ROUTLEDGE INTERNATIONAL HANDBOOKS

The Routledge Companion to Smart Cities

Edited by Katharine S. Willis and Alessandro Aurigi

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The Routledge Companion to Smart Cities explores the question of what it means for a city to be 'smart', raises some of the tensions emerging in smart city developments and considers the implications for future ways of inhabiting and understanding the urban condition. The volume draws together a critical and cross-disciplinary overview of the emerging topic of smart cities and explores it from a range of theoretical and empirical viewpoints.

This timely book brings together key thinkers and projects from a wide range of fields and perspectives into one volume to provide a valuable resource that would enable the reader to take their own critical position within the topic. To situate the topic of the smart city for the reader and establish key concepts, the volume sets out the various interpretations and aspects of what constitutes and defines smart cities. It investigates and considers the range of factors that shape the characteristics of smart cities and draws together different disciplinary perspectives. The consideration of what shapes the smart city is explored through discussing three broad 'parts' – issues of governance, the nature of urban development and how visions are realised – and includes chapters that draw on empirical studies to frame the discussion with an understanding not just of the nature of the smart city but also how it is studied, understood and reflected upon.

The *Companion* will appeal to academics and advanced undergraduates and postgraduates from across many disciplines, including Urban Studies, Geography, Urban Planning, Sociology and Architecture, by providing state of the art reviews of key themes by leading scholars in the field, arranged under clearly themed sections.

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1
Introduction

Katharine S. Willis and Alessandro Aurigi

Introduction

Cities have always been infused by technologies; in fact the urban condition is inherently underpinned by technological processes, interactions and practices. But the relationship of the digital and technical in society and the city is both changeful and evolving (Graham, 2004). The 'smart city' is defined by the emergence of new ways in which material urban systems are interconnected through information and data, changes in the processes through which cities are monitored, managed and analysed and a shift in how citizens participate, interact with the city and inhabit its spaces. This raises questions as to the future governance of cities and the role of interconnected data, people, places and urban systems which makes the challenge of understanding, designing and reflecting on smart cities an important new field to be investigated. To address this challenge, the volume aims to answer the question of what it means for a city to be 'smart', raise some of the tensions emerging in smart city developments and consider the implications for future ways of inhabiting and understanding the urban condition.

The key feature of this volume is that it draws on perspectives from the field of urban studies, architecture, urban design and urban planning. This recognises that the smart city agenda can be seen as part of a legacy of urban studies, urban design and planning thinking as well as being informed by critical thinking from the social sciences and more development-oriented enquiry from fields like computing science and interaction design. It sits within a growing body of edited books that address the smart city from a range of critical perspectives and draw together multidisciplinary empirical research on the topic (Cardullo *et al.*, 2019; Deakin and Wear, 2012; Karvonen *et al.*, 2019; Kitchin *et al.*, 2019; Marvin *et al.*, 2016). To situate the topic of the smart city for the reader, the volume sets out the various interpretations and aspects of what constitutes and defines smart cities in order to frame the topic and establish key concepts. It investigates and considers the range of factors that shape the characteristics of smart cities and draw together different disciplinary perspectives. The consideration of what shapes the smart city will be explored through discussing three broad 'parts': issues of governance, the nature of urban development and how visions are realised, and includes chapters that draw on empirical studies to frame the discussion with an understanding not just of the nature of the smart city but how it is studied, understood and reflected upon.

Overall the book situates the topic as capturing the landscape of the discussion by drawing together a range of disciplinary approaches and discussions and aims to provide a resource to enable readers to take their own critical position within the field of smart cities discourse.

The smart city in context

It is important to recognise that, whilst widely used, the term 'smart cities' is inherently ambiguous and used to describe and characterise a wide range of urban technological systems, strategies and also agendas. The label 'smart city' was first used in the early stages of the noughties, but it was not until around 2006 that it started to be widely accepted (Kitchin *et al.*, 2019; Willis and Aurigi, 2017, p. 2), and is often institutionally led as part of city or industry development or investment strategies. The term smart city is used across commercial, city and academic fields to characterise cities where technology is both embedded within the city in the form of sensors and other monitoring infrastructure and also the devices and platforms that enable people and often commercial or city governments to 'manage' this data in a large scale and 'real-time' way (Cocchia, 2014; Willis and Aurigi, 2017). According to Marvin, Luque-Ayala and McFarlane, the smart city opens up 'a new language of "smartness"' that is reshaping debates around contemporary cities (Marvin *et al.*, 2016, p. 2). In a smart city, computing power moves beyond wired or wireless infrastructure such as the broadband networks of the ubiquitous city, and pervades everyday objects and systems of the city, from parking sensors, to pollution monitoring to pedestrian footfall. William Mitchell, one of the authors to provide the first accessible introduction to the links between the city and technology as they emerged in the nineties (Mitchell, 1995, 2000, 2004), also provides an early overview of some core concepts and technologies that make up a smart city which sees cities 'fast transforming into artificial ecosystems of interconnected, interdependent intelligent digital organisms', which he argues is a 'fundamentally new technological condition confronting architects and product designers in the twenty-first century' (Mitchell, 2006). Mitchell captures some of the basic underlying features of what is termed smart city: a systemisation of city services and infrastructures together with an embedding of technological sensing and monitoring software and hardware into the fabric of the city. Although cities have always inherently been reflexive in nature, they are shaped by the people that inhabit them and their practices, cultures and infrastructures (Sassen 2013). The degree to which smart cities include a level of technological systemisation can be seen to shift the balance of this reflexivity (Crang and Graham, 2007; Shepard, 2011). This is where the challenge of understanding, designing and reflecting on smart cities becomes an important new field to be investigated. The terminology of smart city is still evolving, and it is expected that the term itself will soon be superseded by the new label with new agendas, interests and technological references and dependencies.

Introduction to the structure of the book

The volume is divided into three parts: governance, development and visions, each of which each is also divided into two sub-sections. The aim of the three parts of the book is to frame different perspectives to read and interpret smart urbanism. These underpin different approaches to the smart city agenda in a series of contexts and projects. Each part contributes a critical introduction to a core approaches, drawing on a key text which is introduced with a contextual commentary. The volume also draws on a broad range of different methodological approaches that are used and applied to design, study and analyse smart cities. This ranges from methods from data driven tools from the field of urban science and urban informatics to the more socially

constructed, participatory approaches from the social sciences. These chapters include clearly described examples or case studies that demonstrate how the method is used in a specific context and to investigate the nature of inclusivity, diversity and participation.

Part I Smart city governance

Urban governance, data and participatory infrastructure

In the last decade the issue of governance in cities has become more complex as the nature of data flows have themselves become more integrated and city infrastructures, processes and social practices. The fundamental problem with the technocratic approach in the emergence of smart cities is that they tend to operate on a techno-deterministic logic that prioritises market-led solutions for urban development based on a promise of optimisation and efficiency of resources. Authors such as Aurigi and De Cindio (2008), Kitchin (2015; Kitchin and Perng, 2016), Marvin *et al.* (2016), Rose (2015) and Sassen (2012) have critiqued this approach since it not only reinforces a universalising view of urban development, but also masks the social tensions, issues and roles of its citizens in its construction and the role of the city itself. Haklay highlights how the failure of digital technologies to solve urban challenges is 'linked to the strategy where technology is used to disenfranchise, fails to enable local knowledge, and black boxes devices and technical infrastructure' (Haklay, 2013). The increasing role of software, data and artificial intelligence (AI) in city services and processes has implications for the governance of cities because software is embedded in often subtle and invisible ways and it produces data-driven outcomes that are not analogous with the material, physical and social life of the city. There is also the underlying issue of not only ownership of the software that 'manages' the city, but also consequently management and control (Luque-Ayala and Marvin, 2015; Vanolo, 2013). The high complexity of such data-driven systems means that they rarely, if ever, are developed and managed through city governance mechanisms, but controlled by private sector IT companies such as IBM, Cisco and Siemens who have vested interests well beyond those of the city itself. This leads to new forms of governmentality that rely on generating and monitoring systematic information about individuals which makes the systems and apparatus of governance more panoptical in nature (Kitchin, 2011, p. 949).

Key to this is understanding the role of data within new modes of participatory governance and what Kitchin has highlighted as the multitude ethical issues in smart cities governance. Databases and data analytics are not neutral, technical means of assembling and making sense of data but instead are socio-technical in nature, shaped by philosophical ideas and technical means (2016). In fact, the proper consideration of ethical considerations within smart city projects may prove to be one of the defining points in the development of projects on the ground, as this points to significantly more participatory and open modes of governance than are currently being implemented.

Chapters in this section are as follows:

- A city is not a computer
- Bias in urban research: from tools to environments
- Urban science: a short primer
- Defining smart cities: high and low frequency cities, big data and urban theory
- Digital information and the right to the city
- Shaping participatory public data infrastructure in the smart city: open data standards and the turn to transparency.

Governing, inclusion and smart citizens

Smart cities implement new socio-technical processes that require critical reflection around what constitutes urban management and control. They lead to new thinking about how technology affects cities where one of the key factors is that the digital is not simply about technology, computers or networks or code but about how people use, interact and behave with technology. It is through inhabitation and a context in their lives that the digital becomes meaningful. This is not simply because technology can establish different patterns of social relations and ways of living but because they can act as a potential reorganisation of social relations. This also includes patterns of inclusion and exclusion that emerge through these social relations constructed through technologies, and in particular a discussion on how those that lack digital skills and access to equipment may become excluded as cities become increasingly digital (Cardullo *et al.*, 2019). In this context, there is an increasing body of critical analysis that looks beyond celebrative and top-down approaches to include more diverse thinking about inclusion and 'citizenship' within smart city initiatives (Datta, 2018; Gabrys, 2014; Rabari and Storper, 2015; Vanolo, 2013). These document how smart city agendas rarely address issues of social differences in already-existing cities and March and Ribera-Fumaz (2014, p. 826) highlight the corresponding need to respond to the question of 'whose smartness and whose cities?' This particularly includes cases of smart city projects in the Global South, and the various ways in which new urban technologies are used, negotiated and even subverted by citizens. In this context, a number of authors have drawn on empirical evidence for how smart city projects arguably lead to the exacerbation of existing urban historical, material and social inequalities (Odendaal, 2011; Sadoway and Shekhar, 2014; Vanolo, 2016; Wiig, 2016).

These premium and highly connected networked infrastructures often ignore less-favoured and intervening places, enabling connectivity to operate 'selectively, linking valuable segments and discarding used up, or irrelevant, locales and people' (Castells, 1998, p. 390). Recent work has revealed that many so-called smart technologies do not empower citizens to become active players in their cities (de Lange and de Waal, 2019). This can particularly be seen in the promotion and development of private tech-led smart city initiatives, which are typically underpinned by a focus on highly connected, highly urbanised global cities with a highly skilled workforce (Hollands, 2014). But as Hollands points out, this has the potential to lead to social polarisation and 'the smart/creative city can become not only more economically polarized, but also socially, culturally and spatially divided by the growing contrast between incoming knowledge and creative workers, and the unskilled and IT illiterate sections of the local poorer population' (Hollands, 2008, p. 312). Therefore, the politics and power networks that underlie smart cities are important to address in order to establish how certain groups may benefit and others, often marginalised groups, may be excluded from any benefits of smart city initiatives. Vanolo highlights how this leads to patterns of exclusion since there is 'little room for the technologically illiterate, the poor and, in general, those who are marginalised from the smart city discourse' (2013, p. 893). Although this work is growing, Cardullo and Kitchin highlight that there is still work to do since 'despite the re-orientation towards creating "smart citizens" to date there has been little critical conceptual scrutiny as to how citizens are imagined and engaged by different smart city technologies' (2018, p. 5). Addressing the realities of how to enable smart citizenship in projects that offer more than just tokenistic participation is one of the key challenges for smart city projects, and there are significant implications for this in terms of who participates and how marginalised groups can be given a right to the smart city (Willis, 2019).

Chapters in this section are as follows:

- Towards an agenda of place, local agency-based and inclusive smart urbanism
- Governmentality and urban control
- How smart is smart city Lagos?
- Smart citizens in Amsterdam: an alternative to the smart city
- Governing technology-based urbanism: technocratic governance or progressive planning?

Part II Smart city development

Creative, smart or sustainable?

The smart city agenda is often marketed as a form of urban innovation project, which develops a range of information and communication technology (ICT) infrastructures to support learning and creativity at an urban scale, and draws heavily on an innovation and knowledge approach linked with ICTs (Hollands, 2014). Key to this is a broader, post-industrial shift from economies that rely on manufacturing of goods to those that operate through capitalising knowledge and information led by innovation (Komninos, 2008). Due to its focus on innovation systems, the smart city agenda gives implicit priority to competitiveness and economic growth. In other words, it is how ICTs, in conjunction with human and social capital and wider economic policy, are used to leverage growth and manage urban development that makes a city smart (Caragliu *et al.*, 2011). Often running in parallel to the smart city agenda, the 'knowledge economy' underpins the development of smart city programmes, although associated economic models of what are termed the 'creative economy' and the 'learning economy' are also commonly used. The use of terms such as clever, smart, skilful, creative, networked, connected and competitive are seen as integral to the characterisation of knowledge-based urban development. This can particularly be seen in the promotion and development of smart city initiatives, which are typically underpinned by a focus on highly connected, highly urbanised global cities with a highly skilled workforce. Therefore the politics and power networks that underlie smart cities are important to address in order to establish how certain groups may benefit and others enhance innovation, learning, knowledge and problem solving (Hollands, 2008, p. 305).

In parallel to the link made between ICT investment and economic growth, the smart city is also part of an agenda that sees technological innovation as key to addressing the global challenge of sustainability (Joss *et al.*, 2019). This links to the economic or resource concept of optimisation, where one of the central concepts is that in a world where resources are scarce, seeking solutions that enable a city to be more efficient in its use of resources can lead to sustainable urban development. More developed economies are seen as growing as a result of the more intelligent use of resources to produce greater value, rather than through the addition of new resources (Berkhout and Hertin, 2001). Smart city development plans are seen as key to underpinning alternative economic models where economic value is created primarily through the manipulation of ideas (the knowledge economy), rather than the exploitation of energy and materials. ICTs can contribute to a long-standing structural change in the economy away from materials-intensive activity and towards more service-based and information-intensive activities (Caragliu *et al.*, 2011).

Chapters in this section are as follows:

- Will the real smart city please stand up?
- Smart to green: smart eco-cities in the green economy

- Towards ethical legibility: an inclusive view of waste technologies
- Stand up please, the real sustainable smart city.

Citizen science and co-production

There is a need to ensure that human and environmental values are taken into account in the design and implementation of governance processes and platforms that will influence the way cities operate and are governed (Haklay, 2013). One of the key ways that this can be achieved is through enabling people to participate actively in the way that smart cities are developed. For example, Cardullo and Kitchin identify that 'the normative challenge to creating truly "citizen-centric" smart cities will be to re-imagine the role citizens are to play in their conception, development and governance' (2018, p. 20). Arnstein's 'ladder of participation' has been adopted by a number of authors as a model to critically understand the actual role of citizenship in smart city projects (Cardullo and Kitchin, 2018; Shelton *et al.*, 2015). This has identified that, in the same way as there are different levels of participation, from manipulation and therapy (which are non-participation) to informing and placating (tokenistic), all the way to partnership and citizen control, there are multiple degrees of public engagement in smart cities. For example Haklay distinguishes between four levels of citizen science, from citizens as sensors at the lowest level, to participatory science and extreme collaborative science (2012). The challenge is often to distinguish between the claims of projects around participation and the 'actually existing' reality of smart citizenship in practice (Shelton *et al.*, 2015).

The discussions around citizenship and participation are fundamentally important for forms of engagement and involvement that can be invented and controlled by the people (Mclaren and Agyeman, 2015). This takes a model of participation, or sharing data that is termed 'co-production' whereby 'citizens perform the role of partner rather than customer in the delivery of public services' (Linders, 2012, p. 446). This sees new forms of sharing, enabled by technological devices and platforms (Willis and Aurigi, 2017), that work by enabling citizens to create, adapt and exploit data (Cowley, 2010) and can create new ways in which citizens participate in the governance of the city. A sharing cities approach focuses on bringing local people together through shared activities and cooperation for the benefit of the city and includes initiatives such as carsharing, community currencies, cohousing, hackerspaces, timebanks and tool or kitchen libraries. For example, civic apps developed by citizens, civic organisations and commercial companies (Desouza and Bhagwatwar, 2012) have become widespread and typically create some form of two-way interaction where citizens contribute to commenting on or providing data on public services usually offered by the city such as crime prevention, rubbish collection, public transportation and pollution reduction.

These experiments also initiate new ways of collaboration between citizens and researchers, and between entrepreneurs and city officials and can be seen in cities such Amsterdam, Eindhoven, Aarhus, London, Santander or Barcelona (Brynskov *et al.*, 2018). One of the ways that this model of participation is played out in smart cities is the role of what are termed 'living labs' or urban 'test beds', where the city itself are treated as living laboratories; that is, as sources of data and as test beds to validate the science and test the practical interventions produced (Evans *et al.*, 2016; Laurent and Pontille, 2019). Halpern and colleagues have critiqued the model of the test bed model since 'the logic of the test bed, past data are always used to produce the future' (2013, p. 164) and argue that we need to 'begin to design with less authority and greater interest in the space of society and culture that is produced in the interstices between what is human, machine, and more than human' (Halpern *et al.*, 2013, p. 164). There is still much to be done to understand how co-production, citizen science and other people-centred models of

participation in urban test beds and living lab-type platforms can produce a better model of engagement in smart cities that moves up and across Arnstein's ladder of participation.

Chapters in this section are as follows:

- Sharing in smart cities: what are we missing out on?
- Taxonomy of environmental sensing in smart cities
- Co-creating sociable smart city futures.

Part III Smart city visions

Urban planning, city models and smart storytelling

Smart labelling and rebranding of creative and eco city projects follow the genealogy of technology and urban planning that deals in utopian visions, where historicity is abolished and the vision of a technologically enabled bright future is all pervasive (Anthopoulos, 2017). This is part of a much longer history of urban visioning around future cities that adopt utopian ideals to provide a rationale for technical intervention (Carey, 1999). In fact, much of the smart city rhetoric is characterised by a focus on nominal futures. This is exemplified in the bright future promised by IBM's smarter cities model which does not suggest a revolution in urban morphology but a 'reformist optimization through data, monitoring, interconnectedness and automatic steering mechanisms' (Söderström *et al.*, 2014, p. 317). As Söderström and colleagues reveal, the technique of imagining futures appropriates forms of storytelling to contextualise and to lend a reality to a speculative technology (2014). The smart city rhetoric that markets technology as a revolutionary approach to solving complex urban social and spatial problems is increasingly being shown to be disingenuous. This is evidenced by the failures of many over-hyped smart city projects that have yet to be realised at the scale planned, and that the reality of what has been built is homogeneous and bland urban space (Cugurullo, 2013; Joss *et al.*, 2019). One of the ways to speculate on possible futures is to build models or scenarios that enable the future city to be visualised or 'made real' (Rose, 2018). Increasingly virtual models are being developed that enable the smart city to be experienced as a 'mirror world' (Gelerntner, 1991) that scale up to mirror cities.

The counter approach to techno-deterministic utopian visions is to enable a more relational set of practices for collaborative citymaking as well as affordances of systems for innovation, adaptation and social change. This opens up new ways of thinking and designing for how citizens participate and act in the public spaces of the city. It also introduces different models of placemaking and how people can interact and seek to bring resources back into the public domain, through a citizen-based ownership of the city (de Lange and de Waal, 2013).

Chapters in this section are as follows:

- Smart cities as corporate storytelling
- Will the real smart city please make itself visible?
- From hybrid spaces to 'imagination cities': a speculative approach to virtual reality
- The museum in the smart city: the role of cultural institutions in co-creating urban imaginaries.

Cities and placemaking

At the scale of the built environment, the smart city promises a new model of integrated urban design. This is set in the context of profound shifts in the balance between production and

consumption to mutuality: from professional amateur to wisdom of the crowd, from do-it-yourself culture to the hacker ethic (Botsman and Rogers, 2010). Central to this is the question how collaborative principles and participatory ethics from online culture can be ported to the urban realm in order to coordinate collective action and help solve some of the urgent complex issues that cities are facing.

It also introduces different models of placemaking (Aurigi, 2012) and how people can interact and shape the city, that 'start with the neighbourhood and not with the technology' (McFarlane and Söderström, 2017, p. 321). The smart infrastructures and citizen sensing networks enable new modes of communication and feedback both in terms of people-to-people but also people-to-city (Gabrys, 2014). Similarly, when participatory aspects of social networks are coupled with highly mobile urban citizens then this creates opportunities for new types of social organisation and collaborative decisionmaking (Cowley, 2010; Linders, 2012). Crowdsourcing urban services is also a new model of citizen interaction that can operate at a city scale. Exploiting the model of swarming, the new tools of the 'sharing economy' (Mclaren and Agyeman, 2015) include shared ownership platforms (Shaheen, 2011), makerspaces and fablabs (Niaros *et al.*, 2017), crowdfunding (Carè *et al.*, 2018) and platform coops (Scholz, 2016). These platforms work on models of sharing as a new paradigm of distribution and ownership of resources, and include people sharing transportation modes, public space, information and new services. The common thread in these concepts is that technologies need to serve and work for people and communities first in terms of their design and deployment, but also in relation to setting local civic and infrastructural priorities. This addresses a gap in the approaches to smart cities that has failed to value the importance of urban community insights, as well as a recognition of civic and third sector organisations, social enterprises, cooperatives and places such as libraries and community centres. These need to 'draw lessons from urban planning traditions that emphasize deep and meaningful civic engagement or community control in questions about local urban planning and design' (Sadoway and Shekhar, 2014). So, we will need to engage 'smart' in novel ways, driven not by the adoption of whatever technology is trending to produce global solutions, but by leveraging of local resources, people and wisdom (Willis and Aurigi, 2017) in placemaking and urban design practices in real cities and with real people.

Chapters in this section are as follows:

- The hackable city: a model for collaborative citymaking
- Designing the city as a place or a product? How space is marginalised in the smart city
- Self-monitoring, analysis and reporting technologies: smart cities and real-time data
- Reimagining urban infrastructure through design and experimentation: autonomous boat technology in the canals of Amsterdam
- The death and life of smart cities.

Summary

Smart city rhetoric can be polarising: on the one hand it presents a technocratic paradigm of homogenous and globalised smart driven urban development, whilst on the other it focuses on the positive societal impacts of connected and shared smart networks in the context of the urban condition. Yet, even where the social impacts of smart cities are considered, discourses are usually based on a fairly superficial and 'tokenistic' community participation where the social benefits tend to privilege digitally literate, highly educated (i.e. 'intelligent'), highly skilled young people (Leontidou, 2015, p. 84) rather than on effective participation (Cardullo and Kitchin, 2018; Willis, 2019). To counter this, academics have tried to highlight and prioritise the role of

citizen participation in the governance and making of the smart city, and the importance of recognising the ethical implications in order to solve real problems and to localised projects that work with specific places and communities. Central to this is recognising that many of the urban problems currently being defined in corporate-led smart city projects are often disingenuous and derive from a flawed techno-deterministic model of optimisation of resources which are deemed to require a 'spatial fix' (Martin *et al.*, 2019). Alternatives draw on new peer-to-peer economic models and participatory urban planning techniques, approaches such as 'hackable', sharing and open source cities are recognised as having the potential to enable people to become active in shaping their urban environment to collaboratively address shared urban issues (de Lange and de Waal, 2013) and also importantly recognising the value of the range of Global South and non-Western approaches to technological development.

The essays in this volume bring together a diverse range of perspectives from fields such as geography, computer science, urban studies, urban planning, design and sociology to address not just critical readings but also different methodological approaches to address three broad areas of smart city governance, development and visions. One of the features of the volume is that it draws on voices from outside academia and from academics who have had sustained or collaborative projects with private or third sector partners. That bring insights into how, in practice, questions of citizenship, co-production and governance are answered in the actually existing smart city. Whilst smart cities hold a focus on certain types of digital technologies and infrastructures, they also more importantly require a bridging of disciplinary perspectives and empirical fields that will become increasingly important as smartness and societal challenges such as the climate emergency become increasingly entwined. This leads to asking more inclusive, diverse and sustainable questions of the smart city.

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Part I
Smart city governance

Section 1

Urban governance, data and participatory infrastructure

2

A city is not a computer

Shannon Mattern

Editor's introduction

"We want to build a city" is the strapline on a Y Combinator Research project web page titled "New Cities". Meanwhile Sidewalk Labs, an Alphabet company, sets out its challenge to respond to the following question – "What would a city look like if you started from scratch in the internet era—if you built a city 'from the internet up?'".[1] These tech visions set out the city as the ultimate Silicon Valley "start up". In this chapter, Mattern builds a case for challenging the rhetoric of this sort of computational thinking on cities.[2] Drawing on the marketing strategies of tech funders such as Y Combinator and Alphabet that position a city as the next challenge for the technological optimization model, she highlights the flaws in taking this approach to city-making. The broader argument draws on multiple readings which have revealed the problems with seeking to address complex socio-economic urban challenges with programmable solutions (Gabrys, 2014; Greenfield, 2013; Kitchin, 2014; Marvin et al., 2016; Vanolo, 2016). This ranges from the infrastructural, where a city embedded with networked sensors is reduced to a complex dataset down to the scale of the everyday where city inhabitants and their interactions are considered as users of technology with little or no agency. Mattern argues in this chapter that this focus on treating cities as complex problems to be solved by code means that we have lost a "critical perspective on how urban data become meaningful spatial information or translate into place-based knowledge".

Central to Mattern's discussion is the need to recognize the shortcomings in computational and data-driven models that presume an objectivity in urban data and fail to recognize or accommodate the range of critical and more importantly ethical decisions to the machine (Mattern, 2016, 2017). From IBM's original strategic move into the Smarter Cities arena to the more recent Sidewalk Labs' Toronto Waterfront project, technology companies have failed to adequately acknowledge and address the fact that technology is not neutral and is culturally, socially, economically and politically situated. By conveniently sidestepping the political implications of a city governed by data, schemes such as Sidewalk

Labs' Toronto Waterfront have failed to give adequate space to how the project might impact the relationship between local government and residents. Mattern makes a powerful case for demonstrating that treating the city as a problem to be solved through optimization is inherently a rewriting of any urban governance model, and therefore needs to be scrutinized on this level and not in terms of key performance indicators and productivity gains.

The dream of informatic urbanism is one underpinned by urban science approaches and propagated by tech companies, whilst the broader challenge is what role urban planners, designers and city inhabitants have in a city "designed from the internet up". Fundamentally, the city as a computer project is one where data analysists, marketeers and software engineers are the new planners and designers. As Mattern argues below, the processes of city-making are more complicated than simply rewriting code, and is challenged by "technologists (and political actors) who speak as if they could reduce urban planning to algorithms".

In the current urgent crisis of climate breakdown, it's widely acknowledged that we need to think radically about our cities. Treating the city as a computer may create a slick and palatable solution to city marketing programmes and looks compelling as a strapline on a website. Yet, as Mattern demonstrates, urban intelligence is more than data capture, feedback and processing, it is a much broader kind of knowledge that lives within bodies, minds and communities. This chapter thoughtfully and comprehensively captures the range of issues that combine to form a rejection of the technocractic, data driven vision of problem-solving in cities.

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Introduction

"What should a city optimize for?" Even in the age of peak Silicon Valley, that's a hard question to take seriously. (Hecklers on Twitter had a few ideas, like "fish tacos" and "pez dispensers.") Look past the sarcasm, though, and you'll find an ideology on the rise. The question was posed last summer[3] by Y Combinator—the formidable tech accelerator that has hatched a thousand startups, from AirBnB and Dropbox to robotic greenhouses and wine-by-the-glass delivery—as the entrepreneurs announced a new research agenda: building cities from scratch. *Wired's* verdict: "Not Actually Crazy" (Rhodes, 2016). Which is not to say wise. For every reasonable question Y Combinator asked—"How can cities help more of their residents be happy and reach their potential?"—there was a preposterous one: "How should we measure the effectiveness of a city (what are its KPIs)?" That's key performance indicators, for those not steeped in business intelligence jargon. There was hardly any mention of the urban designers, planners, and scholars who have been asking the big questions for centuries: "How do cities function, and how can they function better?"

Of course, it's possible that no city will be harmed in the making of this research. Half a year later, the public output of the New Cities project[4] consists of two blog posts, one announcing the program and the other reporting the first hire. Still, the rhetoric deserves close attention, because, frankly, in this new political age, all rhetoric demands scrutiny. At the highest levels of government, we see evidence and quantitative data manipulated or manufactured to justify reckless orders, disrupting not only "politics as usual," but also fundamental democratic principles. Much of the work in urban tech has the potential to play right into this new mode of governance.

Tech companies have come out forcefully against the Muslim travel ban, but where will they stand on subtler questions of social "optimization"? Autonomous vehicles and pervasive cameras and sensors are just the sort of disruptive technologies that an infrastructure-championing president might deem "tremendous." Donald Trump's chief strategist (who, years ago, ran the Biosphere 2 experiment into the ground) is also on the board of a data mining and analytics firm that seeks government contracts. Will the president start tweeting about how crime-ridden (and racialized) "inner cities" would be a whole lot better if they were run like computers?

It's a politically complicated environment, to say the least. Into the ring steps the first hire at New Cities: Ben Huh, founder of the meme-and-cat-pic empire Cheezburger. "There's no shortage of space to build new cities," he effervesced, in a post explaining his decision to join the Y Combinator project. "Technology can seed fertile starting conditions across nations and geographies." His goal for the six-month research position: to "create an open, repeatable system for rapid *cityforming* that maximize[s] human potential" (Huh, 2016). No pressure.

Meanwhile, Alphabet (née Google) is moving forward with plans to build its own optimized cities. Its urban-tech division, Sidewalk Labs, has already installed public WiFi kiosks on New York City streets: infrastructural nodes (known as "Links") that may someday exchange data with autonomous vehicles, public transit, and other urban systems.[5]

The company is also partnering with the U.S. Department of Transportation on efforts like the "Smart City Challenge," which awarded a US$50 million grant to Columbus, Ohio. Last June, on the same day Y Combinator announced its New Cities project, *The Guardian* published details of Alphabet's "Flow," the cloud software behind the mobility experiments in Columbus (Harris, 2016). Within months, partnerships were underway in 16 other cities (Davis, 2016).

Urban transportation is the first target for disruption, but it won't end there. Dan Doctoroff, the Michael Bloomberg associate who founded Sidewalk Labs, wonders, "What would a city look like if you started from scratch in the internet era—if you built a city 'from the internet up?'" In November, the company took another step in that direction, launching four new "labs" that will work on housing affordability, health care and social services, municipal processes, and community collaboration. The company plans to run pilot projects in select urban districts, then scale up. Announcing the expansion, Doctoroff recalled past "revolutions" in urban technologies:

> Looking at history, one can make the argument that the greatest periods of economic growth and productivity have occurred when we have integrated innovation into the physical environment, especially in cities. The steam engine, electricity grid, and automobile all fundamentally transformed urban life, but we haven't really seen much change in our cities since before World War II. If you compare pictures of cities from 1870 to 1940, it's like night and day. If you make the same comparison from 1940 to today, hardly anything has changed. Thus it's not surprising that, despite the rise of computers and the internet, growth has slowed and productivity increases are so low … So our mission is to accelerate the process of urban innovation.
>
> *(2016, n.p.)*

While Doctoroff has been telling some version of this story since Sidewalk Labs launched in 2015, the timing of the new expansion, three weeks after the U.S. presidential election, alters the context. As everyone was watching the drama at Trump Tower, the world's largest searching-mapping-driving-advertising-information-organizing company was throwing its resources behind a "fourth revolution" in urban infrastructure.

Dreams of an informatic urbanism

Of course, major companies like Alphabet have already dramatically reshaped the cities where they are headquartered,[6] but they have not yet had the luxury of building on a blank slate. The idea of the "new city" certainly isn't new, and the model now emerging in the United States has precedents in Asian and Middle Eastern countries, where Cisco, Siemens, and IBM have partnered with real-estate developers and governments to build "smart cities" *tabula rasa*.

We don't know how these urban experiments will fare. Since they are in a constant state of development, always "versioning" toward an optimized model ever on the horizon, they are not easily evaluated or critiqued (Halpern et al., 2017). If you believe the marketing hype, though, we're on the cusp of an urban future in which embedded sensors, ubiquitous cameras and beacons, networked smartphones, and the operating systems that link them all together, will produce unprecedented efficiency, connectivity, and social harmony. We're transforming the idealized topology of the open web and Internet of Things into urban form.

Programmer and tech writer Paul McFedries explains this thinking:

> The city is a computer, the streetscape is the interface, you are the cursor, and your smartphone is the input device. This is the user-based, bottom-up version of the city-as-computer idea, but there's also a top-down version, which is systems-based. It looks

> at urban systems such as transit, garbage, and water and wonders whether the city could be more efficient and better organized if these systems were "smart."
>
> *(2014, p.36)*

While projects like Sidewalk Labs and Y Combinator's New Cities were conceived in an age of big data and cloud computing, they are rooted in earlier reveries. Ever since the internet was little more than a few linked nodes, urbanists, technologists, and sci-fi writers have envisioned cybercities and e-topias built "from the 'net up'" (Boyer, 1995; Castells, 1989; Gibson, 1995; Mitchell, 2000, 1995). Modernist designers and futurists saw morphological parallels between urban forms and circuit boards. Just as new modes of telecommunication have always reshaped physical terrains and political economies, new computational methods have informed urban planning, modeling, and administration (Graham and Marvin, 1996; Light, 2004; Vallianatos, 2015).

Modernity is good at renewing metaphors, from the city as machine, to the city as organism or ecology, to the city as cyborgian merger of the technological and the organic.[7] Our current paradigm, the *city as computer*, appeals because it frames the messiness of urban life as programmable and subject to rational order. Anthropologist Hannah Knox explains, "As technical solutions to social problems, information and communications technologies encapsulate the promise of order over disarray … as a path to an emancipatory politics of modernity" (Knox, 2010, pp.187–188). And there are echoes of the pre-modern, too. The computational city draws power from an urban imaginary that goes back millennia, to the city as an apparatus for record-keeping and information management.

We've long conceived of our cities as knowledge repositories and data processors, and they've always functioned as such. Lewis Mumford observed that when the wandering rulers of the European Middle Ages settled in capital cities, they installed a "regiment of clerks and permanent officials" and established all manner of paperwork and policies (deeds, tax records, passports, fines, regulations), which necessitated a new urban apparatus, the office building, to house its bureaus and bureaucracy (Mumford, 1961, p.344). The classic example is the Uffizi (Offices) in Florence, designed by Giorgio Vasari in the mid-16th century, which provided an architectural template copied in cities around the world. "The repetitions and regimentations of the bureaucratic system"—the work of data processing, formatting, and storage—left a "deep mark," as Mumford put it, on the early modern city (Kittler, 1996, pp.721–722).

Yet the city's informational role began even earlier than that. Writing and urbanization developed concurrently in the ancient world, and those early scripts—on clay tablets, mud-brick walls, and landforms of various types—were used to record transactions, mark territory, celebrate ritual, and embed contextual information in landscape (Mattern, 2016b). Mumford described the city as a fundamentally communicative space, rich in information:

> Through its concentration of physical and cultural power, the city heightened the tempo of human intercourse and translated its products into forms that could be stored and reproduced. Through its monuments, written records, and orderly habits of association, the city enlarged the scope of all human activities, extending them backwards and forwards in time. By means of its storage facilities (buildings, vaults, archives, monuments, tablets, books), the city became capable of transmitting a complex culture from generation to generation, for it marshaled together not only the physical means but the human agents needed to pass on and enlarge this heritage. That remains the greatest of the city's gifts.

> As compared with the complex human order of the city, our present ingenious electronic mechanisms for storing and transmitting information are crude and limited.
>
> *(Mumford, 1961, p.569)*

Mumford's city is an assemblage of media forms (vaults, archives, monuments, physical and electronic records, oral histories, lived cultural heritage), agents (architectures, institutions, media technologies, people), and functions (storage, processing, transmission, reproduction, contextualization, operationalization).[8] It is a large, complex, and varied epistemological and bureaucratic apparatus. It is an information processor, to be sure, but it is also more than that.

Were he alive today, Mumford would reject the creeping notion that the city is simply the internet writ large. He would remind us that the processes of city-making are more complicated than writing parameters for rapid spatial optimization. He would inject history and happenstance. *The city is not a computer.* This seems an obvious truth, but it is being challenged now (again) by technologists (and political actors) who speak as if they could reduce urban planning to algorithms (for more on the algorithm as a timely conceptual model, see Mazzotti, 2017).

Why should we care about debunking obviously false metaphors? It matters because the metaphors give rise to technical models, which inform design processes, which in turn shape knowledges and politics, not to mention material cities. The sites and systems where we locate the city's informational functions—the places where we see information-processing, storage, and transmission "happening" in the urban landscape—shape larger understandings of urban intelligence.

Informational ecologies of the city

The idea of the city as an information-processing machine has in recent years manifested as a cultural obsession with urban sites of data storage and transmission. Scholars, artists, and designers write books, conduct walking tours, and make maps of internet infrastructures. We take pleasure in pointing at nondescript buildings that hold thousands of whirring servers, at surveillance cameras, camouflaged antennae, and hovering drones. We declare: "the city's computation happens here" (Mattern, 2013, 2016d).[9]

Yet such work runs the risk of reifying and essentializing information, even depoliticizing it. When we treat data as a "given" (which is, in fact, the etymology of the word), we see it in the abstract, as an urban fixture like traffic or crowds. We need to shift our gaze and look at data in context, at the lifecycle of urban information, distributed within a varied ecology of urban sites and subjects who interact with it in multiple ways. We need to see data's human, institutional, and technological creators, its curators, its preservers, its owners and brokers, its "users," its hackers and critics. As Mumford understood, there is more than information *processing* going on here. Urban information is *made*, commodified, accessed, secreted, politicized, and operationalized.

But where? Can we point to the chips and drives, cables and warehouses—the specific urban architectures and infrastructures—where this expanded ecology of information management resides and operates? I've written about the challenges of reducing complicated technical and intellectual structures to their material, geographic manifestations, i.e., mapping "where the data live" (Mattern, 2016d) (see also Amoore, 2018). Yet such exercises can be useful in identifying points of entry to the larger system. It's not only the infrastructural object that matters; it's also the personnel and paperwork and protocols, the machines and

management practices, the conduits and cultural variables that shape terrain within the larger ecology of urban information.

So the next time you're staring up at a Domain Awareness camera, ask how it got there, how it generates data—not only how the equipment operates technically, but also what information it claims to be harvesting, and through what methodology—and whose interests it serves. And don't let the totalizing idea of the *city as computer* blind you to the countless other forms of data and sites of intelligence-generation in the city: municipal agencies and departments, universities, hospitals, laboratories, corporations. Each of these sites has a distinctive orientation toward urban intelligence. Let us consider a few of the more public ones.

First, the municipal archive. Most cities today have archives that contains records of administrative activity, finances, land ownership and taxes, legislation and labor. The archives of ancient Mesopotamian and Egyptian cities held similar material, although historians debate whether ancient record-keeping practices served similar documentary functions (O'Toole, 2004). Archives ensure financial accountability, symbolically legitimize governing bodies and colonial rulers, and erase the heritage of previous regimes and conquered populations. They monumentalize a culture's historical consciousness and intellectual riches. In the modern age, they also support scholarship (Walsham, 2016). Thus, the "information" inherent in the archive resides not solely in the content of its documents, but also in their very existence, their provenance and organization (there's much to be learned about the ideals of a culture by examining its archival forms), and even in the archive's omissions and erasures (Stoler, 2010).

Of course, not all archives are ideologically equal. Community archives validate the personal histories and intellectual contributions of diverse publics. Meanwhile, law enforcement agencies and customs and immigration offices are networked with geographically distributed National Security Agency repositories and other federal black boxes. These archives are not of the same species, nor do they "process" "data" in the same fashion.

Practices and politics of curation and access have historically distinguished archives from another key site of urban information: libraries. Whereas archives collect unpublished materials and attend primarily to their preservation and security, libraries collect published materials and aim to make them intelligible and accessible to patrons. In practice, such distinctions are fuzzy and contested, especially today, as many archives seek to be more public-facing. Nevertheless, these two institutions embody different knowledge regimes and ideologies.

Modern libraries and librarians have sought to empower patrons to access information across platforms and formats, and to critically assess bias, privacy, and other issues under the rubric of "information literacy" (Mattern, 2016a). They build a critical framework around their resources, often in partnership with schools and universities. Further, libraries perform vital symbolic functions, embodying the city's commitment to its intellectual heritage (which may include heritage commandeered through imperial activities).

Similarly, the city's museums reflect its commitment to knowledge in embodied form, to its artifacts and material culture. Again, such institutions are open to ideological critique. Acquisition policies, display practices, and access protocols are immediate and tangible, and they reflect particular cultural and intellectual politics.

Just as important as the data stored and accessed on city servers, in archival boxes, on library shelves and museum walls are the forms of urban intelligence that cannot be easily contained, framed, and catalogued. We need to ask: What place-based "information" doesn't fit on a shelf or in a database? What are the non-textual, un-recordable forms of cultural memory? These questions are especially relevant for marginalized populations, indigenous cultures, and developing nations. Performance studies scholar Diana Taylor urges us to acknowledge ephemeral,

performative forms of knowledge, such as dance, ritual, cooking, sports, and speech (Taylor, 2003). These forms cannot be reduced to "information," nor can they be "processed," stored, or transmitted via fiber-optic cable. Yet they are vital urban intelligences that live within bodies, minds, and communities.

Finally, consider data of the environmental, ambient, "immanent" kind. Malcolm McCullough has shown that our cities are full of fixed architectures, persistent terrains, and reliable environmental patterns that anchor all the unstructured data and image streams that float on top (McCullough, 2014, p.36, 42). What can we learn from the "nonsemantic information" inherent in shadows, wind, rust, in the signs of wear on a well-trodden staircase, the creaks of a battered bridge—all the indexical messages of our material environments? I'd argue that the intellectual value of this ambient, immanent information exceeds its function as stable ground for the city's digital flux. Environmental data are just as much figure as they are ground. They remind us of necessary truths: that urban intelligence comes in multiple forms, that it is produced within environmental as well as cultural contexts, that it is reshaped over the *longue durée* by elemental exposure and urban development, that it can be lost or forgotten. These data remind us to think on a climatic scale, a geologic scale, as opposed to the scale of financial markets, transit patterns, and news cycles.

Here's some geologic insight from T. S. Eliot's 1934 poem "The Rock":

> Where is the Life we have lost in living?
> Where is the wisdom we have lost in knowledge?
> Where is the knowledge we have lost in the information?
> *Eliot, T. S. (1934)*

Management theorist Russell Ackoff took Eliot's idea one step further, proposing the now famous (and widely debated) hierarchy: Data < Information < Knowledge < Wisdom (Sharma, 2008; Weinberger, 2010). Each level of processing implies an extraction of utility from the level before. Thus, contextualized or patterned data can be called information. Or, to quote philosopher and computer scientist Frederick Thompson, information is "a product that results from applying the processes of organization to the raw material of experience, much like steel is obtained from iron ore." Swapping the industrial metaphor for an artistic one, he writes, "data are to the scientist like the colors on the palette of the painter. It is by the artistry of his theories that we are informed. It is the organization that is the information".[10] Thompson's mixed metaphors suggest that there are multiple ways of turning data into information and knowledge into wisdom.

Yet the term "information processing," whether employed within computer science, cognitive psychology, or urban design, typically refers to *computational* methods. As Riccardo Manzotti explains, when neuroscientists adopt the metaphor of the *brain as computer*, they imply that information is "stuff" that's mentally "processed," which they know is not true in any real sense. The metaphor survives because it makes an irresistible claim about "how marvelously complex we are and how clever scientists have become" (Manzotti and Parks, 2016). Psychologist Robert Epstein laments that "some of the world's most influential thinkers have made grand predictions about humanity's future that depend on the validity of the metaphor" (Epstein, 2016). But the appeal of analogy is nothing new. Throughout history, the brain (like the city) has been subjected to bad metaphors derived from the technologies of the time. According to Epstein, we've imagined ourselves as lumps of clay infused with spirits, as hydraulic or electro-chemical systems, as automata. The *brain as*

computer is just the latest link in a long chain of metaphors that powerfully shape scientific endeavor in their own images.

The *city as computer* model likewise conditions urban design, planning, policy, and administration—even residents' everyday experience—in ways that hinder the development of healthy, just, and resilient cities. Let's apply Manzotti's and Epstein's critiques at the city scale. We have seen that urban ecologies "process" data by means that are not strictly algorithmic, and that not all urban intelligences can be called "information." One can't "process" the local cultural effects of long-term weather patterns or derive insights from the generational evolution of a neighborhood without a degree of sensitivity that exceeds mere computation. Urban intelligence of this kind involves site-based experience, participant observation, sensory engagement. We need new models for thinking about cities that *do not compute*, and we need new terminology. In contemporary urban discourses, where "data" rhetoric is often frothy and fetishistic, we seem to have lost critical perspective on how urban data become meaningful spatial information or translate into place-based knowledge.

We need to expand our *repertoire* (to borrow a term from Diana Taylor) of urban intelligences, to draw upon the wisdom of information scientists and theorists, archivists, librarians, intellectual historians, cognitive scientists, philosophers, and others who think about the management of information and the production of knowledge (Foth et al., 2007). They can help us better understand the breadth of intelligences that are integrated within our cities, which would be greatly impoverished if they were to be rebuilt, or built anew, with computational logic as their prevailing epistemology.

We could also be better attuned to the lifecycles of urban information resources—to their creation, curation, provision, preservation, and destruction—and to the assemblages of urban sites and subjects that make up our cities' intellectual ecologies. "If we think of the city as a long-term construct, with more complex behaviors and processes of formation, feedback, and processing," architect Tom Verebes proposes, then we can imagine it as an organization, or even an organism, that can learn (Verebes, 2016). Urbanists and designers are already drawing on concepts and methods from artificial intelligence research: neural nets, cellular processes, evolutionary algorithms, mutation and evolution.[11] Perhaps quantum entanglement and other computer science breakthroughs could reshape the way we think about urban information, too. Yet we must be cautious to avoid translating this interdisciplinary intelligence into a new urban formalism.

Instead of more gratuitous parametric modeling, we need to think about urban epistemologies that embrace memory and history; that recognize spatial intelligence as sensory and experiential; that consider other species' ways of knowing; that appreciate the wisdom of local crowds and communities; that acknowledge the information embedded in the city's facades, flora, statuary, and stairways; that aim to integrate forms of distributed cognition paralleling our brains' own distributed cognitive processes.

We must also recognize the shortcomings in models that presume the objectivity of urban data and conveniently delegate critical, often ethical decisions to the machine. We, humans, *make* urban information by various means: through sensory experience, through long-term exposure to a place, and, yes, by systematically filtering data. It's essential to make space in our cities for those diverse methods of knowledge production. And we have to grapple with the political and ethical implications of our methods and models, embedded in all acts of planning and design. *City-making* is always, simultaneously, an enactment of *city-knowing*—which cannot be reduced to computation.

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Notes

1 Doctoroff (2016) cited in https://medium.com/sidewalk-talk/reimagining-cities-from-the-internet-up-5923d6be63ba
2 Originally published in *Places Journal* in 2017.
3 See Cheung andAltman (2016) The post drew responses on Twitter from designer and urbanist Fred Scharmen ("fish tacos") and visual journalist Erik Reyna ("pez dispensers"), among others.
4 https://cities.ycr.org/
5 Sidewalk Labs is a key investor in Intersection, the "municipal media company" that is a partner in LinkNYC. See Brown, E. (2016), Mattern, S. (2016c), Lessin, (2016), and Weinberg (2016).
6 See Susie Cagle, "Why One Silicon Valley City Said 'No' to Google," *Next City*, May 11, 2015; Sean Hollister, "Welcome to Googletown," *The Verge*, February 26, 2014; Chris Morris-Lent,"How Amazon Swallowed Seattle," *Gawker*, August 18, 2015.
7 Some argue that the city-as-machine has a much deeper history, as evidenced by use of grid layouts, linear patterns, and regular geometric forms since ancient times, and by the use of standardized patterns for colonial urban development. See, for instance, Kevin Lynch, *Good City Form* (Cambridge, MA: MIT Press, 1981): 81–88. See also Matthew Gandy, "Cyborg Urbanization: Complexity and Monstrosity in the Contemporary City," *International Journal of Urban and Regional Research* 29: (March 2005): 26–49, https://doi.org/10.1111/j.1468–2427.2005.00568.x; Peter Nientied, "Metaphor and Urban Studies: A Crossover, Theory and a Case Study of SS Rotterdam," *City, Territory and Architecture* 3:21 (2016), https://doi.org/10.1186/s40410-016-0051-z; William Solesbury, "How Metaphors Help Us Understand Cities," *Geography* 99:3 (Autumn 2014): 139–42; Tom Verebes (2016).
8 Marcus Foth's conception of "urban informatics" is similarly capacious: it encompasses "the collection, classification, storage, retrieval, and dissemination of recorded knowledge," either (1) in a city or (2) "of, relating to, characteristic of, or constituting a city." See Foth, M. (ed.) *Handbook of Research on Urban Informatics: The Practice and Promise of the Real-Time City* (Hershey, PA: Information Science Reference, 2009): xxiii. Such a definition acknowledges a wide variety of informational functions, contents, and contexts. Yet his focus on recorded knowledge, and on informatics' reputation as a "science" of data processing, still limits our understanding of the city's epistemological functions.
9 For prominent examples, see Andrew Blum, *Tubes: A Journey to the Center of the Internet* (New York: HarperCollins, 2012), and the work of Ingrid Burrington and Mél Hogan.
10 Quoted in Marcia J. Bates, "Information," in Marcia J. Bates, Mary Niles Maac, eds., Encyclopedia of Library and Information Sciences, 3rd ed. (New York: CRC Press, 2010): 2347–2360, available online https://pages.gseis.ucla.edu/faculty/bates/articles/information.html". See also Rafael Capurro and Birger Hjørland, "The Concept of Information," in Blaise Cronin (ed.), *The Annual Review of Information Science and Technology*, Vol 37 (2003): 343–411.
11 See, for instance, the work of Michael Batty.

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