A city is not a galaxy

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Understanding the city through urban data

Martijn de Waal

Introduction

In a 2013 report to the UK Economic and Social Research Council, Michael Batty, the director of the Centre for Advanced Spatial Analysis (CASA), looks back at the time when computers were first being used in urban planning:

> Fifty years ago if you had asked the question 'what can we do with computers with respect to cities?' the answer would have been we can build computer models of cities – abstractions – that can then be used to pose conditional questions such as 'What If . . .'
>
> (Batty 2013a: 22)

Half a century later, Batty argues this vision has been turned inside out. Computers are no longer seen as mere tools to analyse the city, rather they have become part of the city, embedded into its very fabric. From electronic tolling on roads, to CCTV cameras with facial recognition detection, to buildings managed by software systems, to citizens wielding their cell phones to find a nearby restaurant, computers have become active agents in the shaping of urban life.

The rise of these various urban computing systems has contributed to what Rob Kitchin (2014b: xiii) has called a 'data revolution' – the availability of 'a wide, deep torrent of timely, varied, resolute and relational data that are relatively low in cost and, outside of business, increasingly open and accessible'. From citizens posting on social networks to traffic data aggregated by navigation service providers, a constellation of computer systems has started to generate a broad variety of real-time 'urban data', producing what some have called the 'real-time city', wherein the city can be known and managed in the here-and-now through control rooms and urban dashboards (Townsend 2008; Kitchin 2014c; Kloeckl *et al.* 2012).

This chapter explores how the creation of the so-called 'real-time city' is changing our understanding of cities and creating new scientific approaches to urban studies. At least three different (partially overlapping) ways of understanding the city through urban data have emerged. The first can be understood as a new 'action oriented epistemology' of the city. Researchers in academia and business consultancy have started to claim that real-time data can give us a new kind

of knowledge in which cities can be understood as complex systems, not unlike galaxies or rainforests. In turn, these insights can be made actionable through the deployment of smart city technologies. A second approach has a more critical and often also an ontological orientation and seeks to understand the production and experience of urban space mediated by computation. The third approach has focused on normative theories of urban culture at large. The main argument to be made here is that cities are different from other complex systems such as galaxies or rainforests, in that they are social-cultural-political systems that can be framed and evaluated normatively. After all, it is humans themselves that set – and can change – many of the rules that govern urban life. What kind of city do we want to live in? And what do we make of the changes brought about by the various assemblages that employ software and urban data to manage urban life in new ways? Besides providing us insights into the workings of a city, as with the first approach, it is contended that a 'new science of cities' should play a role in addressing these kinds of questions.

An action oriented epistemology

In 2008, in the introduction to a seminal anthology on the then newly emerging discipline of urban informatics, Anthony Townsend proclaims that the rise of real-time urban data might lead to a paradigm shift in the way we understand our cities:

> if aerial photography showed us the muscular and skeletal structure of the city, the revolution in urban informatics is likely to reveal it's circulatory and nervous systems. I like to call this vision the 'real-time city' because for the first time we'll see cities as a whole the way biologists see a cell – instantaneously and in excruciating detail but also alive . . .
>
> (Townsend 2008: xxvi)

More recently, Townsend notes that this line of thought has given rise to at least a dozen new academic labs, departments and schools that explore this new understanding of the city (Townsend 2015b). What is remarkable is that many of these institutes are not grounded in disciplines such as planning or urban sociology, but – as Townsend alluded in 2008 – rather seek inspiration in biology, physics and astrophysics. A case in point: the director of Singapore's Future Cities Lab was trained as a rainforest ecologist; the director of the Centre for Urban Science and Progress in New York is a physicist. What these new institutes seek, according to Townsend is to pursue 'deeply quantitative and computational approaches to understanding the city' (Townsend 2015a; 2015b).

The ecological and physical understanding of cities that we find in the new science of cities is not completely new. The beginning of the twentieth century already witnessed scientists like the evolutionary biologist Patrick Geddes starting to map cities in order to gain an 'objective' understanding of them. Likewise, the sociologists of the Chicago School in the 1920s were inspired by evolutionary theories, and sought to understand the 'human ecology' of cities as a complex

system (Sennett 1969; Park 1969). A second wave of this approach emerged with the rise of cybernetics after the Second World War. The social problems of cities, it was believed by, amongst others, the newly founded United States Department of Housing and Urban Development (HUD), could be tackled by modelling cities with the aid of computers. One of the projects in this program was one of the first geodemographic profiling systems, designed by Jonathan Robbin, that was later turned into the commercial PRIZM database of zip-code based lifestyle clusters (Burrows and Gane 2006). However, the enthusiasm for the models waned quickly when they failed to live up to their promises. Both the data sets used as well as the models were too crude and received much criticism (Lee Jr 1973; Townsend 2015a, 2015b).

What is new this time around is the availability of massive amounts of real-time data generated by all kinds of assemblages of hardware, software, algorithms and institutions in the city itself, plus increased computational power and data analytics utilizing machine learning. Batty (2013a) argues that these may change the logic of the city and at the same time could give us a new understanding of cities as complex systems in which the decisions of millions of heterogeneous individual actors add up to a hard-to-understand system that nevertheless seems to have an order. This system is not static: as cities grow, they also change qualitatively, yet how exactly remains undertheorized. This new understanding is based on flows and networks, shifting our thinking from the city as a system in place to a system in time (Batty 2013a, 2013b).

Whereas some of the new institutes addressing the city as a system of flows are mainly oriented toward finding new theoretical models to understand the city, others are linking the new insights the real-time city may produce to an agenda of urban improvement and citizen empowerment. 'Giving people visual and tangible access to real-time information about their environment', claim Nabian and Ratti (2012: 76), 'enables them to make decisions that are more in sync with what is actually happening around them.' The research projects in their Senseable City Lab aim to explore this idea. For instance, their project Trash Track, that reveals the ecology of trash collection and waste disposal by adding tracking sensors to items that are thrown away, gives clues on how to 'create a more efficient removal chain'. In addition, the data could be used by local governments 'to promote behavioral changes among its citizens' (Ratti and Townsend 2011: 45).

Outside academia we have seen somewhat related (but not completely similar) claims by professional communities working on theories for the now widely discussed 'smart city' (Allwinkle and Cruickshank 2011; Caragliu *et al.* 2011; Hemment and Townsend 2013; de Waal 2014; Kourtit *et al.* 2012). As a research paper by IBM proclaims:

> Smart Cities provide a new form of instrumentation for observing in fine detail the way that people use the city and so may enable new approaches to theories of cities. Through new sources of information cities hope to create insight, innovation, opportunity and real jobs that will increase prosperity and quality of life.
>
> (Harrison and Donnelly 2011: 5)

Here, the city is mainly understood as a series of infrastructural services that can be optimized by better understanding their dynamics.

According to some proponents of this trend, this will lead to a paradigm shift in our knowledge about cities. Rob Kitchin (2014a) has described how a new empiricist school of thought has emerged that takes the data these computer systems are generating at face value to produce direct insights in (amongst others) urban patterns. As one of their protagonists, Chris Anderson (2008), claims:

> We can throw the numbers into the biggest computing clusters the world has ever seen and let statistical algorithms find patterns where science cannot . . . Correlation supersedes causation, and science can advance even without coherent models, unified theories, or really any mechanistic explanation at all.

In their vision, Batty's observation about the use of computers in the city has come full circle: computer systems produce data about the city that allegedly give us a transparent look into the city's dynamics. In turn, these data can be used to analyse the city in order to optimize that system. In the feedback loop that emerges from these assemblages of computer systems, the institutions that manage them and their users, the software might even start fine-tuning its own algorithms, producing a new form of an autopoieitic city (Kryssanov *et al.* 2002).

Where the new empiricists see a system that makes the workings of a city more transparent, their critics point to the fact that they overlook the social and ideological dimensions active in the production of data through these systems (Kitchin 2014b; Greenfield 2013; Batty 2013a; Hollands 2008; de Waal 2014; see Chapters 2, 5, 10, 12, 15). As such, these systems may reinforce social, political and economic power relations rather than providing ways to challenge them or come up with alternatives.

In addition, Batty argues, whereas the new science of cities could provide new insights into the complexity of the city and the feedback loops between individual agents and the workings of the system as a whole, many of the smart city approaches seem to reduce the city to a set of seemingly simple technical problems that can be monitored, analysed and solved, falling into the trap of modernism. Rather, he claims cities should be understood as wicked problems:

> Moreover the notion that urban problems are simple to solve should by now have been dispelled for the experience in everything from garden cities to green belts, from the provision of public housing to the provision of transport systems over the last 50 to 100 years, has been salutary and sobering. Problems in cities are 'wicked' in the terminology of Rittel and Webber (1973) in that they are more likely to get worse than better if you attempt to address them in directly obvious ways which seek simple solutions. The smart city movement has to yet address this question.
>
> (Batty 2013a: 11)

To be fair, a number of actors involved in smart city developments – especially some local governments – have not been deaf to these criticisms, and have started to look for alternative approaches. One of them is bringing 'smart citizens' to the processes of knowledge production about the city (Saunders and Baeck 2015; Hemment and Townsend 2013). Others have invited citizens to the design process of interventions, turning the city into living labs (Concilio *et al.* 2013; Pallot *et al.* 2010; Friedrich *et al.* n.d.; Coenen *et al.* 2014). One way these programs now try to evade the modernist trap is to use urban data to bring various perspectives to the table in the design process. For example, outside academia, an alternative urban data movement has emerged in the form of citizen sensing communities who frame urban issues and the categories of data they need to get a hold on them in different ways (see Chapter 11). A number of new labs and city programs have currently moved into this direction. Here, data are not understood as indexical registrations of urban reality, but as social constructs. Data can be used to produce insights into urban issues, but they are understood as potentially contested, and produced in relation to social and political conditions.

Data and the production and experience of urban space

What unites the approaches discussed so far is that they seek a new understanding of the city through the analysis of urban data in order to intervene in the city. What has not been fully addressed is this: the rise of urban data does not only produce a new way of making sense of the city. At the same time, the interventions that result from the analysis of these data may produce new kinds of spatial organizations and experiences. If computers are indeed used to run the city, rather than merely to analyse it, this could lead to new spatial regimes. What are the power structures and ideologies operative in the ways data are collected, categorized, analysed and acted upon? How does that affect the production and experience of place and our ability to act?

A number of scholars have taken up this issue in their research, resulting in a variety of approaches that seek to understand the role of software and urban data in the production of urban space and the urban experience. To do this, a theory is needed that understands the city as a complex system and provides ways to detangle the various individual actors and their discursive, social, political and social contexts coming together in the production of space. In this line of thought, Kitchin and Dodge (2005) argue that space needs to be theorized as 'ontogenetic'. (Urban) space should not be understood as a given, but is continuously reproduced through the interaction of various actors.

> This ontogenetic conception of space acknowledges that the forms and spatial relations of the world around us are clearly not static and fixed; they are constantly being altered, updated, and constructed in ways that alter sociospatial relations. . . . space is not a container with pregiven attributes frozen in time; rather, space gains its form, function, and meaning in practice.
>
> (Kitchin and Dodge 2005: 171–172)

In their article 'Code and the transduction of space' they provide a number of examples of the way software has become a part of this process. Code they assert 'mediates, supplements, augments, monitors, regulates, operates and facilitates many everyday task and routines related to domestic living, travel, work, communication, and consumption' (Kitchin and Dodge 2005). However, this code is not a given or a neutral factor, but it is produced in assemblages of institutions, governments, companies and/or individuals that seek to manage particular processes with particular aims, as well as the discursive and material practices and the economic and political context around these processes. Following Latour, they describe how these (power) relations may become encoded into the software, and how in turn this software plays a role in the constitution of material and discursive practices.

The strength of this approach is that it allows for the un-black-boxing of the production and use of software by 'following the actors' involved. It seeks to understand the situational context in which tools are produced and used. In *The Data Revolution*, Kitchin (2014b) develops a somewhat similar framework for the understanding of (urban) data. Data itself can be thought of as produced in particular assemblages: 'amalgams of systems of thought, forms of knowledge, finance, political economies, governmentalities and legalities, materialities and infrastructures, practices, organisations and institutions, subjectivities and communities, places, and marketplaces' (Kitchin 2014b: xiv), and as such can be problematized as one of the factors contributing in the production of space.

This ontogenetic approach is a welcome addition to the epistemological ones described above, as it forwards the construction of data in complex assemblages and opens up the debate for critical understandings of smart city epistemologies. As such it fits within a growing interest in urban studies towards ANT methodologies (Farias and Bender 2010), bringing in the production and consumption of data as one of the many aspects of urban assemblages.

Whereas these approaches focus on (our understanding of) the production of space, and the role of data in it, others have started to focus on the role of urban data in the experience of space, shifting the vantage point from the production of space to the experience of the subject. Urban space, as has been theorized widely, should now be understood as 'hybrid' (de Souza e Silva 2006), meaning that its experience is no longer confined to the physical conditions of a particular site, but now includes the networks of communication that can be tapped into through a variety of devices. Gordon and de Souza e Silva (2011: 2) have called this 'networked locality', or 'net locality':

> Net locality implies a ubiquity of networked information – a cultural approach to the web of information as intimately aligned with the perceptual realities of everyday life. We don't enter the web anymore; it is all around us.

On the one hand these theories foreground the connective affordance of mobile media networks, providing the ability to connect with others in remote locations. On the other hand, a variety of digital media interfaces also provide us access to

(real-time) information about the city or to stored representations of experiences. In fact, De Souza e Silva and Gordon argue, the mobile phone is a device that turns our urban experiences into data, allowing others to access these in real-time or at a later point in time, either as individual experiences or aggregated in data sets or streams that could reveal particular urban conditions – as for instance in live traffic information that partly consists out of the aggregation of data generated by the networks of mobile phone providers.

As Leighton Evans (2015) has pointed out, this availability of communication and information networks should not only be understood instrumentally – as in a way to solve a particular problem by accessing information databases, say: where can I find a nearby restaurant? These devices also change our experience of being in place in a phenomenological sense, revealing the world 'poetically' (Evans 2015), meaning that they can be used to make meaning of a particular space. A number of researchers have found for instance how the notion of 'presence' changes (Okabe and Ito 2006; Matsuda 2006), or how citizens use mobile devices to 'tune' their experience of place, by tuning in and out layers of information revealed by their devices (Coyne 2010). Evans himself has shown how devices, such as a smart phone, allow users to 'dwell' (find themselves at home) even in so called non-places (Auge 1995) through the connectivity of their devices (Evans 2015). Evans (2015: 6) makes use of Jameson's concept of 'social cartography' to explain how these technologies can be used 'as a means of understanding and regaining a capacity to act'. The apps, maps, social graphs and network updates on our mobile devices provide us with access to all kinds of urban data, enabling particular ways to act, and this changes our experience of urban space.

These studies can be seen in a broader framework of urban studies that has taken an interest in 'situatedness' that goes all the way back to (at least) the studies of Goffman in the 1950s (Goffman 1959). As Goffman demonstrated in his work, subjects take clues from their surroundings as to what cultural codes are present, and they might attune their behaviour accordingly. As theories on performativity have shown, in turn every instantiation of these clues into a particular behaviour, speech act, or more lasting act of (re)design, reinforces the cultural code as others might take it as another clue. At the same time, this system is never stable. Dominant codes may be challenged radically, or the performance of them might be modulated in more subtle ways, leading to gradual change. Similarly, other theories have given us insights in how people develop a sense of place, including feelings of belonging to a particular place (Geertz 2000; Gordon 2008).

What is new in our present-day experience of space is that these contexts and behaviours are no longer limited to the physical scene. Our situatedness is mediated through mobile media networks, giving us on the one hand clues that are absent in the physical location, and at the same time turning our performances into data that can be circulated within these networks, both within and outside the original situated contexts.

The theories referred to here provide us with an inroad to redefine the ontology of the urban experience as one that is partly constituted through this production, processing and representation of urban data. On the one hand, these theories allow

us to understand our situated experience of and performances in urban spaces as partly mediated through urban media systems and their data. On the other hand, they also allow us to un-black-box these media systems and the role of urban data in them to understand what power or interest may be operative in them, and how these might produce a particular urban spatiality.

Urban data and urban culture

So far, we have seen how the 'revolution' in urban data has led to new ways to gain insight into the city as a complex system, as well as to new understandings of the production of place and our experience of it. The first may provide us with important insights in the complex logic of urban systems. Likewise, theories that seek to unpack the production and experience of place are valuable in their own right and give us tools to understand our cities and evaluate and critique the way it is constantly being remade. A third approach that focuses on urban culture at large could complement these new understandings of the city. Here the issue at stake is the often normative question: what makes a city 'work' as a social-cultural system? What makes cities different from other kinds of complex systems such as galaxies or rainforests? In other words: what constitutes the 'cityness' in the city? And how is this 'cityness' affected now that production and experience of space has become hybridized and the computational production and analysis of urban data have started to play a role in them?

Discussion on what it is that makes a city a special form of social organization go back to the German and Chicago schools of sociology that flourished in the first quarter of the previous century, when for instance Robert Park wrote: 'The city is not in other words merely a physical mechanism and an artificial construction. It is involved in the vital process of the people who compose it. It is a product of nature, and particularly of human nature' (Park 1969: 91). As many have argued, what makes cities special is that they consist of constellations of strangers: people who do not know each other, not personally nor categorically, yet who have to find a way to live together (Simmel 1969; Jacobs 2000; Blokland 2003; Lofland 1973; 1998). That condition is both an opportunity (these strangers are potential customers for our services, they might teach us something we would like to learn, bring us excitement, love or consolation), as well as a challenge (can we trust these strangers? Will they not thwart our ambitions?).

Cultural critics have argued that the city is a cultural system that balances these two sides of the equation. As Lewis Mumford wrote:

> Now, the great function of the city is . . . to permit, indeed to encourage and incite the greatest possible number of meetings, encounters, challenges between all persons, classes and groups providing, as it were, a stage upon which the drama of social life may be enacted, with the actors taking their turns as spectators, and the spectators as actors.
>
> (Mumford, cited in Goldberger 2004)

Mumford describes the city both as a market place and as a theatre. In the city, supply and demand in various spheres of life are brought together spatially. Strangers come together physically so they can interact. At the same time, these interaction spaces function as theatres: we act out our lives for others to see. This is how we get familiar with the strangers around us and it provides us with opportunities to identify or distance ourselves from them (Jacobs 2000; Blokland 2003). At the same time, the 'sets' or the 'scenes' we find ourselves in, may give us clues as to how to behave there.

More contemporary, we find a similar argument in the work of Manuel Castells (2002: 382):

> Cities have always been communication systems, based on the interface between individual and communal identities and shared social representations. It is their ability to organize this interface materially in forms, in rhythms, in collective experience and communicable perception that makes cities producers of sociability, and integrators of otherwise destructive creativity.

Particular social practices, Castells argues, become spatially institutionalized ('a material organization') at particular places in the city, making the chaos of urban experience legible and manageable: by experience we learn what to expect where in the city. At the same time, these forms and rhythms produce collective experiences that in some way or another connect all those individuals that co-inhabitate the city into a community of strangers (Boomkens 1998). To put it in the words of Paul Goldberger (2001): 'The role of the city . . . is to be a common place, to be common ground, and as such, to support us and to stimulate us . . . the urban impulse is an impulse toward community – an impulse toward being together, and toward accepting the idea that however different we may be, something unites us.'

What unites these theories is that they see the urban public sphere as a crucial ingredient that makes cities 'work', that integrate the otherwise 'destructive creativity'. The organization of a broad variety of urban practices in the nineteenth and early twentieth centuries produced a type of space that brought strangers together and allowed them to interact, and at the same time experience a sense of community. To quote Goldberger (2001) once more:

> In a sense, [the city] is the original Internet, the original hyperlink – since cities are places in which random connections, rather than linear order, often determines what will happen. Cities aren't linear, even though they exist in real space. Random connections are what make them work, and surprise and a sense of infinite choice is what gives them their power.

What's interesting in these theories, is that they understand the city itself as an interface, as a mechanism that through its spatial organization connects its citizens to each other, producing amongst others trust and a sense of community, as

well as economic opportunities. Cityness then, lies in the spatial organization of density and diversity, and the somewhat chaotic interaction that results from it, as well as in the social goods that this may produce: solidarity, creativity, innovation, trust, community. What's important in this line of thinking is that it's best understood as a normative assumption: a city works best when it functions as an open and somewhat disorderly system with ample public spaces as catalysts for chance encounters (Sennett 2001; Jacobs 2000; Boomkens 1998; 2006), as it is in these public spaces that 'urban publics' emerge (de Waal 2014).

As we have seen in the previous paragraphs, the datafication of urban life and the emergence of the real-time city have led to digital interfaces that have started to represent what Castells referred to as the rhythms, collective experience and shared social representations. Even more so: these interfaces have started to function as the market places and theatre spaces through which citizens perform part of their lives and forge connections with others. If Castells's city can be understood as an offline interface that produces urban publics, our digital interfaces have taken over some of the functions of the city. Whether it is finding a date through Tinder, a ride through Uber, a power drill to borrow through Peerby, funders through Kickstarter, or a plumber through Taskrabbit, the network society has been turning into a platform society. To come back to Batty's insight: computers are now not just tools that automate and optimize existing urban functions such as traffic flows, they have partially taken over essential characteristics of the cityness we find in cities: their functioning as a 'market place' and a 'theatre'.

Research in cultural geography or urban sociology has just started to give us some first insights into what this may mean for the way our urban societies come into being. An interesting example is for instance Manuel Tironi's research into the experimental music scene in Santiago de Chile. Tironi describes how the practitioners in this subculture do not have a single hangout in the city, a site where their practices have materialized and is recognizable for both in- and outsiders as the locus of a particular scene. In the course of three years Tironi counted 45 different venues in which the scene performed and numerous rehearsal spaces scattered throughout the city. Yet, he did find the scene had a central meeting place: the online platform Myspace:

> MySpace has become the scene's place of publicness. In the absence of a geographical realm in which competing agents can map out the industry's innovations, MySpace has become the site where the members of the scene can watch each other, check their innovations and hear their new products – to defy, emulate or transubstantiate them. To be sure, MySpace is not just a promotional platform, a social network on which the scene can observe itself. MySpace, more radically, is a condition of possibility for the scene.
>
> (Tironi 2010: 46)

Members of the scene used the digital media platform to plan and communicate activities, to meet up with the likeminded as well as to perform by uploading audio samples. The website functioned as a market place and a theatre space, and

Tironi goes as far as to state that without this platform the scene could not have come into existence at all.

The point here is that whereas a digital platform has taken over some of the central functions of the 'cityness' we find in our cities, it does not substitute spatial activities. Members of the experimental music scene still meet up for live gigs and rehearsal sessions. But it does lead to a different, networked cultural geography and new ways of building trust and community organized through the datafications of musical activities and the algorithms of the platform.

As of yet, we are unsure as to what kind of urban culture this may produce. Various scenarios abound. On the one hand, this could lead to 'software sorted cities', where public spaces no longer function as Goldberger 'original hyperlinks', forging random connections between citizens. Rather, the platforms will connect us mainly with the likeminded and guide us to those places in the city where we will encounter them (Shepard and Greenfield 2007; Graham 2005; Pariser 2011). On the other hand, this could lead to a situation in which, as William Mitchell predicted in the end of the 1990s, function starts to follow code (Mitchell 2005). Once a connection is made through a digital platform, a physical meeting could take place anywhere in the city, rather than in a specialized location per se. And particular locations could be usurped by a variety of urban publics at the same time. As such, this might increase the density and heterogeneity of our cities even further (de Waal 2014).

Conclusion

It is beyond the scope of this chapter to provide a full overview of the possible implications of the datafication of urban life in the constitution of urban culture. In fact, much more research is needed in this domain, and the new ways of understanding the city brought out in the first two sections can help to get a better understanding of these processes. The point here is to demonstrate that the 'data revolution' in urban life should be approached from multiple perspectives. The emergence of computing systems in our everyday life does not just produce a new way of understanding our cities, and new ways in which space is produced and experienced. It may also bring about a shift in the 'cityness' of our cities, in the functioning of our urban culture. In that respect, cities are different from galaxies or rainforests. As Rob Kitchin has pointed out, many of the epistemological approaches 'wilfully ignore the metaphysical aspects of human life (concerned with meanings, beliefs, experiences) and normative questions (ethical and moral dilemmas about how things should be as opposed to how they are)' (Kitchin 2014b: 136).

Cities and almost everything they behold from masterplans to algorithms are different from galaxies in that they are human constructs, that partially operate according to rules and laws created as outcomes of political (rather than natural) processes. As such, these rules are not given, but can be adapted to the normative preferences of those in power. Likewise, the urban data and algorithms that operate upon them are not neutral products that in a natural way produce a particular instance of urban culture, but they can be attuned to a particular normative idea

of cityness. In the end, insights in the workings of the city as a complex system should be combined with such normative discussions: what kind of city do we want to live in, and what do we make of these changes brought about by the various assemblages that employ software and urban data to manage urban life in new ways? A new science of cities should therefore contribute to our understanding of cities in addressing these kinds of questions as well.

References

Allwinkle, S. and Cruickshank, P. (2011) 'Creating smart-er cities: an overview', *Journal of Urban Technology* 18(2): 1–16.

Anderson, C. (2008) 'The end of theory: The data deluge makes the scientific method obsolete', *Wired* magazine online, 23 June, available at: www.wired.com/2008/06/pb-theory/.

Auge, M. (1995) *Non-places: Introduction to an Anthropology of Supermodernity*. London: Verso.

Batty, M. (2013a) *Urban Informatics and Big Data. A Report to the ESRC Expert Group.* London: CASA, UCL, available from: www.spatialcomplexity.info/files/2015/07/Urban-Informatics-and-Big-Data.pdf [accessed 24 November 2016].

Batty, M. (2013b) *The New Science of Cities*. Cambridge, MA: MIT Press.

Blokland, T. (2003) *Urban Bonds: Social Relationships in an Inner City Neighbourhood*. Cambridge, UK: Polity.

Boomkens, R. (1998) *Een drempelwereld: moderne ervaring en stedelijke openbaarheid*. Rotterdam: NAi Uitgevers.

Boomkens, R. (2006) *De nieuwe wanorde. Globalisering en het einde van de maakbare samenleving*. Amsterdam: Van Gennep.

Burrows, R. and Gane, N. (2006) 'Geodemographics, software and class', *Sociology* 40(5): 793–812.

Caragliu, A., del Bo, C. and Nijkamp, P. (2011) 'Smart cities in Europe', *Journal of Urban Technology* 18(2): 65–82.

Castells, M. (2002) 'The culture of cities in the information age', in I. Susser and M. Castells (eds), *The Castells Reader on Cities and Social Theory*. Malden, MA: Blackwell, pp. 367–389.

Coenen, T., van der Graaf, S. and Walravens, N. (2014) 'Firing up the city: a smart city living lab methodology', *Interdisciplinary Studies Journal (Special Issue on Smart Cities)* 3(4): 118–128.

Concilio, G., Puerari, E. and Rizzo, F. (2013) *Living Labs Models for co-designing in Urban and Public Space*. Report from My Neighborhood | My City Research Project.

Coyne, R. (2010) *The Tuning of Place, Sociable Spaces and Pervasive Digital Media*. Cambridge, MA: MIT Press.

de Souza e Silva, A. (2006) 'Mobile technologies as interfaces of hybrid spaces', *Space and Culture* 9(3): 261–278.

Evans, L. (2015) *Locative Social Media: Place in the Digital Age*. New York: Palgrave Macmillan.

Farias, I. and Bender, T. (2010) *Urban Assemblages: How Actor-Network Theory Changes Urban Studies*. New York: Routledge.

Friedrich, P., Karlsson, A. and Federley, M. (n.d.) *Report 2.1 Boundary conditions for successful Urban Living Labs*. Report from SubUrbanLab research project.

Geertz, C. (2000) *Local Knowledge: Further Essays in Interpretive Anthropology*. New York: Basic Books.

Goffman, E. (1959) *The Presentation of Self in Everyday Life*. New York: The Overlook Press.

Goldberger, P. (2001) 'Cities place and cyberspace', lecture at University of California, Berkeley, available from: www.paulgoldberger.com/lectures/cities-place-and-cyberspace/ [accessed 24 November 2016].

Goldberger, P. (2004) 'New School University Convocation', available from: www.paulgoldberger.com/lectures/new-school-university-convocation/ [accessed 24 November 2016].

Gordon, E. (2008) 'Towards a theory of networked locality', *First Monday* 13(10).

Gordon, E. and de Souza e Silva, A. (2011) *Net Locality: Why Location Matters in a Networked World*. Malden, MA: Wiley-Blackwell.

Graham, S. (2005) 'Software-sorted geographies', *Progress in Human Geography* 29(5): 562–580.

Greenfield, A. (2013) *Against the Smart City*. New York: Do projects.

Harrison, C. and Donnelly, I.A. (2011) 'A theory of smart cities', in *Proceedings of the 55th Annual Meeting of the ISSS – 2011, Hull, UK*, available from: http://journals.isss.org/index.php/proceedings55th/article/view/1703 [accessed 24 November 2016].

Hemment, D. and Townsend, A. (2013) *Smart Citizens*. Manchester: FutureEverything Publications.

Hollands, R.G. (2008) 'Will the real smart city please stand up? Intelligent, progressive or entrepreneurial?', *City* 12(3): 303–320.

Jacobs, J. (2000) *The Death and Life of Great American Cities*. London: Pimlico.

Kitchin, R. (2014a) 'Big data, new epistemologies and paradigm shifts', *Big Data & Society* 1(1): 1–12.

Kitchin, R. (2014b) *The Data Revolution: Big Data, Open Data, Data Infrastructures and Their Consequences*. London: SAGE.

Kitchin, R. (2014c) 'The real-time city? Big data and smart urbanism', *GeoJournal* 79(1): 1–14.

Kitchin, R. and Dodge, M. (2005) 'Code and the transduction of space', *Annals of the Association of American Geographers* 95(1): 162–180.

Kloeckl, K., Senn, O. and Ratti, C. (2012) 'Enabling the real-time city: LIVE Singapore!', *Journal of Urban Technology* 19(2): 89–112.

Kourtit, K., Nijkamp, P. and Arribas, D. (2012) 'Smart cities in perspective – a comparative European study by means of self-organizing maps', *Innovation: The European Journal of Social Science Research* 25(2): 229–246.

Kryssanov, V., Okabe, M., Kakusho, K. and Minoh, M. (2002) 'Communication of social agents and the digital city – a semiotic perspective', in K. Tanabe, P. van den Besselaar and T. Ishida (eds), *Digital Cities II: Computational and Sociological Approaches*. Berlin: Springer, pp. 56–70.

Lee Jr, D.B. (1973) 'Requiem for large-scale models', *Journal of the American Institute of Planners* 39(3): 163–178.

Lofland, L. (1973) *A World of Strangers: Order and Action in Urban Public Space*. New York: Basic Books.

Lofland, L.H. (1998) *The Public Realm : Exploring the City's Quintessential Social Territory*. Hawthorne, NY: Aldine de Gruyter.

Matsuda, M. (2006) 'Mobile communication and selective sociality', in M. Ito, D. Okabe and M. Matsuda (eds), *Personal, Portable, Pedestrian: Mobile Phones in Japanese Life*. Cambridge, MA: MIT Press, pp. 123–142.

Mitchell, W. (2005) *E-topia: 'Urban life, Jim – But Not as We Know It'*. Cambridge, MA and London: MIT Press.

Nabian, N. and Ratti, C. (2012) 'Top-down/bottom-up urbanism', in D. Offenhuber and K. Schechtner (eds), *Inscribing a Square. Urban Data as Public Space*. Vienna: Springer, pp. 76–79.

Okabe, D. and Ito, M. (2006) 'Technosocial situations: emergent structuring of mobile e-mail use', in M. Ito, D. Okabe and M. Matsuda (eds), *Personal, Portable, Pedestrian: Mobile Phones in Japanese Life.* Cambridge, MA: MIT Press, pp. 257–276.

Pallot, M., Trousse, B., Senach, B. and Scapin, D. (2010) 'Living Lab research landscape: From user centred design and user experience towards user cocreation', in *First European Summer School 'Living Labs'*, Paris.

Pariser, E. (2011) *The Filter Bubble: What the Internet is Hiding from You*. New York: Penguin.

Park, R. (1969) 'The city: Suggestions for investigation of human behavior in the urban environment', in R. Sennett (ed.), *Classic Essays on the Culture of Cities*. New York: Appleton-Century-Crofts, pp. 91–130.

Ratti, C. and Townsend, A. (2011) 'The social nexus', *Scientific American* 305(3): 42–48.

Saunders, T. and Baeck, P. (2015) *Rethinking Smart Cities from the Ground Up*. Nesta, public report, London.

Sennett, R. (1969) *Classic Essays on the Culture of Cities*. New York: Appleton-Century-Crofts.

Sennett, R. (2001) 'A flexible city of strangers', *Monde Diplomatique*, February.

Shepard, M. and Greenfield, A. (2007) *Situated Technologies Pamphlet 1: Urban Computing and its Discontents*. New York: The Architectural League of New York.

Simmel, G. (1969) 'The metropolis and mental life', in R. Sennett (ed.), *Classic Essays on the Culture of Cities*. New York: Appleton-Century-Crofts, pp. 47–60.

Tironi, M. (2010) 'Gelleable spaces, eventful geographies. The case of Santiago's experimental music scene', in I. Farias and T. Bender (eds), *Urban Assemblages. How Actor-Network Theory Changes Urban Studies*. New York: Routledge, pp. 27–52.

Townsend, A. (2008) 'Foreword', in M. Foth (ed.), *Handbook of Research on Urban Informatics: The Practice and Promise of the Real-Time City*. Hershey, PA: Information Science Reference, pp. xxiii–xxvii.

Townsend, A. (2015a) 'Cities of data: Examining the new urban science', *Public Culture* 27(2): 201–212.

Townsend, A. (2015b) *Making Sense of the New Urban Science.* Rudin Center and Data & Society Research Institute, New York, available from: www.citiesofdata.org/wp-content/uploads/2015/04/Making-Sense-of-the-New-Science-of-Cities-FINAL-2015.7.7.pdf [accessed 24 November 2016].

Waal, M. de (2014) *The City as Interface*. Rotterdam: Nai010 Publishers.