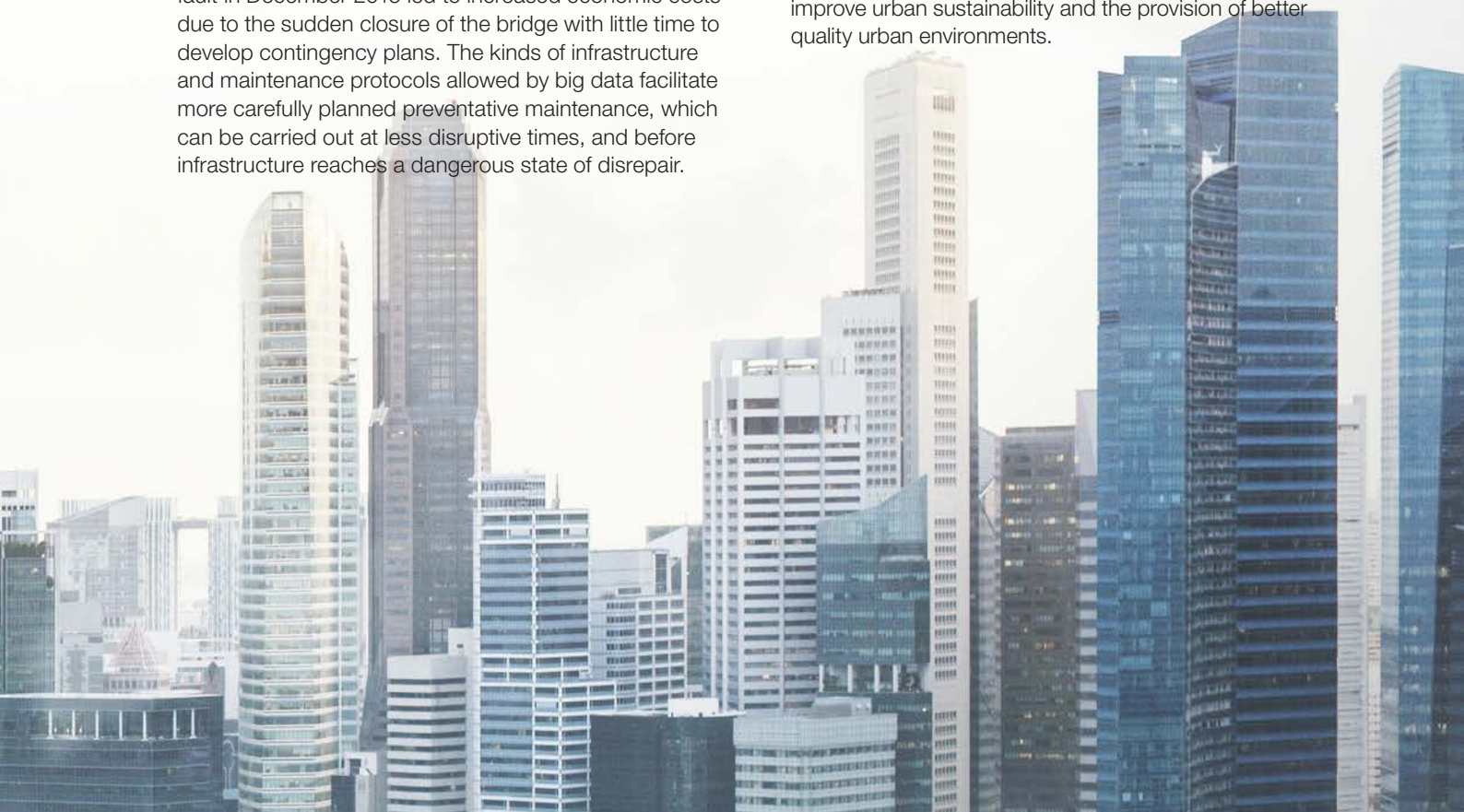
15.0 Managing city operations

The use of big data is opening new avenues in the way cities may be shaped in the future, as well as generating a better understanding of the components that make up cities, such as buildings and infrastructure. Cities and the built environment represent an overlapping group of complex systems. These range in scale from individual lamp posts or waste bins, to buildings, streets, green spaces, neighbourhoods and communities. They cover urban, national and international networks, including energy, transport, leisure, waste, and water distribution systems. Big data and sensor technologies are creating a tsunami of information that is presented to built environment professionals and city authorities in real time. The challenge is how to assimilate, analyse and act on this information.

improving both preparedness and response times. Every organisation, especially government bodies, needs to have a well-rehearsed emergency response plan and a disaster recovery plan, both of which need to be supported by a crisis management plan. Big data can be an invaluable tool in the task of exercising (or testing) these plans, helping to build resilience in both physical and digital infrastructures.

Planning and policy based on big data risks over-representing certain demographic groups to the detriment of others, and cautionary tales have emerged in the use of big data to manage operations in the ways described earlier. Many of the data used are gathered using the internet, with emphasis on mobile devices, which can generate the highly localised and continuous data streams

Figure 4: Rio De Janeiro Operations Centre. Images: Rachel Glickhouse, AS/COA

Figure 4 shows the Rio De Janeiro Operations Centre. Rio is a big city with over 6 million people and the operations centre works 24/7 and employs 400 people. It assimilates data from over 30 separate departments and integrates the city operations. It has been described by IBM as a mission control room for a 21st-century city.

The Rio Operations Centre is part of a trend to draw all forms of data from surveillance and analytics into a single hub. Data are a resource that can transform the capability of a city by delivering a fine-grained understanding of urban activities and processes. This is often linked to a desire to improve security and tackle crime, which is one of the more controversial applications of big data.

The operational demands placed on a city administration are many, ranging from the routine to the disaster. For Rio, the spur to develop an integrated system followed devastating storms in the summer of 2010 that killed over 500 people and left over 10,000 homeless.

For disasters, an operations centre can help in meeting obligations under the emergency response legislation,

required by big data systems. A good example of this was the 2011 'street bump' programme in Boston, in which an app used smartphone hardware to detect bumps in cars as an indicator of potholes. Data from this programme meant that road maintenance was directed to the most affluent neighbourhoods with younger populations. There was a demographic bias in the data collection methods that skewed results towards a tech-savvy demographic with the know-how to download the app and the money to afford the smartphone.

The problem is that decision-makers, planners and other real estate professionals are unlikely to have the necessary expertise and must rely on big data specialists to deliver benefits from data to meet the objectives for their city. Managers may even lack the expertise to understand what is possible. A discussion of the skills needed to take full advantage of big data was set out in chapter 4 *Jobs and Skills*.

16.0 Conclusions

Big data offers the opportunity to understand the way both natural and human systems work, but many of those whose professional lives could be impacted by big data are still unaware of the full implications. This includes RICS professionals and other built environment professionals. Big data technologies have already entered into widespread use and they are changing the way the urban realm is being analysed and managed.

PropTech, underpinned by big data, is already transforming the urban landscape. Big data operates on a variety of scales from individual people or devices, to buildings and streets, to urban systems and even to whole cities.

At the smallest scale, big data will be used by individuals in apps, such as intelligent maps, which actively guide users through transport networks.

At another level, big data gives intelligent buildings the ability to monitor and regulate themselves. This means a building management system can manage heating or cooling and can automatically control light levels in specific rooms. Such buildings are also capable of monitoring their own states of repair, allowing preventative maintenance work to be flagged before serious or dangerous problems develop.

At the highest scales under consideration, big data offers the opportunity for improvements in urban systems such as transport, infrastructure, and urban development.

Smart cities will integrate these different scales to deliver new understandings of the interaction between people and their surroundings, and influence how urban systems are used in the real world.
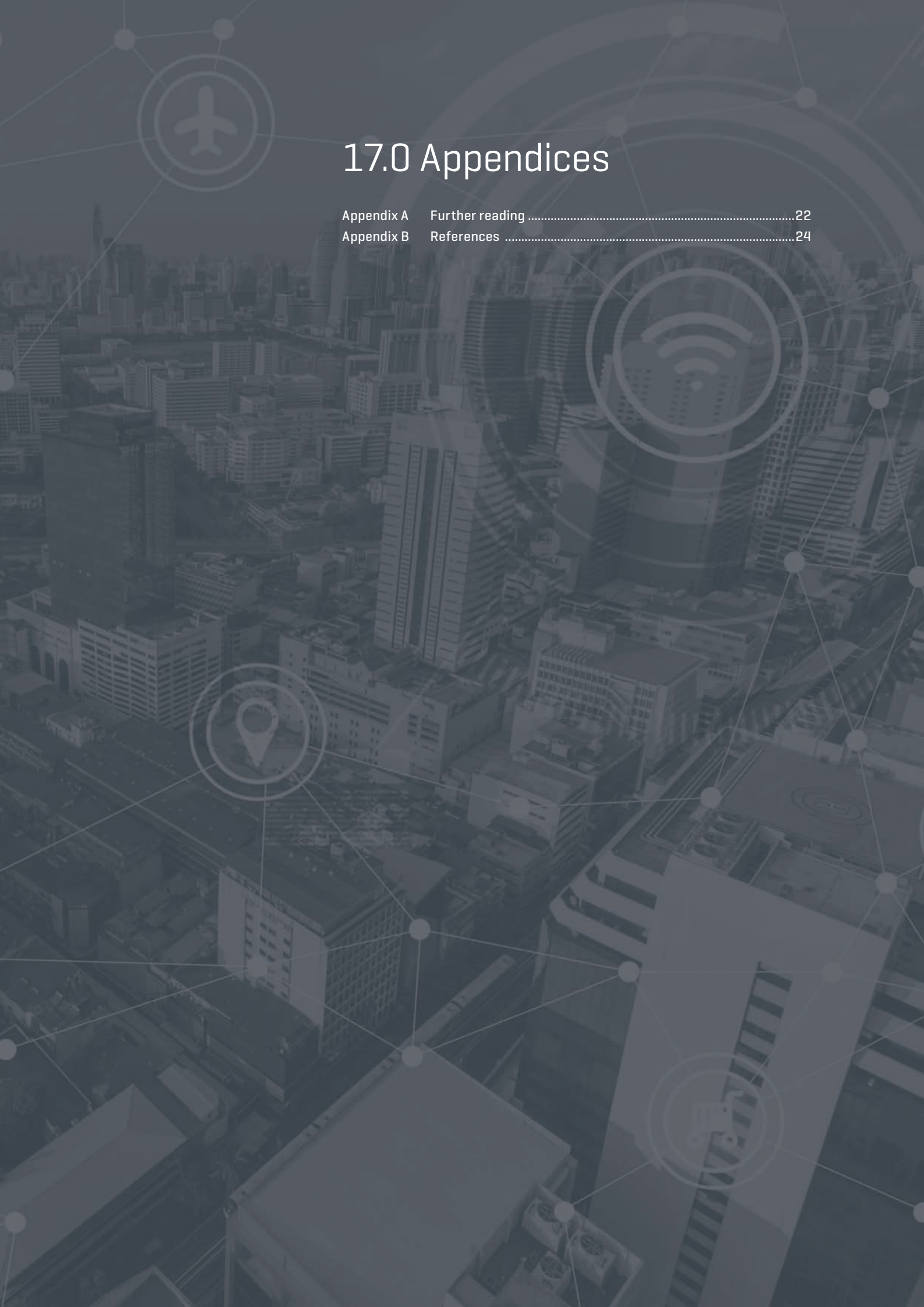
With big data applications at this scale, cities become sentient, taking on a new level of automation, as intelligent buildings and complex information systems gain autonomous functionality. This will allow for greater efficiency in the use of city resources such as energy, transport, water, and the state of repair of crucial pieces of infrastructure. These cities will also minimise the disruption caused by maintenance work as an understanding of how various urban systems interact with one another and their citizens inform planning strategies before any closures effect changes to the system. One key benefit of big data is in the potential to make evidence-based policy decisions.

Aside from the multi-faceted changes that are already being seen as a result of big data, there is also a new set of challenges that must be dealt with. The first of these is the processing and analysis of big data: the amount of information available goes beyond the capabilities of familiar statistical tools, and this means that new systems and tools are needed to handle it. Next, there is the problem of the skills required for professionals to work with big data: extensive retraining may be needed to augment the new possibilities of big data applications with the existing knowledge and experience that exists within professional disciplines. Big data changes the range of qualifications needed in professional teams, as computing and data specialists take on greater relevance across the employment market. This could be a problem in the UK where there are already skills shortages in science, technology, engineering and mathematics subjects.

Big data represents a technology that delivers many benefits. It offers an opportunity for those who can successfully navigate and implement the technology landscape, but the risk of professional marginalisation in the face of changing technologies is ever present and big data is bringing big change to the built environment. Chartered surveyors need to keep abreast of developments in this field and they need to embrace new skill sets if the relevance of the profession is to be maintained and strengthened in the future.
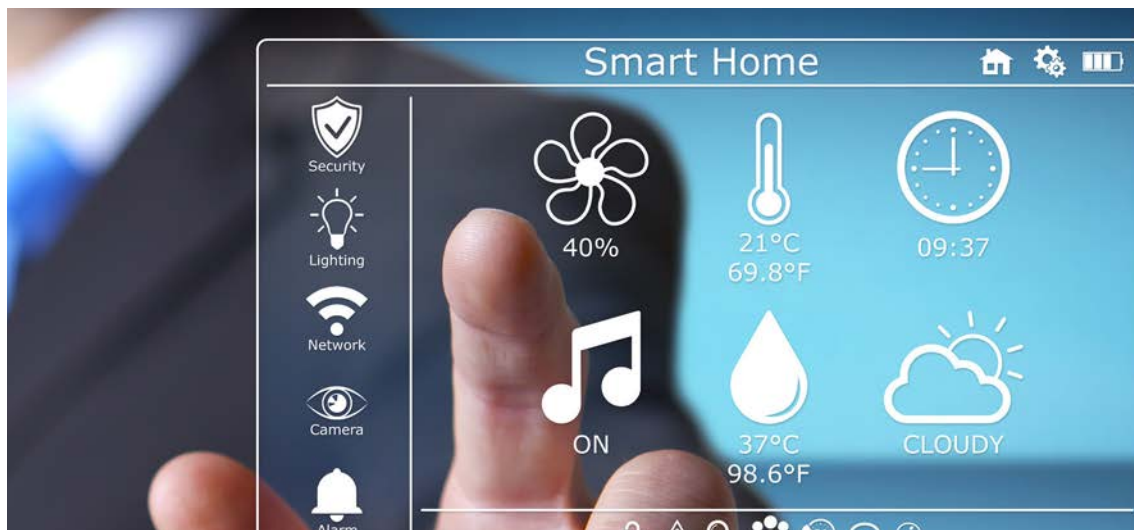
17.0 Appendices

Appendix A: Further reading

These suggested further readings give a broad overview into big data, and insights into what it may mean for professional practice.

The following two reports are specific to the property profession.

Baum, A., *Prop Tech 3.0: the future of real estate*, University of Oxford Research, 2017.

Dixon, T., et al., *Smart Cities, Big Data and the Built Environment: What's Required?* RICS Research Trust Project, University of Reading, November 2016.

The following annotated works are listed in order from introductory general texts to those that deal more specifically with big data or the built environment.

Harkness, T., Big Data: *Does Size Matter?* Bloomsbury Sigma, London, 2016.

Provides an accessible, yet informative introduction to big data, looking at the history of computing and data analysis, before touching on a variety of real-world big data applications and some of the concerns raised by the broader technological trend.

Ford, M., *The Rise of the Robots: Technology and the Threat of Mass Unemployment*, Oneworld Publications, London, 2015.

Looks at the implications of emerging technologies underpinned by artificial intelligence, in particular with regards to the types of jobs at risk, and the changes needed in human skillsets to meet the possible demands of future industries. The social and economic aspects of information technology are given particular emphasis.

Mayer-Schönberger, V., and Cukier, K., *Big data: A revolution that will transform how we live, work, and think*, John Murray Publishers, London, 2013.

Contains a strong, non-technical introduction to big data with a number of case studies to highlight key points of big data, and how it has and will continue to shape the future with ever-greater digital integration into social and economic functions.

Big Data the next frontier for innovation, competition and productivity, Mckinsey Global Institute, May 2011.

Analyses the development of big data before taking a closer look at some of the sectors likely to see powerful applications, along with the implications of big data for organisations and policy makers.

www.mckinsey.com/business-functions/digital-mckinsey/our-insights/big-data-the-next-frontier-for-innovation

UN. *A World that Counts: Mobilising the Data Revolution for Sustainable Development*, UN Independent Expert Advisory Group on a Data Revolution for Sustainable Development, New York, November 2014.

Analyses how big data can be harnessed for sustainable development to provide better social, environmental and economic outcomes globally. It identifies five key recommendations about how big data must be managed in order to advance the sustainability agenda.

www.undatarevolution.org/wp-content/uploads/2014/12/A-World-That-Counts2.pdf

Kitchin, R., *The Data Revolution: Big Data, Open Data, Data Infrastructures & Their Consequences*. SAGE Publications Ltd, London, 2014.

Highly informative seminal work which gives a deeper analysis of how big data has developed with reference to the philosophical, mathematical and technological dimensions of big data applications. Alongside these fundamental underpinnings of big data, Kitchin delivers a well-considered critique of social, political and ethical dilemmas that have shaped and may continue to shape the field.

Kitchin, R., *Getting smarter about smart cities: Improving data privacy and data security*, Data Protection Unit, Department of the Taoiseach, Dublin, Ireland, 2016.

Gives a strong critical analysis of how big data is used in smart cities. The emphasis is on Irish cities, but the lessons have wider application. The report looks at some of the concerns relating to data privacy, protection, and security which must be taken into consideration alongside technological progress.

www.taoiseach.gov.ie/eng/Publications/Publications_2016/Smart_Cities_Report_January_2016.pdf

Picon, A., *Smart Cities: A Spatialised Intelligence*, John Wiley & Sons, Chichester, 2015.

Looks at the technological and spatial foundations upon which smart cities are being built and contrasts them with the social and participatory elements driving the development of smart cities. It looks at a number of case studies highlighting current progress in a smarter built environment, and projects possible future developments in smarter urban forms.

Offenhuber, D., and Ratti, C., *Decoding the city: Urbanism in the age of big data*, Birkhäuser Verlag, Berlin, 2014.

Technical introduction to the applications of big data in managing the built environment, built around the narrative of new skills, insights and approaches that are being brought to bear to improve the understanding of how cities function and how big data can inform urban management.

Special report: Managing Information: Data, data everywhere, The Economist, February 25, 2010; Volume 394, Issue 8671

Provides a series of brief yet invaluable insights into issues with big data that were identified at the very earliest stages. It looks at the issues of information overload; the transformational effect data abundance had on business; the growth of profitable e-businesses; open data, data visualisation; and data governance and regulation.

www.emc.com/collateral/analyst-reports/ar-the-economist-data-data-everywhere.pdf

World Bank *Digital Dividends*, World Development Report, 2016.

Paper analyses digital dividends, or the benefits gained from the implementation of digital technologies and systems, and the fact that there is an existing digital divide that does not reflect the breadth of the uptake of digital technologies. This disparity may arise due to issues with "analogue complements" to digital technologies: the skills, governance, lack of internet access, and institutional capacity which inhibit the ability of certain countries to generate digital dividends that reflect the level of penetration and uptake of digital technology.

www-wds.worldbank.org/external/default/ WDSContentServer/WDSPIB/2016/01/13/ 090224b08405b9fa/1_0/Rendered/PDF/ World0developm0l0dividends0overview.pdf

See also World Bank App for this report:

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