Manchester Metropolitan University

Sengupta, U (2017) *ICT, Open Data and the Internet of Things: Potential future trajectories in urban planning.* In: The Virtual and the Real in Planning and Urban Design: Perspectives, Practices and Applications. Routledge Research in Planning and Urband Design . Routledge, pp. 69-90. ISBN 1138283487

DOI: https://doi.org/10.4324/9781315270241

ICT, OPEN DATA AND THE INTERNET OF THINGS: POTENTIAL FUTURE TRAJECTORIES IN URBAN PLANNING

Ulysses Sengupta

Manchester School of Architecture, Manchester Metropolitan University

Prepublication Open Access copy. Please only cite from the published article at:

Sengupta, U., *2017. 'ICT, Open Data and the Internet of Things: Potential future trajectories in urban planning'. In De Roo, G., Yamu, C., Dewisch, O. and Poplin, A. (eds.) The Virtual and the Real in Planning and Urban Design: Perspectives, Practices and Applications, Routledge.*

"[…] You will look into a computer screen and see reality. Some part of your world – the town you live in, the company you work for, your school system, the city hospital – will hang there in a sharp color image, abstract but recognizable, moving subtly in a thousand places. This Mirror World you are looking at is fed by a steady rush of new data pouring in through cables […]. They are software models of some chunk of reality, some piece of the real world going on outside your window. Oceans of information pour endlessly into the model (through a vast maze of software pipes and hoses): so much information that the model can mimic the reality's every move, moment-by-moment […]. Such models, such Mirror Worlds, promise to be powerful, fascinating, and gigantic in their implications. They are scientific viewing tools – […] on the human-scale social world of organizations, institutions and machines; […] The intellectual content, the social implications of these software gizmos make them far too important to be left in the hands of the computer sciencarchy."

("Mirror Worlds: or the Day Software Puts the Universe in a Shoebox… How It Will Happen and What It Will Mean", David Gelernter, 1991, p. 1–4)

Introduction: Information and Communications Technology in Urban Futures

Almost twenty-five years ago, David Gelernter in his book 'Mirror Worlds', predicted virtual computer city models fed by large amounts of data, allowing citizens, corporations and governments to understand and intervene in their environments. He believed that the primary use of these models would be to provide what he called 'topsite', a term he described as a 'far-overhead vantage point' or a 'bird's eye view' that reveals 'how the parts fit together'(Gelernter, D H 1991, 52-54). In its most democratic interpretation a form of civic participation related to spatial planning and urban living was revealed in direct contrast to the possibility of a surveillance state controlling personal and public information on behalf of a ruling elite. Recent information and communications technology (ICT) developments such as the dissemination of sensors throughout cities in the name of improved urban management and planning resemble aspects of Gelernter's Mirror Worlds, accentuating the immediacy of an informed and cognizant approach to innovation and regulation in the field of planning toward democratic and intelligent future initiatives. ICT is an umbrella term that encompasses devices and applications used for communication, including television, mobile telephones, computer networks, as well services such as distance learning and online shopping. Herein, the aspects of ICT referred to are primarily the Internet, Big Data (Laney, D 2001) (with an emphasis on Open Data) and associated communication technologies related through geo-locational possibilities to socio-spatial urban issues, governance and related planning potentials. Digital computation and modelling has developed over decades in support of synoptic planning with the ultimate aim of forecasting the effect of policies, initiatives and interventions. With the shift towards communicative planning and more recently an increasing recognition of the usefulness of complexity science frameworks in understanding cities (Portugali, J 2011, Roo, G D, Hillier, J, and Wezemael, J V 2012), older top-down computational models are being challenged and bottom-up open-ended possibilities are being explored (Batty, M and Marshall, S 2012, Sengupta, U 2011) partially enabled by the growth of available data in the public and corporate realms. It is essential to consider the discussions in this paper in relation to changing theoretical frameworks for spatial planning related to the increasing use of complexity theories and related phenomena such as emergence (Holland, J H 1998, Weinstock, M 2010), co-evolution (Allen, P M 2012) and resilience (Holling, C S 1973), and in the context of e-government and the distinctions between efficiency, responsiveness and democratic governance (Silcock, R 2001, Layne, K and Lee, J 2001, Rossel, P and Finger, M 2007). Thus, the aim of this book chapter is to examine the potentials and criticisms surrounding recent ICT development in the context of spatial planning. Therefore, herein we summarise ICT based future disruptors (Manyika et al 2013) such as Big Data/Open Data, the internet of things, ubiquitous computing, augmented reality (AR), machine learning and Smart Cities. A meta-analytic method based on current public and academic discourse is used to situate these initiatives within spatial planning debates using a complexity theory framework. Systems of control from cybernetics to engineering resilience are contrasted with complex adaptive systems and ecological resilience (Sengupta, U and Cheung, E 2016) to locate criticisms and potentials for ICT enabled open ended future planning practice (Figure 1.4.1). Initiatives are categorised within trajectories of control and co-evolution on the basis that positive feedback enabled emergence is essential for cities as evolutionary systems (Allen, P M 1997, Portugali, J 2000, Weinstock, M 2010) rather than only negative feedback loops as found in engineered or equilibrium systems. Additionally, selected examples of new ICT platforms are mapped against identified stages of e-governance and comparable stages of ICT enabled co-evolution for spatial planning (Figure 1.4.2).

Big Data

At some point in the mid-1990's the term Big Data was used in the context of ICT related data growth and new types of data in a number of presentations by John Mashey, at the time the chief scientist at Silicon Graphics in California (Lohr, S 2013). This term was further elaborated on using the 'three V's' (2001) by Douglas Laney a data analyst for Gartner. The three V's, namely data volume, data velocity and data variety were used to describe phenomena and related strategies to work with the increasing data generated by businesses and the need for new management structures (Laney, D 2001). SAS (originally Statistical

Analysis System at North Carolina State University) a developer of advanced analytics platforms and related services, recently expanded the three V's to five dimensions by including the consideration of variability and complexity (Sas). Due to both the common usage and multiple interpretations of the term Big Data, it is difficult to pinpoint a single universally accepted definition. Oracle suggests Big Data is the derivation of value from traditional relational database-driven business decision making, augmented with new sources of unstructured data such as blogs, social media, sensor networks, image data and other forms of data which vary in size, structure, format and other factors. Intel company appears to link Big Data to organisations generating a median of 300 terabytes of data a week, with the most common forms of data analysed in this way being business transactions stored in relational databases, followed by documents, e-mail, sensor data, blogs, and social media. Microsoft claims, "Big Data is the term increasingly used to describe the process of applying serious computing power - the latest in machine learning and artificial intelligence - to seriously massive and often highly complex sets of information" (Redmond, W 2012). The Method for an Integrated Knowledge Environment open-source project (abbreviation: MIKE) argues that Big Data is not a function of size, but rather its complexity. They suggest the high degree of permutations and interactions within a data set that defines Big Data (Hillard, R 2012). Jonathan Stuart Ward and Adam Barker identify all of the above in a technical report in the School of Computer Science at the University of St. Andrews, UK. They even attempt to formulate their own definition and state, "Big data is a term describing the storage and analysis of large and or complex data sets using a series of techniques including, but not limited to: NoSQL, MapReduce and machine learning" (Ward, J S and Barker, A 2013).

In 2012, Wikibon (www.wikibon.org) provided some Big Data statistics to help situate the phenomenon about growth of user-generated data, the marketplace, and business issues related to Big Data. In the context of the business and technology environment, they stated 2.7 Zeta bytes of data existed in the digital universe in 2012, and that IDC Estimates by 2020, business transactions on the internet will reach 450 billion per day. Facebook was already storing, accessing, and analysing 30+ Petabytes of user generated data, while Walmart handled more than 1 million customer transactions every hour, which was imported into databases estimated to contain more than 2.5 petabytes of data. In 2008, Google was processing 20,000 terabytes of data (20 petabytes) a day. With reference to the rapid growth of unstructured data, YouTube users uploaded 48 hours of new video every minute of the day, 571 new websites were created every minute and 100 terabytes of data uploaded daily to Facebook. Data production was expected to rise by 44 times in 2020 compared to 2009. This was contextualised as the amount of data in the world being equal to every person in the US tweeting three tweets per minute for 26,976 years (Wikibon 2012). Herein, Big Data can be accepted to mean extremely high volumes of both structured and unstructured data that is difficult to process using traditional database and software techniques. It will also refer to the technologies required to both handle and generate this data.

In the context of spatial planning our interest is in various types of Big Data ranging from geo-located social media to live infrastructure updates, much of which is loosely structured data that is often incomplete or inaccessible. The aim of identifying Big Data is to address this data in terms of collecting, organizing and analysing large sets of data in an effort to discover patterns and other types of potentially useful information. Big data analytics while primarily aimed at identifying data most important to business and future business decisions is increasingly becoming a part of decision making by both organisations such as Amazon – who uses data analysis on multiple fronts, from customer recommendations to running its own physical warehousing operations – and individuals using Google Maps to find locations and services. In the age of Big Data, there are several issues to be addressed regarding the ownership and use of data, and several interesting new avenues for urban planning are related to Open Data.

Open Data – Open Government Data

Open data is data that is available for anyone to use free of charge, and can be republished or reused without copyright restrictions or patents. While the open data movement is similar in principle to other open movements such as open access or open source, it is more directly associated with the Internet and World Wide Web. The Open Knowledge Definition which is meant to be an umbrella for open data, open content and *libre open access*, by the Open Knowledge network (formerly Open Knowledge Foundation) defines the key features[1] related to 'openness' as 'availability and access', 'reuse and redistribution' and 'universal participation'. Availability and access is related to the data being available whole at a reasonable reproduction cost and useful format, reuse and redistribution refers to permission for reuse, redistribution and machine-readability, and universal participation to lack of discrimination or restriction of use by specific groups (Knowledge, O). There are several subject areas under which open data is grouped such as Open Data in science, Open Data related to weather, Open Data in economics and Open Data in Transport, etc. In the context of ICT and urban planning, release of open government data has potential for significant impact in terms of informed economic and environmental decision-making [P1] (See Figure 1.4.1), as well as stakeholder communication between government, business and civil society [P2]. Most governments collect and collate large amounts of data on citizens, development, infrastructure and businesses. A number of government institutions have chosen to start releasing data historically collated and controlled by them into the public realm. USA (Data.gov), UK (data.gov.uk), Canada (data.gc.ca) and the European Commission (open-data.europa.eu) are some of the early examples, with Japan (data.go.jp) and a number of other nations initiating their own portals more recently. The primary aims and ambitions of open government data are to encourage transparency, create value through innovation and a more dynamic relationship between citizens and government (Office, C 2013). Where, transparency of government is an obvious anti-corruption requirement of a democratic system, with data not simply released, but rather released both raw for various types of bottom-up analysis, and in collated communicative forms. The site 'wheredoesmymoneygo.org' provides an example of how UK citizens can understand what their taxes are used for and compare this to various other countries. The release of open government data is aimed at enabling economic value in terms of new industries through innovative uses of this data, leading to more companies, more jobs and more tax revenues. Civic participation and awareness is the other primary area that can be transformed through open government initiatives when considered in the context of Web 2.0 – websites with user-generated content. Whether this relates to transport service updates, information on getting a malfunctioning street light fixed or reporting pollution to authorities. Current criticisms and concerns regarding Open Data include social-economic exclusion [C1] based on ICT non-use, duplication of existing commercial data services by governments [C2], potential higher benefits to select sectors or groups of citizens [C3] and sensitivity of private data [C4] (Figure 1.4.1).

Mobile Devices – Geo-located Data

One identifiable technological disrupter is the shift from fixed internet usage – information access and production – to mobile. In 2009 ITU (International Telecommunication Union) the United Nations specialized agency for information and communication technologies confirmed that mobile cellular the most rapidly adopted technology in history was already the most popular and widespread personal technology on the planet, with an estimated 4.6 billion subscriptions globally. Mobile broadband subscriptions overtook fixed broadband subscribers at some point in 2008 (International Telecommunication Union 2009). In 2013, there were almost as many mobile-cellular subscriptions (6.8 Billion) as people in the world (7.1 Billion) (International Telecommunication Union 2013), and by the end of 2014 mobile-cellular subscriptions are predicted to reach almost 7 billion, with 3.6 billion of these in the Asia-Pacific region (International Telecommunication Union 2014). This signifies a phenomenon similar to the shift from fixed telephones to mobile telephones in the 1990's, but if considered in the context of the wider impact of data usage and production, is likely to have much wider societal impacts.

Two major aspects of this shift to mobile data use which are interesting for urban planning relate to geo-located data. Infrastructural updates from traffic conditions and delayed trains have increasingly become live, with user-generated data feeding additional applications available to the public [P1]. This mobile related shift from corporate or government-generated data is symptomatic of multiple realms and is observable in the reliance of consumers on peer reviews [P3], rather than simply corporate advertising. Destinations visited, books bought, and eventually expectations of experience related to cities and places are all subject to information on Flickr, Facebook and Twitter, enabled by automatic uploads and immediate feedback the mobile devices in our hands allow us to orientate and navigate an increasingly information dependent world [P2]. The ease of information exchange and formation of online networks can result in formation of online communities which have a real presence in the governance of our cities [P4] (Figure 1.4.1), ranging from those wishing to conserve a historic area, to those wishing to overthrow governments, such as in the Arab Spring (Khondker, H H 2011). Geo-tagging is having an impact not only on immediate usage, but also in terms of a growing archive of geographically located user-defined socio-spatial data to be analysed in multiple ways. Townsend in his popular book 'Smart Cities' states, "With our days and nights increasingly stretched across the vastness of megacities, we've turned to these smart little gadgets to keep it all synchronized" (Townsend, A M 2013). Growth in the use of mobile devices and geo-tagged data will no doubt continue to increase, but with little regulation in relation to this new phenomenon, observable outcomes of user-generated data include multiple abuses related to freedom of use and control. Internet networks are shut down and controlled by governments for political reasons [C4], as observed in Egypt during the Arab Spring or San Francisco in 2011 (Morgenstern, M 2011, Dunn, A 2011). Peer reviews can be manipulated [C2] by reviewers, corporations and even authors themselves such as in the case of R.J. Ellory giving himself positive reviews and others negative ones (Flood, A 2012). User-data is analysed and aggregated by corporations with and without the knowledge of the user to tailor advertising and enhance products [C3], with the example of Google clearly stating in their privacy policy that they will use user-data for advertising (Erickson, C 2012). When opt-out options are available, they tend to come with a reduction of services compared to opt-in options [C1] (Figure 1.4.1).

The Internet of Things

The number of devices connected to the Internet was estimated at 12.5 billion by 2010, when the world's human population reached approximately 6.8 billion. Cisco IBSG (Internet Business Solutions Group) estimates that at some point in 2008 the internet of people was overtaken by the Internet of Things (IoT) (Ashton, K 2009, Evans, D 2011). By 2015 Cisco predicts there will be 25 billion devices connected to the Internet, which will increase to 50 billion by 2020 (Evans, D 2011). Kevin Ashton, cofounder and executive director of the Auto-ID Centre at Massachusetts Institute of Technology is credited with coining the term 'the Internet of Things' (1999). He described how the Internet was so far predominantly dependent on people to input data or information, through typing text, uploading recorded pictures, etc. and how this was a limitation due to the limited time, attention and accuracy of people. Instead suggesting, "If we had computers that knew everything there was to know about things – using data they gathered without any help from us – we would be able to track and count everything and greatly reduce waste, loss and cost. We would know when things needed replacing, repairing or recalling and whether they were fresh or past their best" (Ashton, K 2009). The IoT is widely understood to refer to a scenario in which people, objects and even animals are tagged with unique identifiers and have the ability to transfer data over a network without requiring human action. A shift is required and underway from the limited number of IP addresses (Internet Protocol identifiers allowing delivery of data from one source to another) possible with IPv4 – approximately 4.3 billion – to the IPv6's 340 trillion (Wigmore, I 2014). The IoT is of particular importance to planning as it connects the physical world to the Internet [P4]. If considered in stages, following the provision of unique identifiers (IP address) for everything and everyone, and giving each of these the ability to communicate wirelessly, the following step would be to enable remote controls of embedded electronics. In Mirror World's Gelernter envisages "*[...] an ocean of information, fed by many data streams. Some streams represent hand-entry[...] Others are fed by automatic data gathering and monitoring equipment [...]*"(Gelernter, D H 1991, 27). He predicts Smart Cities, explored later in this article. The IoT easily lends itself to improvement of existing systems such as greater efficiency [P1] in factories and cheaper energy use though smart grid connected smart devices (even washing machines). Increasingly it is being applied to an ageing population and self-medication combined with remote monitoring [P3]. 'Things' can refer to a wide variety of devices such as transport location sensors [P2], heart rate monitors and operational aids for industry. The commonalities in operation are monitoring of internal or external environments, followed by data exchange, data analysis and if need be interaction by machines or people. If we imagine the increasing number of IoT objects 'talking' to each other and us over the Internet, the amount of data recorded for long-term analysis also increases. As an example, the GPS enabled Nike+ sensor (which fits in your shoe) enables monitoring and analysis of pace, distance, time, calories and route while remotely uploading this to a device belonging to the runner, who can then track his or her progress over time and per run. As with most ITC areas connected to Big Data, the IoT is progressive and the danger of being controlled by a technocracy made up of the big technology companies is imminent. Appropriate regulations and controls to avoid the average user ending up in a Panopticon situation [C3] with all their data visible to a select few are yet to be implemented. The dangers of IoT run from misuse of data, resulting in intrusion and control of services [C2] – for example medical insurance being refused to certain patients based on their data – to the possibility of external hackers compromising the security of the data collection entities themselves with implications stretching across all aspects of any individual. Another aspect of the increase of data from the growth of IoT will be the possibility of too much complexity [C1] (Figure 1.4.1), requiring completely new ways to analyse and extract useful information from oceans of mundane exchanges.

Ubiquitous Computing

Closely related to IoT is the idea of 'Ubiquitous Computing' – also called pervasive computing – where computers are embedded seamlessly into every object and aspect of our lives. One of the widely stated definition or objectives of ubiquitous computing is that it would be "invisible but everywhere around us" (Weiser, M 1993) and would not need a dedicated GUI (graphic user interface), instead becoming a part of everyday behaviour. In 2013, PAN Studio realised the 'Hello Lamp Post' project in Bristol, where everyday street furniture and objects such as lamp posts could be asked questions using a mobile phone and the objects unique identification code, building up stories over time and allowing people to see what the previous interactions were (Pan 2013). Ubiquitous computing is well on its way with contactless tickets and credit card payments, and is part of an expanding phenomenon which shifts 'machine-to-machine' (M2M) communication from its 'business to business' (B2B) origins to a 'business to consumer'(B2C) trend [P1]. The concept of machines monitoring the real world without specific permissions being needed and developing a machine intelligence or consciousness [C1] (Figure 1.4.1) continues to be highly contested subject (Kurzweil, R 2005).

Augmented Reality

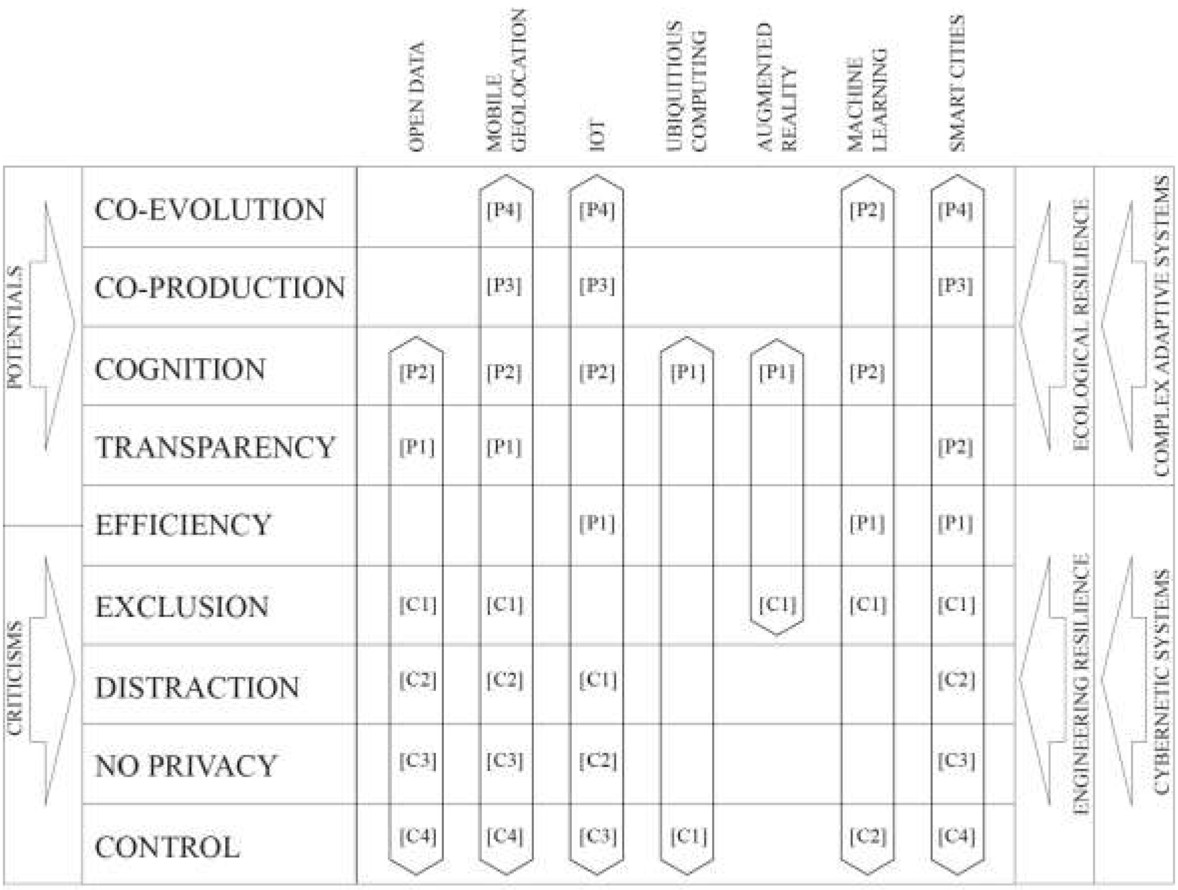
As traditional user-interfaces for ICT are eroded new and long-promised user experiences are coming to the foreground. Physical reality is being overlaid with previously invisible information made visible. Google glasses and Nokia City Lens – which uses the camera of a mobile phone – provide the opportunity to see reality with the addition of dynamic information, about shops and services, providing the user with access to a layer of information that would previously have required a dedicated search. Interacting with the real city and information layers about the real city at the same time could provide interesting degrees of cognition [P1], but the real debate may be about how much information about location, preferences and other personal interests individuals are willing to surrender, and to who, in order to become part of this information society – i.e. what is the price of admission? [C1] (Figure 1.4.1).

Machine Learning
Machine Learning is a branch of Artificial Intelligence (AI) (McCarthy et al, n.d.) concerned with the study of systems that learn from data. With the advent of Big Data, this branch of research is expanding in order to address the impossibility of making sense of the vast amounts of new data though more traditional means. We are already surrounded by Machine Learning applications whether we know it or not. Search engines such as Google or Bing rank websites and order them for us to view based on relevance, rather than simply presenting everything on the Internet with a key word match. Junk mail filters within our anti-virus programs learn our habits over time and unobtrusively filter our inboxes.
Machine learning algorithms basically figure out how to perform tasks comparing unknown examples against defined examples (supervised learning) or by categorising patterns using clustering (unsupervised learning) logic. Using the first method, one of the main uses of Machine Learning has been in the diagnosis of cancer in patients, based on the development of increasingly larger databases of known cases [P2]. The optimisation of engineering solutions and services through feedback loops and sensors in Smart Cities, such as urban transport and smart electricity grids, also relates to this method [P1]. Pattern recognition can be observed in examples such as Yahoo's Launchcast music streaming application that matched user tastes through simple 'like or dislike' rating options by all users. Recent developments in Computer vision (E.g. in face recognition) and Natural language processing (NLP) have begun to demonstrate translation of real world knowledge into digitally recognisable data without the need for human intervention [C1]. In the context of Mirror World's, given these existing functionalities, one can begin to see how Machine Learning can play a significant role in creating virtual systems that can start to regulate and update themselves based on external stimuli and simulate real cities with live updates [P3]. The accuracy of parallel behaviour between virtual/simulated cities mentioned in Mirror World's and reality will depend on the focus in Machine Consciousness research shifting from simulating single entities to the collective intelligence [C2] (Figure 1.4.1) we see in cities (Weinstock, M and Gharleghi, M 2013).

Smart Cities – The Promise and the Critique
Smart City is a widely used concept, promoted by American and European governments and cities, and more recently by Asian cities. It is based loosely on the precept that increased ICT

and related activities (including engagement with technologies and phenomena already mentioned) will lead to more efficient [P1], better connected and more creative cities [P4], in turn resulting in sustainable urban and economic growth. This concept is particularly important, as it exists in direct relation to urban planning, growth [P3], spatial change and urban governance. BIS, the Department for Business Innovation and Skills in the UK identifies a series of steps in their Smart Cities Background Paper (2013), towards more 'liveable' and 'resilient' cities. These steps state the need for digital infrastructure with an open access approach, citizen centric service delivery, intelligent physical infrastructure including 'smart' systems and data analytics, openness to experimentation and learning from others, transparency [P2] (Figure 1.4.1) of performance between institutions, and leadership with a clear vision of the future based on citizen consultation and aimed toward creating an attractive business environment (Department for Business Innovation and Skills 2013a).
While the aims of the smart city agenda appears to promote the idea of a technologically connected information society, the initial modes of implementation appear to be aimed at infrastructural efficiency and government to business (G2C) information flows. BIS Research Paper 136 undertaking a series of case studies on smart cities – by ARUP, a global engineering practice – emphasises the use of smart city technologies to leverage data towards better city service delivery. The same paper identifies various findings, including the need for cities to situate their smart city visions in a department that works horizontally across city silos, and to develop e-government for greater citizen accessibility (Department for Business Innovation and Skills 2013b).
However, in contrast to several findings related to the need for government action, there is also an identification of city governments not being the top-down drivers of development, and the need to reposition government initiatives within a wider ecosystem of stakeholders, including community groups and the private sector. The Smart Cities label is a contested term due to its loose use by several cities and institutions in an attempt to either claim they are 'smart' or define a wide smart agenda. The term smart cities has been used in an attempt to incorporate reference to all ICT, creativity and knowledge based concepts in the context of urban economies, such as Dutton's 'wired cities' (1987), 'digital cities', e-governance, Komninos' 'intelligent cities' (2002), the knowledge economy, Florida's 'creative cities' and the 'smart growth' agenda. The second area of contestation is the proliferation of uncritical assumptions about the positive outcomes of advancing an ICT based agenda for cities based largely on a self-congratulatory tone and a sense of technological determinism (Hollands, R G 2008). Some of the potentially dangerous socio-political implications within the smart cities agenda – ranging from technological exclusion [C1] to the scenario of strengthened governing elites functioning as a police state [C4], with only the interests of businesses at heart – are hidden within the efficiency initiatives undertaken by cities in order to promote a 'sustainable' development agenda. Rio de Janeiro, the winner of 2013's World Smart City Award, is perhaps best known for the implementation of the IBM designed 'citywide control centre', which allows the city to better manage its emergency services, monitor transport, water and weather using a number of sensors across the city. Some of this information is disseminated back to citizens via Twitter and other popular media. While the degree of increased

surveillance and cross-departmental information exchange may result in the hoped for efficiencies of operation, it is yet to be seen how the original problems identified as crime, aging infrastructures and natural disasters will be positively affected [C2]. Barcelona's Fab Lab won the Smart City Award in the initiative category for the development of 'Smart Citizen', a mobile sensor dependent digital platform for citizens to share real time data about levels of air pollution, noise and humidity in their immediate context. While this initiative (currently in a test phase) if implemented may provide valuable data landscapes of the mentioned environmental factors, the actions to improve the conditions reported remain undiscussed. These two examples demonstrate the typical technological approaches being promoted through smart city agendas through use of collected or surrendered user (often citizen) data. The major promoters of the concept to city governments are large technology companies such as IMB, Siemens and Cisco, who have vested interest [C3] (Figure 1.4.1) in the promotion of their solutions to urban problems. The bias towards optimisation of service delivery in the name of sustainability, is comparable to optimisation in large businesses aiming to streamline their processes, a concept related directly to income remains a questionable solution to the complex nature of urban problems and the continuous evolutionary change in cities (Marshall 2009).



〈 FIGURE 1.4.1: Potentials and Criticisms 〉

Stages of e–Governance towards Participation

Increasing use of ICT has resulted in attempts promote electronic or ICT driven governance (e-governance). E-governance is often conflated with electronic government (e-government) and it is useful to clarify that the term e-governance is being used here to refer to acts, methods and structures of e-government, including those involved in urban planning, both in regulatory and in forward planning contexts. E-government when used will refer to the specific bodies involved in e-governance. E-governance is generally referred to in the context of improving and delivering government services and integrated exchange of information using the acronyms G2C (government to customer or citizen), G2B (government to business), G2E (government to employee) and G2G (government to government). The primary aim of G2C e-governance is to offer a variety of services to citizens using ICT, resulting in economic and efficient transactions, especially in the context of information dissemination and customer applications on matters such as tax payments and address changes. Two-way communication in the form of online voting is also being implemented in some aspects. G2E e-governance focuses on the development of online information exchange and learning tools for employees and employee companies. This can include linked payroll records and ongoing training using ICT. G2G in e-governance refers to a wide range of strategies employed by governments to find efficiencies and move beyond departmental silos. The strategies can be seen as inward facing or outward facing depending on whether they attempt to co-ordinate different government departments and agencies, or link up a number of governments, for example across national boundaries. G2B e-government refers to an attempt to increase productivity by providing business with greater access to information in an organised, transparent, time saving and cost-efficient manner. As yet there is a gap between the intention and implementation of e-governance which can be examined simply using five stages of technical integration (Moon, M J 2002), namely 1) One-way information dissemination; 2) Two way communication with responses to requests; 3) Service and Financial transactions; 4) Vertical and horizontal integration referring to single point information sources and marketplaces; 5) Political participation (Figure 1.3.2). Dissemination of information and financial transactions can be seen in many new government portals (E.g. GOV.UK) and the incentive to enable greater two-way communication and business orientated market places appears to be simply a matter of time based on the overall aims of G2B and G2C. However, aspects of political participation (beyond voting) appear to be mired in a complex set of problems, from lack of regulation on protection of data privacy, to the fear of strengthened community reactions against top-down planning resulting in greater inefficiencies.

Complex Adaptive Systems, Co-evolution and ICT

Complex Adaptive Systems (CAS) a specific type of complex system demonstrates phenomena of particular importance to complex networked real world systems, such as those accelerated by new ICT development. CAS can demonstrate the ability to learn from experience and display evolutionary traits. Typical qualities of such systems are self-similarity, the ability of agents in the system to adapt to changing conditions and the ability of the system itself to adapt. The ability to learn and anticipate in the process of adapting to future conditions, adds yet another layer of complexity (Holland, J H 1992). Ecologies and human social group-based endeavours in a cultural and social system such as political parties, communities, online tagging or social systems and the global economy can be understood as some form of CAS. Cities are increasingly being studied as CAS, as they are open-ended non-deterministic spatio-temporal and behavioural structures affected by and affecting the various individual and collective agents made up of citizens, socio-economic subsystems and socio-technical endeavours, with multiple internal and environmental factors acting to influence the system at any one time (Portugali, J 2011, Roo, G D, Hillier, J, and Wezemael, J V 2012). In planning, the description of a city, its evolution and planning processes are being reframed using CAS theories. The critiques of blueprint planning, which may be understood as a misappropriation of resilience theory (Holling, C S 1996), and synoptic planning, which can often be framed using cybernetics (Wiener, N 1965), revolve around both the negation of a systems ability to evolve positively and top down approaches to management of cities. The potential of ICT development for planning is considered here using a CAS framework related to possibilities of co-evolution and structural change within cities as open-ended systems.

Existing ICT Initiatives: Potential for Co-evolution and Emergence

The five levels of technical implementation in e-Governance by M. Jae Moon described earlier can be re-interpreted to relate to six levels (A to F) of ICT enabled co-evolution in relation to spatial planning (Figure 1.4.2).

PARTICIPATION	LEVELS OF TECHNICAL IMPLEMENTATION IN E-GOVERNANCE TECHNICAL IMPLEMENTATION	ICT IMPLEMENTATION RELATED TO CO-EVOLUTION IN SPATIAL PLANNING	ECOLOGICAL RESILIENCE/EMERGENCE	COMPLEX ADAPTIVE SYSTEMS	CO-EVOLUTION
	1. ONE-WAY INFORMATION DISSEMINATION	A. ICT ENABLED INFORMATION DISSEMINATION			
	2. TWO WAY COMMUNICATION WITH RESPONSES TO REQUESTS	B. ICT ENABLED INFORMATION EXCHANGE			
	3. SERVICE AND FINANCIAL TRANSACTIONS	C. ICT ENABLED SERVICE PROVISION			
	4. VERTICAL AND HORIZONTAL INTEGRATION REFERRING TO SINGLE POINT INFORMATION SOURCES AND MARKETPLACES	D. ICT ENABLED SERVICE COLLATION			
	5. POLITICAL PARTICIPATION	E. ICT ENABLED CO-PRODUCTION STAKEHOLDER PARTICIPATION			
		F. ICT ENABLED CO-EVOLUTION			

〈 FIGURE 1.4.2: Stages of e-Governance and ICT enabled co-evolution. 〉

The first four categories (A, B, C and D) in the 'ICT implementation related to co-evolution in spatial planning' column refer to the use of ICT in delivering greater access, convenience, efficiency and communicative possibilities based on existing services and practices. The final two categories (E and F) refer to progressing greater stakeholder participation and co-evolution of governance or governmental structures based on changes enabled by ICT platforms and initiatives. Five separate ICT based platforms or initiatives are compared below in terms of their potential to enable greater participation, co-evolution, emergence and ecological resilience in spatial planning, using the categories described. The examples selected are functioning platforms suitable for demonstration of the progressive categories (A-F). Each of the examples is, either the first such ICT platform or the most cited in the field.

CityDashoard (London)

CityDashboard is a web based ICT initiative launched in 2012 and designed by UCL's Centre for Advanced Spatial Analysis. Oliver O'Brien and Duncan Smith developed the project. UCL suggests it is an "at-a-glance view of eight cities around Great Britain" (Casa, U 2012). In addition to the dashboard, the web page (http://citydashboard.org/london/) is able to display either a grid of boxes with rollover statistics or a map view with real time data. The data itself is from a variety of sources and includes weather data and forecasts, status of tube lines (London), Transport for London service, air quality measurements, BBC news and twitter trends, etc. Some of the data is interpreted or borrowed, such as the 'mood' indicator related to the London School of Economics and Political Science's Mappiness app (www.mappiness.org.uk). CityDashboard provides us with an example of ICT use related to category (A) from figure one. The webpage collates, processes and visualises various types of data for convenient public dissemination.

Citizen Connect (Boston)

Citizens Connect is a mobile app (www.newurbanmechanics.org) initiated in Boston that helps residents report issues, such as damaged roads and graffiti to City Hall. The City of Boston suggests it "empowers residents to be the City's eyes and ears, helping us make our neighbourhoods even better" (Boston, C O 2009). The initiative makes use of an app designed for mobile phones/devices to easily select the type of case they wish to report, take a photograph and add a note if they wish. The success of the app (Mechanics, N U 2013) is being attributed to clear accountability and ease of use. The function of the app is in reality more sophisticated in its ability to engage citizens. All cases submitted by citizens are entered into the City's 'work order management' system, where it immediately reaches the correct person in City Hall. The case reporter is provided with a tracking number and is alerted when the problem is resolved. Citizens can also choose to make their cases public and follow other cases in their locality or city resulting in transparency and the possibility of collective lobbying. In addition, citizens connect to the actual teams undertaking the remedial work, allowing for a personal connection and update once the project is complete, and communication between the reporters and the repair teams. The Citizens Connect initiative is a highly emulated example of categories (B), (C) and possibly (D) (Figure 1.4.2). The app and related service clearly enables information exchange between citizens and government, while providing services based on submitted information, and collating some services through a simple interface.

Minstad (Gothenburg)
Gothenburg has initiated a web-based platform called Minstad (my city) (www.minstad.goteborg.se). Citizens who sign in – using their Facebook accounts or interactive public displays located in the city – are invited to interact with a 3D map of Gothenburg and submit suggestions. The realistic 3D interface is designed to help users understand the city and geo-locate their proposals in a virtual model of Gothenburg closely reflecting the real city. The navigation is similar to a Google 3D environment and hence familiar to many users even before they start. Users can choose from various categories and make proposals related to culture, shopping, cycling etc. The suggestions are recognisable on the map by their category icons. The platform is not simply an archive of suggestions, as it allows voting and discussion on existing suggestions, creating an online public forum for the citizens to debate future desires. Minstad 2.0 (2015) was released with additional features allowing citizens to create basic shapes and use colours to illustrate their suggestions if they so desire. The City Planning Authority of Gothenburg currently does not comment or respond to proposals. This lack of accountability (while possibly a temporary stage) means that the platform addresses categories (A) and (B), some aspects of (D) and a small portion of (E), but is limited primarily to an information creation, and discussion forum for citizens, instead of being the a platform for co-evolution (Figure 1.4.2).

Participatory Budgeting and Open Budgets
Participatory budgeting (PB) was developed in Porto Allegre, Brazil in 1989 (Pbp 2014, Santos, B D S 1998), and has been trialed in New York since 2011. The aim of the initiative is to enable community members to have a direct say in the allocation of discretionary funds from the public budget. The typical process involves community meetings to brainstorm ideas, which are then formulated into realistic projects with the help of experts, before residents in the community vote on the projects they wish to be implemented. Public funds are awarded to the most popular projects falling within the available budgets. The concepts of transparency and participation in PB are currently being explored through the use of ICT enabled data analysis and visualization at both national and city scales.
In 2010, the New York Times published a digital tool called 'Budget Puzzle: You Fix the Budget' (Carter, S et al. 2010a).This tool encouraged anyone who wanted to try, to understand and balance the US national budget. It categorised the budget into various groups such as domestic programs and foreign aid, healthcare, and military. Each group consisted of a number of actions that could be selected using a tick box, such as 'Raise the Social Security retirement age to 68, displaying projected income/savings by 2015 and 2030 (Carter, S et al. 2010b). The tool also helpfully provided a short explanation of the ramifications of each selection. Following this example, cities such as Oakland in co-operation with 'Open Oakland' (openoakland.org) have developed a number of ICT based initiatives to engage citizens in budgetary considerations. 'Open Budget Oakland' is an open-source project by OpenOakland, a nonprofit civic innovation organization. They suggest it is a tool to "help citizens better understand Oakland's spending and budget process" (Openoakland 2013).

Open Budget Oakland visualises city budget data online and provides information on the budget process, including a timeline for various stages. While in the early stages of the open budget development, citizens were provided with the 'Oakland Budget Challenge', allowing them to build their own city-budget and submit a link with a summary of policy choices, this was no longer available at the point this paper was written. Open Budget Oakland currently aims to clearly illustrate and communicate complex budgetary issues to citizens in order to raise awareness and 'stimulate dialogue'.

At this time, most budgetary tools can be categorised as one of the two types described above. Initiatives such as Cook County Budget (City, O 2013) and OPENGOV based initiatives for 'Financial Transparency and Business Intelligence'– such as for Palo Alto (Opengov 2014) – present budgetary information in order to encourage informed decision making. OPENGOV states, "More than 150 governments in 30 states use OpenGov to access, analyse, and share financial data. OpenGov's web-based platform empowers senior executives to see trends, drill down to transaction-level details, and compare actual spending to the budget. It also enables governments to share the financial data with elected officials and the public to improve communication and build trust. Initiatives such as the California Budget Challenge (Next10 2014) provide online tools for interested parties to try and balance the budget themselves, and invites comments and suggestions at various stages. The latter approach was adopted by the Federal Budget Challenge. It provides an online platform (https://www.federalbudgetchallenge.org/pages/overview) to attempt balancing the US national budget priorities. At this stage, the OPENGOV type initiatives of open budget fall primarily into category (A) in Figure 1.4.2, namely information dissemination, and the budget challenge type initiatives fall into category (B) I.e. information exchange. Next 10 the developers of the California Budget Challenge are currently involved in live voting events with local communities to encourage better understanding of budgets, greater participation, and potentially future accountability through e-government.

Open Data to Policy: Vancouver

In January 2012, Vancouver city council mandated the creation of an online searchable database of rental apartments in Vancouver, based on a similar database in New York. The database updated nightly included information on building ownership, outstanding working orders and property violations. The primary aim of this mandate was to ensure property owners maintained their properties in good order. The immediate output of this public access database was the identification of the province of British Columbia as the property owner with most health and safety violations, and these being concentrated in single resident occupancy (SRO) buildings it owns in Vancouver. As a result, the province of British Columbia announced it would spend $1 million (Canadian) to address these issues. This process of a politically smaller actor (city) in co-ordination with citizen actions, creating an ICT based initiative eventually requiring a larger political body (province) to create policy and demonstrate changes on the ground, is an example of engagement with levels (A) to (F) in figure 1.4.2. While the ICT tool was not created with the result in mind, the eventual outcome reflects an element of co-evolution and political participation (Figure 1.4.2).

Conclusion

This overview of ICT based disrupters, initiatives and platforms, demonstrate the urgent need for further research and engagement. Future trajectories for ICT in planning continue to form contested field between new possibilities of control and co-evolution. The use of a complexity science framework allows categorisation and a comparison of long-term aims and theoretical outcomes. Initiatives primarily aimed at management and information dissemination – e.g. smart cities, city dashboards and live updates on city infrastructure for decision-making – demonstrate systemic approaches related to mechanical resilience and cybernetics. The long-term aims of these initiatives are primarily efficiency and control. ICT aimed towards open-ended participation and structural change – e.g. open budgets – typically concentrating on bottom-up processes and positive feedback loops relating to negotiated and emergent outcomes. The process of learning and adjusting current trajectories in the context of an open-ended system, if understood through a complex adaptive systems framework, provides the route to co-evolution in urban transformation. This is demonstrated in the Vancouver example. Combination of short-term management in parallel with long-term strategies embracing new modes of participatory and negotiated outcomes need to be progressed in parallel in order to address the danger of ICT being developed primarily towards systems of control or as distractions from genuine issues resulting from urban transformation. Potentials and criticisms related to the various development areas of ICT related to planning have been identified. Looking ahead, the potential for surveillance and control, misuse of private data, corporate control of technologies, technological exclusion, development of artificial intelligence and lack of capacity or regulation within existing governance structures, remain significant areas of concern. It is vital for planners and transdisciplinary urban researchers to engage with the development of ICT platforms and initiatives towards enabling new processes of participation and co-evolution in cities. As Gelernter warned, "*The intellectual content, the social implications …make them far too important to be left in the hands of the computer sciencarchy"* (Gelernter, D H 1991, p.4).

References

Allen, P M. 1997. *Cities and regions as self-organizing systems: models of complexity*. London: Taylor & Francis.

Allen, P M. 2012. "Cities: The Visible Expression of Co-evolving Complexity." In *Complexity Theories of Cities Have Come of Age*, edited by Portugali, J., Meyer, H., Stolk, E. and Tan, E., 67-89. Springer Berlin Heidelberg.

Ashton, K. 2009. "That 'internet of things' thing." *RFiD Journal* 22:97-114.

Batty, M, and Marshall, S. 2012. "The Origins of Complexity Theory in Cities and Planning." In *Complexity Theories of Cities Have Come of Age*, 21-45. Berlin, Heidelberg: Springer Berlin Heidelberg.

Boston, C o. 2009. "CitizensConnect: Making Boston Beautiful." City of Boston.gov, accessed 18/08/2014. http://www.cityofboston.gov/doit/apps/citizensconnect.asp.

Carter, S, Ericson, M, Leonhardt, D, Marsh, B, and Quealy, K. 2010a. "Budget Puzzle: You Fix the Budget." The New York Times, accessed 2016. http://www.nytimes.com/interactive/2010/11/13/weekinreview/deficits-graphic.html?_r=0.
Carter, S, Ericson, M, Leonhardt, D, Marsh, B, and Quealy, K. 2010b. "Outdated - Budget Puzzle: You Fix the Budget." [Newspaper Web Article]. The New York Times, accessed 17/10/2014. http://www.nytimes.com/interactive/2010/11/13/weekinreview/deficits-graphic.html?_r=0.
CASA, U. 2012. "City Dashboard is Launched." [web page]. UCL, accessed 21/08/2014. http://www.bartlett.ucl.ac.uk/casa/news/2012-05-16-citydashboard.
City, O. 2013. "Cook County Budget." [web page]. Cook County Commissioner, accessed 24/11/2014. http://lookatcook.com/.
Department for Business Innovation and Skills. 2013a. Smart cities: background paper. edited by Department for Business, I. S.
Department for Business Innovation and Skills. 2013b. The Smart City Market: Opportunities for the UK. edited by Department for Business, I. a. S. UK: GOV.UK.
Dunn, A. 2011. "Unplugging a nation: State media strategy during Egypt's January 25 uprising." *Fletcher F. World Aff.* 35:15.
Erickson, C. 2012. "Google Privacy: 5 Things the Tech Giant Does With Your Data." Mashable, Last Modified 24/08/2014. http://mashable.com/2012/03/01/google-privacy-data-policy/#yhQV0kfRjqqW.
Evans, D. 2011. "The Internet of Things: How the Next Evolution of the Internet is Changing Everything." CISCO, accessed 24/08/2014. http://www.cisco.com/web/about/ac79/docs/innov/IoT_IBSG_0411FINAL.pdf.
Flood, A. 2012. RJ Ellor's secret Amazon reviews anger rivals. *The Guardian*. Accessed 24/08/2014. http://www.theguardian.com/books/2012/sep/03/rj-ellory-secret-amazon-reviews.
Gelernter, D H. 1991. *Mirror worlds, or, The day software puts the universe in a shoebox--: how it will happen and what it will mean*: Oxford University Press New York.
Hillard, R. 2012. It's time for a new definition of big data. In *The open source standard for information management*: Method for an Integrated Knowledge Environment
Holland, J H. 1992. "Complex adaptive systems." *Daedalus* 121 (1):17-30.
Holland, J H. 1998. *Emergence: From chaos to order*. Redwood City, CA: Addison-Wesley.
Hollands, R G. 2008. "Will the real smart city please stand up?" *City* 12 (3):303-320. doi: 10.1080/13604810802479126.
Holling, C S. 1973. "Resilience and stability of ecological systems." *Annual review of ecology and systematics* 4:1-23.
Holling, C S. 1996. "Engineering resilience versus ecological resilience." In *Engineering within ecological constraints* 31-44. Washington, DC, USA: National Academy.

International Telecommunication Union. 2009. The World in 2009: ICT Facts and Figures. Accessed 22/08/2014. http://www.itu.int/ITU-D/ict/material/Telecom09_flyer.pdf.
International Telecommunication Union. 2013. The World in 2013: ICT Facts and Figures. Accessed 22/08/2014. http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2013-e.pdf.
International Telecommunication Union. 2014. ITU Releases 2014 ICT Figures. 2014. Accessed 2015. http://www.itu.int/net/pressoffice/press_releases/2014/23.aspx#.U_dpy65wZD8.
Khondker, H H. 2011. "Role of the New Media in the Arab Spring." *Globalizations* 8 (5):675-679. doi: 10.1080/14747731.2011.621287.
Knowledge, O. "What is Open?". Open Knowledge, accessed 23/08/2014. https://okfn.org/opendata/.
Kurzweil, R. 2005. *The singularity is near: When humans transcend biology*: Penguin.
Laney, D. 2001. 3D data management: Controlling data volume, velocity and variety. In *Application Delivery Strategies*: META Group Research Note.
Layne, K, and Lee, J. 2001. "Developing fully functional E-government: A four stage model." *Government Information Quarterly* 18 (2):122-136. doi: http://dx.doi.org/10.1016/S0740-624X(01)00066-1.
Lohr, S. 2013. "The Origins of 'Big Data': An Etymological Detective Story." The New York Times, accessed 20/08/2014. http://bits.blogs.nytimes.com/2013/02/01/the-origins-of-big-data-an-etymological-detective-story/?_php=true&_type=blogs&_r=0.
Marshall, S. 2009. *Cities design & evolution*: Routledge London/New York.
Mechanics, N U. 2013. "Citizens Connect." New Urban Mechanics, accessed 02/11/2014. http://www.newurbanmechanics.org/projects/participatory-urbanism-projects/project-information-citizens-connect/.
Moon, M J. 2002. "The Evolution of E-Government among Municipalities: Rhetoric or Reality?" *Public Administration Review* 62 (4):424-433. doi: 10.1111/0033-3352.00196.
Morgenstern, M. 2011. Mubarak-Like Tactics? *The Blaze*. Accessed 24/08/2014. http://www.theblaze.com/stories/2011/08/13/mubarak-like-tactics-transit-officials-jam-cellphone-signals-in-san-francisco-to-block-protests/.
Next10. 2014. "California Budget Challenge " [web page]. Next 10, accessed 01/12/2014. http://www.budgetchallenge.org/pages/home.
Office, C. 2013. "G8 Open Data Charter and Technical Annex." [web page]. GOV.UK, accessed 21/06/2014. https://www.gov.uk/government/publications/open-data-charter/g8-open-data-charter-and-technical-annex.
OPENGOV. 2014. "Finacial Transparency and Business Intelligence." [web page], accessed 20/11/2014. https://www.opengov.com/.
openoakland. 2013. "Open Budget: Oakland." openoakland, accessed 22/11/2014. http://openbudgetoakland.org/.
PAN. 2013. "Hello Lamp Post." PAN, accessed 27/08/2014. http://www.hellolamppost.co.uk/.
PBP. 2014. "Participatory Budgeting Project." [Web Site]. Participatory Budgeting Project, accessed 22/11/2014. http://www.participatorybudgeting.org/.
Portugali, J. 2000. *Self-Organization and the City*, *Springer Series in Synergetics*. Berlin/Heidelberg: Springer-Verlag

Portugali, J. 2011. "Complexity Theories of Cities Have Come of Age: Achievements, Criticism, and Potentials." In *Complexity, Cognition and the City*, 95-109. Berlin/Heidelberg: Springer.
Redmond, W. 2012. "The Big Bang: How the Big Data Explosion Is Changing the World." Microsoft. https://news.microsoft.com/2013/02/11/the-big-bang-how-the-big-data-explosion-is-changing-the-world/#sm.0000l0rcabyrve2ttl22rca3bwn6v#qaKO7KoiJDM0PGu7.97.
Roo, G D, Hillier, J, and Wezemael, J V. 2012. *Complexity and Planning: Systems, Assemblages and Simulations*. Farnham, UK: Ashgate Publishing.
Rossel, P, and Finger, M. 2007. "Conceptualizing e-Governance." Proceedings of the 1st international conference on Theory and practice of electronic governance, Macao, China.
Santos, B d S. 1998. "Participatory budgeting in Porto Alegre: Toward a redistributive democracy." *Politics & society* 26 (4):461-510.
SAS. "Big Data: What it is and why it matters." SAS Institute Inc., accessed 21/08/2014. http://www.sas.com/en_us/insights/big-data/what-is-big-data.html.
Sengupta, U. 2011. "Urban Morphology: Incorporating Complexity and Variation." In *Urban change: the prospect of transformation*, 180-189. Wroclaw: UN-HABITAT & Wroclaw University of Technology.
Sengupta, U, and Cheung, E. 2016. "Gamifying 'Smarter' Planning: Adaptive and resilient future cities." Association of American Geographers Annual Meeting, San Francisco, CA, 4 April 2016.
Silcock, R. 2001. "What is E-government." *Parliamentary Affairs* 54 (1):88-101. doi: 10.1093/pa/54.1.88.
Townsend, A M. 2013. *Smart cities: big data, civic hackers, and the quest for a new utopia*: WW Norton & Company.
Ward, J S, and Barker, A. 2013. "Undefined By Data: A Survey of Big Data Definitions." *preprint arXiv:1309.5821*.
Weinstock, M. 2010. *The architecture of emergence: the evolution of form in nature and civilisation*. Chichester: Wiley.
Weinstock, M, and Gharleghi, M. 2013. "Intelligent Cities and the Taxonomy of Cognitive Scales." *Architectural Design* 83 (4):56-65.
Weiser, M. 1993. "Ubiquitous computing." *Computer* 26 (10):71-72.
Wiener, N. 1965. *Cybernetics or Control and Communication in the Animal and the Machine*. Vol. 25: MIT press.
Wigmore, I. 2014. Internet of Things (IoT). Accessed 24/08/2014. http://whatis.techtarget.com/definition/Internet-of-Things.
Wikibon. 2012. "A Comprehensive List of Big Data Statistics." Wikibon, accessed 21/08/2014. http://wikibon.org/blog/big-data-statistics/.

[1] The full Open Knowledge Definition can be found at http://opendefinition.org/od/