Maps as objects:

Exploring an object-oriented approach to cartography through maps in the smart city

By

Tuur Driesser

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Interdisciplinary Studies

University of Warwick, Centre for Interdisciplinary Methodologies

July 2021

Table of Contents

List of Figures

Declaration

Parts of Chapter 2 and of the Conclusion have been published in Driesser, T. (2018). Maps as objects. In S. Lammes, C. Perkins, A. Gekker, S. Hind, C. Wilmott, & D. Evans (Eds.), Time for mapping: Cartographic temporalities. Manchester University Press.

Parts of Chapter 3 have been published in Driesser, T. (2018a). Exemplifying. In C. Lury, R. Fensham, A. Heller-Nicholas, S. Lammes, A. Last, M. Michael, & E. Uprichard (Eds.), *Routledge handbook of interdisciplinary research methods* (pp. 296–300). Routledge.

I confirm that this thesis is my own work and has not been submitted for a degree at another university.

Acknowledgements

I am grateful for the wisdom and guidance from my supervisors Celia Lury and Stuart Elden. While it has been a long journey with many challenges, they have always remained patient, understanding and practical. They each have an unparalleled knowledge of their own fields, as well as their individual approaches to researching, writing and supervising. Together, they have ensured and enhanced the depth and breadth of this thesis as well as of myself as a researcher.

I would like to thank the Economic and Social Research Council (ESRC) for funding this research.

The Centre for Interdisciplinary Methodologies at the University of Warwick has proved to be an inspiring environment with lively discussions with both staff and fellow students, including Ana Gross, Craig Gent, Emma Uprichard, Esteban Damiani, Greg McInerny, James Tripp, João Porto de Albuquerque, Loup Cellard, Matt Spencer, Michael Dieter, Nathaniel Tkacz, Nerea Calvillo, Noortje Marres, Pablo Velasco Gonzalez, Sam Martin, Scott Wark and Szymon Piatek.

This research could not have been done without the generosity and openness of the interviewees: Alan-Miguel Valdez, Open University; Stephen Potter, Open University; John Miles, University of Cambridge; Ernst Kretschmann, Building Intellect; Daniela Krug, Building Intellect; Alan Waldock, Future Cities Catapult; Mike Holland, CUSP, Constantine Kontokosta, CUSP; Varun Adibhatla, The Urban Technology Hub at the New Lab in Brooklyn, New York. In addition, I would like to thank Shannon Mattern, of the New School for Social Research, for an interesting conversation on smart cities during my visit to New York.

The Charting the Digital Team – Sybille Lammes, Chris Perkins, Sam Hind, Alex Gekker and Clancy Willmott – were extremely welcoming, inviting me to their workshops in Oxford and Venice where I first tested out some of my ideas. These discussions were instrumental in opening my eyes to the many different, creative approaches to studying maps.

Combining a PhD with a professional career is a challenge at the best of times, but it would have been practically impossible without a supportive work environment. I was very lucky to receive such a large amount of support, encouragement and enthusiastic curiosity from all of my line managers: first Lloyd Langman at Palgrave and later Ben Doak and Rachel Foskett-Tharby at NHS England and Improvement.

I am also grateful to my family, who despite the distance have always been encouraging and supportive. My mom's promise of a trip to Berlin was the last motivation I needed to finish the project. (It's down in black and white now!)

Most of all I would like to thank my partner Dawn, who encouraged me to start this project and, more importantly, to see it through. I look forward to our next chapter together.

Abstract

This thesis starts from the premise of the changing nature of maps in the context of digital technologies and big data on the one hand, and a burst in theorising them, on the other. One context in which these developments in mapping technologies is particularly prominent is that of the smart city. This provides an interesting context in which to study developments in map use and production and the way in which new theories may be helpful in understanding this changing nature of maps. The thesis therefore explores two case studies of mapping projects in the smart city – MotionMap in Milton Keynes and Whereabouts London – to ask: *can object-oriented ontology be used to inform cartographic theory and research*?

It considers the philosophical debates on object-oriented ontology (OOO) to examine how a different theoretical framework can yield new perspectives on the role of maps in the representation and production of space. It reviews key cartographical traditions such as the communication approach, critical and post-representational cartography, and discusses how OOO challenges their assumptions. Based on this, it develops a number of different lines of enquiry for an object-oriented approach to cartography. In particular, these lines of enquire revolve around relationship between emergence and change: the interior withdrawal of objects on the one hand and their outward ability to relate and affect on the other. Bringing together these concerns about OOO, cartography and the smart city, the aims to contribute to a number of research areas. Firstly, it explores the relevance of object-oriented thinking to the cartographic theory and research. Secondly, it is an examination of the methodological and theoretical relevance of the philosophical principles of OOO to empirical research. Finally, it contributes to the literature on case studies of the smart city.

Introduction

Data – big, small, open and beyond – and new computational techniques have become increasingly prominent and influential in virtually all areas of social life. Much of our online activity is geo-tagged and, in this way, can be used to produce large scale, sometimes real-time information on their movements and behaviour across space. The availability of new types of data allows for the mapping of spaces and activities that have thus far been un-mapped: from the traces of everyday digital lives, to the vast amounts of information stored and made available by governmental and non-governmental bodies. Moreover, the ever-developing possibilities of analysing and representing these data enables forms of mapping and visualising cities in ways that were not possible before, e.g. real-time, interactive. This has led to a multiplication of scenarios in which maps, in their many forms, can be used – for example to guide, to monitor, and to track.

One context in which these developments in mapping technologies is particularly prominent is that of the smart city. Maps take an important role in the smart city: the expansion of what can be mapped and how has generated a catalogue of ways in which maps can be used and put to work, whether to aid citizens' navigation in the city through apps, or to promote efficient central management through city dashboards and control rooms. Many cities are committed to making large bodies of data publicly available in the name of transparency and to promote public participation (Ojo et al., 2015). Low-cost sensors can be installed throughout cities to monitor anything from light, sound and heat to numbers of available parking places or numbers of people on a bus. Control rooms and central dashboards are able to monitor what goes on and enable quick intervention where necessary (Mattern, 2015). Governments, researchers, companies and individuals are creating apps that allow for real-time information of and interaction with particular aspects of urban life.

The smart city is therefore an interesting context in which to study developments in map use and production and the way in which new theories may be helpful in understanding this changing nature of maps. As maps have proliferated in their forms and applications, so too have the ways of thinking about them. Cartography as the science and art of making maps has a history as long as maps themselves. However, over recent years there has been a burst in theorising the ways in which maps are made, how they represent and what kind of relationships exist between maps, their places and their media, their makers and their users. As will be discussed in Chapter 2, cartographic theory has often developed in conversation with thought in disciplines such as geography, sociology and social theory more generally. In this thesis, I will evaluate this conversation to trace how thinking of maps has changed since the second half of the 20th century and consider what this may mean for cartographic thought going forward.

Critical cartography, emerging in the 1980s, was built on foundations of then popular French thinkers such as Foucault, Derrida and Barthes, through notions such as hermeneutics, deconstruction and mythology (see Harley, 1989; Wood & Fels, 1986). Initial debates in critical cartography often revolved around key concepts of discourse, knowledge and power. Maps were conceived as tools to further the interest of the powerful. They displayed certain elements while hiding others, emphasising a particular narrative. The methods of critical cartographers were aimed at unpicking this process of selection, reading between the lines, to understand the mechanisms of power at work and discover alternative narratives. A crucial contribution of this field was the idea that maps are not simply neutral methods of communication, but are bound up with political, social and cultural processes.

More recently, cartography thinking has been strongly influenced by encounters with the non-representational turn in geography and social theory, giving rise to understandings of maps in terms of being performative, post-representational and ontogenetic (for an overview see, for instance, Rossetto, 2015). These new forms of cartographic thinking started questioning the relationship between maps and their territories – the ideas of maps as mirrors of the world. Post- and non-representational in this context does not mean without representation, or some sort of argument that the representational function of maps is not important. Rather, these approaches to cartography entail the study of additional ways maps can be related to what is being mapped – the work they do in the world beyond representing it. They draw attention not just to the finished products of maps, but also to the activity of mapping and to the unfolding of situations in which maps are used (e.g. Kitchin & Dodge, 2007).

Moreover, this focus on the work maps do is not only the result of developments in social theory, but also of the changing nature of maps in the context of digital technologies and big data. Map-making has become increasingly popularised and de-professionalised (Batty et al., 2010). People without any training are able to produce, influence and engage with maps as part of their everyday lives. Maps are no longer static, but continuously transform in interaction with their users, blurring the boundaries between map users and producers (Coleman & Georgiadou, 2009). Their roles in not only representing but also mediating and producing space have become more varied and more pronounced. As Chapter 1 will discuss, new theories of cartography and of spatial media (e.g. see Kitchin et al., 2017a) more generally are trying to make sense of this changing nature of maps and their changing relationship to the places they represent, and the forms the take.

Research question

Building on this interchange between developments in cartographic theory, social theory, and map technology, this thesis will consider how subsequent developments in social theoretical and philosophical debates can contribute to studying maps in the digital age. In particular, it will focus on the field of object-oriented ontology (OOO), developed by writers such as Graham Harman, Ian Bogost and Timothy Morton, and associated thinkers such as Jane Bennett, who has proposed her own notion of thing-materialism. What unites these thinkers is a focus on objects as the starting point of analysis, independent of their contexts and of their being grasped by a knowing (human) subject. OOO revolves around the twin principles that objects are more than the parts of which they consist and can never be fully known or exhausted in any particular situation. It emphasises the thing-in-itself while also positing that no subject has full or direct access to this thing-in-itself.

As will be discussed in detail in Chapter 2, OOO is formulated in opposition to a large number of philosophical and social theoretical schools of thought, not least to those that have informed cartographic thinking as described above. It is a response to various forms of constructionism which, it is claimed, understand objects only as expressions of larger forces such as those of power and culture. At the same time, it argues against theories based on notions of becoming, in which objects emerge in particular contexts and in relation. Through this polemic, OOO rethinks many of the concepts that have been central to the various approaches to studying maps. It problematises concepts such as representation, (social) construction, causality, becoming, power, the relationships and distinctions between systems and things, change and continuity, subject and object, materialism and idealism.

Thus, this thesis brings together three distinct research interests – namely, maps, smart cities and OOO. In doing so, it has taken an approach which can usefully be understood as a puzzle, in a way that Andrew Abbott describes as common for many research projects:

> We often don't see ahead of time exactly what the problem is, much less do we have an idea of the solution. We often come at an issue with only a gut feeling that there is something interesting about it. We often don't know even what an answer ought to look like. Indeed, figuring out what the puzzle really is and what the answer ought to look like often happen in parallel with finding the answer itself. (Abbott, 2004, p. 38)

This research started out with two areas of concern that seemed like they had 'something interesting' about them: on the one hand the smart city as a context for understanding the changing nature of maps on the one hand, and on the other OOO as a potential way of challenging existing schools of cartographic thought. In putting this puzzle together, it has drawn on the polemic nature of OOO and examines what its philosophical challenge may offer to empirical research on maps, set within the context of the smart city.

This thesis therefore explores the potential of an object-oriented approach to cartography, analysing if approaching maps as objects may help develop new perspectives on their role in the representation and production of space. It considers how drawing on a new set of theoretical references may lead to different types of questions and issues to become of concern in the study of maps. As the smart city provides an interesting and pertinent context for understanding the changing nature of maps, the thesis will look at two case studies of mapping in the smart city to address its main research question:

> *Can object-oriented ontology be used to inform cartographic theory and research?*

Rather than presenting an argument for object-oriented cartography and describing precisely what this should look like, this thesis investigates what an object-oriented approach might be able to contribute cartography. It will experiment with various texts from the OOO literature to explore what new insights it may be able to produce in the analysis of the two case-studies.

The first of these cases is MotionMap, a project developed in Milton Keynes by a partnership between university researchers at the Open University and a Cambridge technology start-up, Building Intellect. The aim of this project was to create a map based on a wide range of locally sourced data, including traffic data, cameras, sensors and public transport schedules. Using this information, the map intends to provide local residents a real-time overview of the 'busyness' of Milton Keynes in order to enable them to make better-informed travel choices. In this way, the map was intended to alleviate the congestion associated with a rapidly growing urban population and to improve overall quality of life. By taking a local approach, the project was able to capture a wider range of data sources specific to the city in a way that would not have been feasible with one of the tech giants. Moreover, it was conceived as an opportunity for closer engagement with the city's residents to provide them with a map relevant to local issues and ideas, and to inspire them to start using data to come up with their own solutions.

The second case study is of Whereabouts London, a geodemographic mapping project developed by the Future Cities Catapult. Using open data from the London Datastore 2, as well as a range of other publicly available sources, the project built up a profile of the city's population. This profile was based on a range of characteristics, from home ownership and occupation, to age, education and access to green spaces. The project used a clustering algorithm to find similarities among the population based on these characteristics. The result was a classification of London into eight groups – eight Whereabouts – distributed across the city. This classification offered a new approach to grouping people and places: the eight categories were not based on pre-defined criteria but emerged from relationships residing within the data, uncovered by a clustering algorithm. This information was thought to be useful for policy makers, who would be able to identify similarities between people stretching across council boundaries. In addition, it was hoped that the novelty of such a representation of London would encourage businesses and residents to engage with the London Datastore and thus stimulate the bottom-up establishment of London as a smart city.

Through these two case studies, the thesis hopes to contribute to debates not only on object-oriented ontology, cartographic theory, but also on smart cities. Firstly, the thesis speaks to the study of maps – i.e. cartography theory and research. By investigating the fault lines between OOO and those philosophical and social theoretical positions that underpin existing cartographic arguments, it explores different ways of conceptualising and studying maps. What does it mean to conceptualise a map as an object? What does this entail for the ways in which maps can or should be studied? How can such a conceptualisation help address questions regarding the society in which these maps are produced, used and circulated? The theoretical framework and the way this will be approached in this thesis will be introduced in more detail in Chapter 2.

Secondly, the research speaks to the ongoing discussion on the practical relevance of OOO. Many of the foundational texts in OOO are framed with reference to a variety of real-world examples, such as videogames (Bogost, 2012), poetry and literary criticism (Bennett, 2012; Harman, 2012; Morton, 2012a), ecology (Morton, 2012b), food, metal, and stem cells (Bennett, 2010). While these texts make strong arguments – for example on objects' withdrawal and their inexhaustibility, the decentring of the human subject, the power of things – the methodological applicability of OOO to empirical research is not necessarily given. By applying these arguments to case studies of maps, the thesis will assess how and to what extent they might be helpful for doing research.

Finally, the case studies hope to add to the ever-growing literature on smart cities. The analysis of both MotionMap and Whereabouts London will contrast promise with reality, weaving between utopian, dystopian and managerial voices. It will unpick some of the different points of view, not to side with one or the other, nor to argue for what the smart city could or should be, but to investigate what they entail in actual smart city initiatives. What are the ideas that shape smart cities, and how do conflicting ideas play out in practice? What are the problems the smart city tries to address, and to what extent does it actually address these? In this way, the research aims to be of interest to scholars of and practitioners in the smart city alike.

Exploring the potential intersections between OOO and cartographic theory, this thesis shares some of the objectives of Tania Rossetto's (2019) book, *Object-Oriented Cartography: Maps as Things*. Here, Rossetto 'poses the question of the object as a question of the life of cartographic objects, including maps within the universe of things to which OOO directs our attention' (p.26). In this context, it is interested in questions such as:

> Are maps completely accessible to us? Do maps exist solely for us? Are maps dependent on us? Have maps a life of their own? What do maps experience? What would maps say if they could talk? (p. 26)

In other words, Rossetto is primarily interested in the question of access to the inner life of the map as object. However, as will be discussed in more detail in Chapter 2, underpinning the case studies in this thesis are the twin principles of OOO, simultaneously emphasising the inexhaustible, withdrawn interior of objects on the one hand, and their ways of relating on the other. Thus, while this thesis starts from a similar vantage point as Rossetto's book, to explore what an object-oriented approach might offer to our thinking about maps, it takes a different approach in addressing this issue – as will be explored in some more detail in the Conclusion. By looking at different case studies and by engaging with different texts and emphasising different aspects in the OOO literature, this thesis hopes to build on and add to this project elaborated by Rossetto.

Thesis outline

The first chapter provides an overview of the literature on smart cities and the developments in digital mapping within this context. It highlights how this has become an area of interest for the social sciences and beyond and introduces some of the key themes in the literature, including global cities, smart city definitions, urban laboratories, the new science of cities and urban informatics. These themes have been selected because they expose some of the interesting different viewpoints around smartness. To explore these themes, the chapter draws on literature from a range of sources. It uses publications from the practice of smart cities, such as local governments, research agencies, consultancies and NGOs. In addition, it includes scholarly material from academic disciplines engaged with building smart cities such as geography, policy studies and computer science. These sources form a bridge to more critical scholarship that places the developments of smart cities in broader theoretical contexts on which the chapter also draws. As such, the themes encapsulated here emerge from both those trying to build the smart city and those studying it. This literature review and the themes it highlights are used to frame and inform the substantial case study chapters later in the thesis.

In Chapter 2 the thesis starts developing the idea of an object-oriented cartography. It provides a historical overview of the ways in which maps have been theorised, covering key cartographical traditions such as the communication approach, critical and post-representational cartography, introducing some of the key thinkers in these areas. Building on recent debates in social theory around objects, things and ontology, it discusses how OOO challenges previous assumptions and its implications for conceptualising maps. It discusses the ways in which object-oriented and thing-materialist authors distinguish themselves from other schools of thought that have been influential in cartographic theory. Based on this, it sets out a number of different lines of enquiry for an object-oriented approach to cartography.

Chapter 3 provides a discussion of methodology. It sets out the concept of the example as a particular approach to casing – that is, of connecting the case studies to theory and the research question. The chapter will describe various approaches to using case studies and discuss both criticisms and defences of case study methodologies. Building on these criticisms and defences, it will develop the concept of the example to approach the case study methodology. As will be argued, such a methodology of exemplification draws on the singularity of the case, while remaining open to the use of different methods, different techniques, which can carve out different ways of studying maps as objects.

Thus, the first three chapters set up the context, theoretical approach and methodology that will guide the two case study chapters. Chapter 4 contains the first case study – that of MotionMap. It outlines the methods used to study this project, including interviews with participants, attending workshops and reading various academic outputs of the project. It uses the social science literature on the concept of prototype, which emerges as a result of the participants' own reflections on the project as well as through a connection with recent debates on experimentation, prototyping and urban laboratories that are highlighted in Chapter 1. The chapter describes the epistemic community of academic researchers and a private technology company, exploring the different views and interests of the various actors involved and examining how the map as prototype helps to navigate these tensions and contradictions. From an object-oriented perspective, the prototype is a useful concept as it emphasises the tension between past, present and future inherent in every object in a way that enables attention to the map as autonomous entity as well as to the way it affects its environment.

Chapter 5 presents the second case study, analysing Whereabouts London developed by the Future Cities Catapult. This chapter employs a different method, namely the reverse engineering of the clustering algorithm and the visualisation of the data. This process of reverse engineering is facilitated by the concept of the little analytic (Amoore & Piotukh, 2015), which focuses on the way algorithms are instrumental in making sense of big data by making perceptible hidden patterns and relationships. Through this method, the case study traces a series of steps in which Whereabouts London ingests, clusters and visualises its data into a map. These different steps are analysed from an object-oriented perspective through the notion of unit operations. Understanding unit operations as configurative, they offer a way to study the relationship between the way the map establishes and presents itself as an object and the ways in which it perceives and relates to other objects in the smart city.

Finally, the Conclusion brings together the literature review, theory, methodology and case study chapters to address the main question of whether object-oriented ontology can be used to inform cartographic theory and research. After briefly recapping the chapters, it draws out some of the commonalities and differences between the two cases and the way they have been approached through the lens of OOO. Evaluating these commonalities and difference, it will reflect on what this means for the methodological applicability of OOO, its potential for cartographic theory and research, and its relevance to the smart city literature. It ends by evaluating possible further avenues for taking forward the idea of an object-oriented cartography.

1. Literature review

The smart city is a widely studied and debated topic across a spectrum of academic disciplines, policy makers, technology firms and community activists. The promise of technology to change the way in which the city operates, its systems are measured and managed, and its citizens engage with urban space has evoked a diverse range of utopian as well as dystopian visions. The smart city is simultaneously the answer to today's problems of climate change, a tool for citizen engagement and empowerment, a market for new products and services, an experiment in urban living, and the latest manifestation of a technocratic and neoliberal governmentality. Thus, it is hard to summarise the concept into a neat definition. It is shaped by a wide range of actors with a wide range of commercial, academic, political, economic and social interests. This chapter will provide an overview of the context in which these come together and some of the key ideas that shape the discourse around smart cities. In this way, it aims to lay out a number of themes and concerns that will inform the discussion of the case studies in Chapters 4 and 5.

Outlining this area of study, this literature review will start by outlining the concept of the smart city and the various ways it has been defined and researched. This will introduce some of the different approaches to understanding what makes a city smart, and how technology could or should be used to improve urban life. The emergence of the smart city is often framed as a convergence of the massive scale of urbanisation on the one hand and the rise of new technology on the other. Both of these trends will be covered in this chapter. Next, there will be a discussion on the ways in which new technologies and forms of data collection and analysis are used to measure, monitor and manage the city. Finally, the chapter examines how these new technologies and data have produced new ways of mapping, and various conceptual approaches to make sense of this changing nature of maps.

This chapter draws on a wide range of literature. It looks at academic books and papers as well as policy documents and consultancy research reports. It includes sources from those engaged in the creation and promotion of smart cities from a variety of perspectives, and from those that critically examine these efforts. It also makes use of a number of interviews carried out in New York in June 2016. These were with: Mike Holland, then Executive Director at the Center for Urban

Science and Progress (CUSP); Constantine Kontokosta, then Deputy Director of Academics at CUSP; and Varun Adibhatla, CUSP graduate and then Director of the Urban Technology Hub at the New Lab in Brooklyn, New York. CUSP is pioneer in the field of urban informatics and smart cities. It was set up as the result of a successful bid of the city's Applied Sciences NYC competition (Koonin, 2013). Its purpose is broadly described by Holland as trying to 'develop data science tools to help agencies do whatever it is they do better' (Interview with Mike Holland, 8 June 2016).

First led by physicist Steven Koonin, CUSP is a partnership between the city of New York and New York University, supported by a number of industry partners including IBM, Microsoft, Cisco and Siemens. It is also partnered to a number of academic partners abroad, including in the US, Canada and India. In the UK, it has entered in a partnership with WISC, the Warwick Institute for the Science of Cities. In addition, together with the University of Warwick, CUSP has partnered with King's College London to establish a Centre for Urban Science and Progress in London ("Centre for Urban Science and Progress in London," 2015).

These interviews should not be understood as portraying a representative sample of the entire area of smart cities. Rather, they present some insights from a small selection of people that are working in this area that may be of interest.

The smart city concept

With increasing rates of urbanisation across many parts of the worlds, cities are often seen as the places that will be most susceptible to threats such as overcrowding, allocation of resources, breakdown of critical infrastructures, terrorism and perhaps most notably – climate change. One element that is deemed crucial to the solution of these problems is technological innovation and progress for the improvement of the city. Here the idea of the smart city emerges: the future is urban, and smart cities are the cities of the future. However, what this smart city entails, it will be argued here, is far from clear or agreed upon. The term smart city has a wide range of meanings to a large number of actors and stakeholders. As Adibhatla argues, there's no one-size-fits-all definition of a smart city (Interview with Varun Adibhatla, 6 June 2016). One effort to present an 'operational definition' of the smart city is made by Caragliu, Del Bo and Nijkamp:

> We believe a city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance. (2011, p. 70)

Elsewhere, Anthony Townsend (2014, p. 15), prominent author in the area of smart urbanism, describes smart cities succinctly as:

> places where information technology is combined with infrastructure, architecture, everyday objects, and even our bodies to address social, economic, and environmental problems.

Although most smart city definitions include many of these same terms – information technology, infrastructure, architecture, objects, bodies – the way they are 'combined' varies significantly. Moreover, many definitions include additional terms to suit their specific purpose.

This chapter explores the diversity of definitions and conceptualisations of what the smart city is and what it should be. For example, as displayed in Figure 1.1, Alexopoulos et al.'s (2019) taxonomy of smart city initiatives revolves around a 'quadruple helix' consisting of stakeholders from industry, civil society, cities and academia. However, while these different actors may be neatly represented together in a circle, it should not be assumed that all of their interests always align. As will be discussed in Chapter 4, on the MotionMap, different stakeholders may have different aims and ideas, even when working together on the same smart city project.

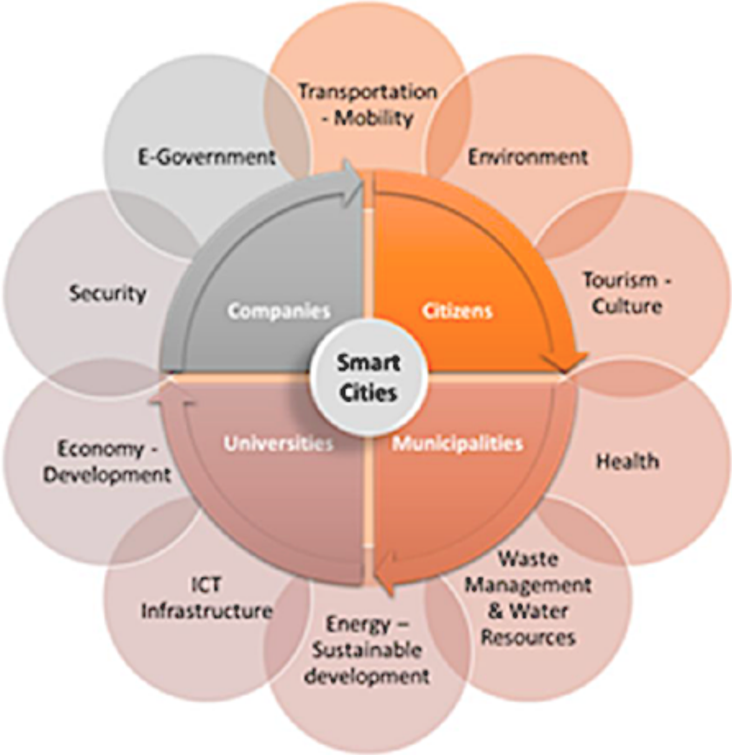

Figure 1.1 Smart Cities Main Axes and the Quadruple Helix (Alexopoulos et al., 2019, p. 285)

As a concept concerning the transformation of the city through technology, the smart city stands in a long lineage of terms such as intelligent, wired, networked, digital, ubiquitous and sentient cities (Albino et al., 2015; Hollands, 2008; Nam & Pardo, 2011). These related notions have originated at particular moments in the trajectory of implementing digital technologies in urban space and thus emphasise different aspects of their relationship. A systematic review of definitions of the smart and digital cities found that the term "smart city" started to slowly gain in popularity around 2005, overtaking "digital city" in 2009, but increasing exponentially from 2010 onwards (Cocchia, 2014). This rise in popularity is reflected in the increasing number of smart city strategies by cities across the world, growing slowly from 3 in 2008 to 13 in 2014 and then to 36 in 2015 and 42 in 2016 (Zelt et al., 2019, p. 5).

As the latest in a series of concepts, the smart city can be seen to envelope many of its predecessors. As such, it builds on the technological approaches of digital, intelligent and wired cities, in combination with people centred notions such as creative, learning, and knowledge cities (Nam & Pardo, 2011). Moreover, it relates to outward-oriented perspectives such as the entrepreneurial city (Hollands, 2008) that aim to create sustainable, resilient and liveable cities while at the same time enhancing competitiveness in order to advance in a world of global cities. While concepts such as intelligent, wired and digital focus on the implementation of hardware to facilitate various processes, what distinguishes the smart city is a focus on the social function and value of these technologies. Accordingly, Hollands's (2008, p. 315) foundational article analysing the use of the smart city label argues that 'progressive smart cities must seriously start with people and the human capital side of the equation, rather than blindly believing that IT itself can automatically transform and improve cities.'

However, this focus on the social value of technology marks a point of tension between corporations, governmental and non-governmental practitioners and scholars. While corporations often claim to have citizens at the heart of their smart city plans, visions by firms such as IBM – as analysed in a number of critical studies (e.g. McNeill, 2015a, 2016; Söderström et al., 2014; Wiig, 2015) – are often criticised for being both technocratic and neoliberal rather than emancipatory. As Hollands (2015a) warns, these corporate visions often remain silent on cultural, social and political aspects in favour of an unequivocal belief in the progressive and inevitable nature of technology. This dominance of this particular use of the notion of the smart city has even led some to abandon the terminology altogether. As Kontokosta explains:

> I don't ever use that term. I think it's so ambiguous, but at the same time so loaded that it's just meaningless and I think the smart city [has] also really been co-opted. (…) It was initiated by large technology firms. That's where the start of it came and it was to sell products. That's just not where the excitement lies. The smart city is very much a technocratic view of the world and it's very much a hardware version or a technology version or a city. I don't find it very useful. (Interview with Constantine Kontokosta, 8 June 2016)

Likewise, in a case study of a smart city project in Philadelphia, Wiig (2016) argued that the term smart city served as a 'vacant rhetorical device' (p. 547). Despite the project's aim of alleviating urban inequality, positioning the city as a smart city was primarily envisioned to convey an 'entrepreneurial governance strategy,' to attract industry and investment.

Smart city visions driven by large multinational corporations are often contrasted to more critical or community-led approaches. As Luque-Ayala and Marvin (2015, p. 2112) argue, however, in reality many real-world programmes sit somewhere in the middle between these '"dominant" ("top-down", formal or supply based)' and '"alternative" ("bottom-up", informal or demand-based) discourses and approaches.' Accordingly, Niaros (2016) organises his taxonomy of the smart city across the two axes of commons and capital on one hand and centralised/global and distributed/local on the other (see Figure 1.2).

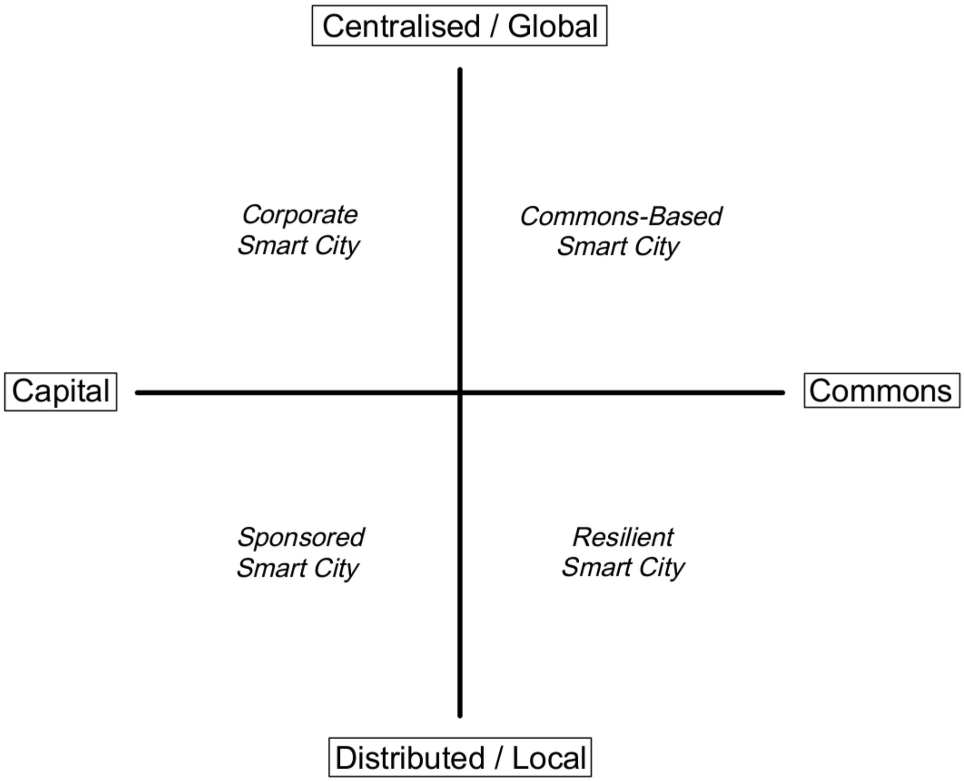

Figure 1.2 A taxonomy of the smart city (Niaros, 2016, p. 53)

Similar to Luque-Ayala and Marvin's argument, the benefit of this taxonomy is that smart city initiatives can be placed across the two-dimensional space, rather than in any one confined category. As will be explored in the case study of the MotionMap, moreover, even within cities and within projects different visions can coexist and compete with one another.

Smart city research

As the smart city has become a widespread concept in urban policy making, so too has it been a popular area of academic research. Mora, Bolici and Deakin (2017, p. 4) describe how, since the first usage of the term with the publication of *The Technopolis Phenomenon: Smart Cities, Fast Systems, Global Networks* (Gibson et al., 1992), the number of scholarly publications on smart cities on Google Scholar grew from 16 in 1992 to 9,494 in 2015. Most notably, similar to the trend of smart city strategies, academic research particularly took off between 2010 and 2012. However, this research, Mora et al. (2017) describe, is fragmented, with various unconnected clusters of publications, which can be categorised into two distinct groups: peer-reviewed, academic research on the one hand, and grey literature produced by technology firms and consultancies on the other. The differences between these groups, they argue, can be understood through competing narratives with 'holistic' and 'human-centric' perspectives on one side and corporate, technocratic visions of the smart city on the other.

While this analysis is useful in that it draws attention to competing narratives, in reality this distinction between academic and holistic and human-centric versus corporate and technocratic is less than straightforward. Much of the research on and practice of smart cities takes place in partnerships of academia, business and government. Within these partnerships and collaborations, these different narratives may compete or co-exist. An example of this development is the emergence of the field of the 'new science of cities' or the new urban science – two terms which are often used interchangeably (e.g. Townsend, 2015). The development of this field has been propelled through the establishment of a number of research institutes at universities across the world (see Figure 1.3). Many of these institutes are partnerships between academic-corporate partnerships and their research ranges from studying how to make cities smarter, to developing general understandings of how cities work, to producing critical reflections of the use of technology in urban space.

Townsend (2014, pp. 73–82) traces the emergence of this field within a longer history of urban planning and computer modelling and simulation. Starting in the 1950s and '60s, computer scientists attempted to develop new models to take over the tasks of urban planning through a series of projects, which were eventually discredited and abandoned. The failure of these models was mainly due to the limitations in the number and nature of equations included so that predictions were often either nonsensical, or too obvious to be of any added value. Moreover, Townsend argues, a more fundamental issue lay in that these models were based on inaccurate, oversimplified theories of how systems function. The rise of 'increasingly abundant data, computing power, and analytical tools,' however, has led to a 'renaissance' in the use of computing technology for the study of and contributing to urban planning (Townsend, 2015, p. 5).

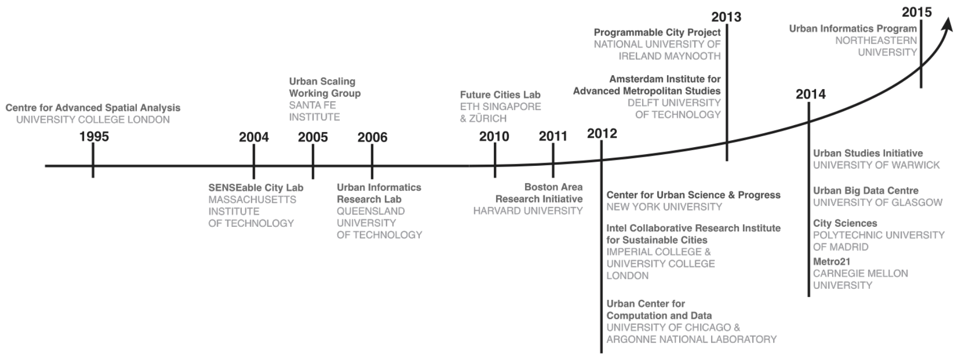

Figure 1.3 Timeline of New Urban Science institutions (Townsend, 2015, p. 12)

Townsend describes this new urban science through three lenses (Townsend, 2015, pp. 5–8). Firstly, it is characterised by a 'tension between science and design.' This tension refers to the fact that, while this new science is interested in the study and improvement of the design of particular cities, its research focuses on identifying universal laws that govern all cities. One of the boldest formulations of this focus on universal laws is Bettencourt and West's (2010) attempt to develop 'a unified theory of urban living.' In this unified theory, Bettencourt & West claim to have found a universal '15% rule' according to which variables such as crime rate, GDP, income and number of patents increase 1.15 times as fast as city size. This rule is intended to serve as a benchmark according to which policy makers will have to measure their cities' progress and adapt their performance.

Secondly, Townsend argues, a defining feature of the new science of cities is the way in which it involves researchers from disciplines not traditionally associated with urban planning or research, such as physicists and biologists. This is exemplified by Adibhatla's experience of studying at CUSP:

> It was truly a melting pot, because you did have folks coming from the traditional urban planning thing, but you also had folks who had physicist

> backgrounds or people who were in management consulting and wanted to shift focus and maybe get technical skills while doing that. Because it was such an early stage academic programme (…) so we were part of the second cohort and we were given ample opportunity to make it fit our needs really. (Interview with Varun Adibhatla, 6 June 2016)

This interdisciplinary approach was an intentional feature of CUSP's educational programme as Kontokosta explains:

> It's a wonderful mix. They come in with different backgrounds and expectations and levels of training, but we bring them there, we give them foundational skills. We give them interesting data and problems to work on, we throw them together, we throw sociologists and economists in a room with astrophysicists and computer scientists and some good stuff comes out of it. So that's all very exciting. (Interview with Constantine Kontokosta, 8 June 2016)

Finally, the third lens is that of the 'computational juggernaut,' where 'ideas and innovations from information and computer science will open up previously unthinkable lines of inquiry' (Townsend, 2015, p. 7). Using big data, this scientific approach claims to displace 'anecdotal' knowledge (Koonin, 2013, p. 1) of the traditional social sciences, based on interviews, ethnographies, or even surveys and statistics. The capacity of new forms of data and data analytics to identify relations and patterns is understood to offer an almost direct insight in the world as it is. This allows the new urban scientists to pose the question: 'if you could know anything about a city, what do you want to know?' (Koonin, 2013, p. 2; Koonin & Holland, 2014, p. 139).

As Rob Kitchin (2017) describes, however, this new urban science has not been without criticism. Gleeson (2013), for instance, criticises social scientists for not insisting on the relevance of critical insights of urban theory, thereby losing ground to urban science. In particular, he argues, the issue with the new 'urbanology' is that it is explicitly naturalist and positivist, advocating a view of all cities as governed by natural regularities which can be studied through scientific method. In this way, Brenner and Schmid argue (2015, p. 157), such 'technoscientific urbanisms replicate, and indeed reinforce, the basic urban age understanding of cities as universally replicable, coherently bounded settlement units.' Moreover, it reduces cities not only to one another, but to almost mechanical units, ignoring their social, cultural or political complexities. In this conception, there is no need for or interest in digging underneath the surface of what can be quantified. Instead, through a fetishization of data and method (Mattern, 2013a), knowledge remains stuck in a '"problem-solving" epistemology' (McNeill, 2015a, p. 569) in the name of efficiency.

Taking a historical perspective of utopian thought around the relationships between technology and the urban, Hügel argues that this absence of a common definition 'also exemplifies the problems which attended the rise of the garden city: the lack of a robust theoretical framework capable of assessing the quality of its own real-world output, which can be subjected to examination and critique, and which can evolve to accommodate change' (Hügel, 2017, p. 3). For Hügel, the concept of the smart city has the potential to stimulate imaginative thought about the relationship between technology and the city. Without this robust framework, however, it often lends itself to uncritical adoption by city governments and corporations in projects that are neoliberal or technocratic rather than empowering or inclusive. In other words, the positive character of the adjective "smart" appeals to entrepreneurial imperative of urban planners and policy makers (see Hollands, 2008). Consequently, the term is used to describe all sorts of policies (Albino et al., 2015), as 'ambitious politicians and civil servants are ever on the search for the next "big idea" to move their city to the top of the rank of attractive places' (Glasmeier & Christopherson, 2015, p. 4).

In response to the research produced by this new urban science, various scholars have argued for a more critical approach to studying smart cities. In 2015, for instance, Luque-Ayala and Marvin (2015, p. 2107) argued that 'current understandings of [smart urbanism] lack a critical perspective compounded by an undue emphasis on technological solutions that disregard the social and political domains.' At the same time, Kitchin (2015, p. 132) wrote that 'this largely hegemonic discourse is countered by a relatively small cadre of more critically oriented urban scholars who have sought to unpack, contextualise and make theoretical sense of smart city rhetoric and initiatives.' Specifically, for Kitchin, such scholarship should focus on providing a historical context to the smart city concept, on doing in-depth research of a wide variety of initiatives, and on engaging with practitioners and scholars from across disciplines. Luque-Ayala and Marvin similarly emphasised the need for interdisciplinary research and for working collaboratively with stakeholders and practitioners, as well as the importance of international comparative analysis.

Over the years, there has been a large variety of studies responding to such concerns and engaging critically and reflectively with the notion of the smart city. Thus, a distinction can be made between scholarly research contributing to producing smarter cities – building on or in synchrony with the corporate, technocratic, problem-solving ideas – and critical research reflecting on the social and political implications of embedding technology in urban space. However, while some studies sit clearly on one side of the fence, in practice this distinction is often blurred. Various projects involve collaboration between scholars and practitioners and community organisations to experiment with creating alternative versions of the smart city (e.g. Tironi & Valderrama, 2018).

For example, the Programmable City project in Dublin 'is actively contributing empirical and theoretical insights into big data (and urban big data specifically), ubiquitous computing, and smart cities' ("Introducing the ERC-Funded Programmable City Project," n.d.). It has both developed smart city technology, such as the Dublin Dashboard (McArdle & Kitchin, 2016), which provides interactive visualisations of a wide range of data and produced a body of critical literature covering themes such as big data (Kitchin, 2014), digital urbanism (Coletta et al., 2017) urban and social media (Evans & Saker, 2019) and citizenship (Cardullo & Kitchin, 2019a; 2019b). Moreover, as will be seen in the case study of the MotionMap, even within projects there may be different perspectives and interests co-existing alongside one another.

The smart city industry

The smart city constitutes a new urban technology market drive by a number of 'smart city suppliers' (Bélissent & Giron, 2013). Much is to be gained: estimates and projections of the size of the global smart city market has been growing rapidly. In 2014, for instance, this was predicted to increase from 8.8 billion USD per year in 2014, to 27.5 billion USD per year by 2023 (Woods & Goldstein, 2014). More recently, consultants Frost and Sullivan (2019) expected 'smart cities to create huge business opportunities with a market value of $1.56 Trillion by 2025', with the largest values anticipated in the smart building (1 trillion USD) and smart transportation (423 billion USD) sectors. Meanwhile, PricewaterhouseCoopers (2019) describes – using the figures from a Grand View Research report – how the global smart city market 'is gathering pace' (p.2) as it is set to exceed 2.5 trillion USD by 2025.

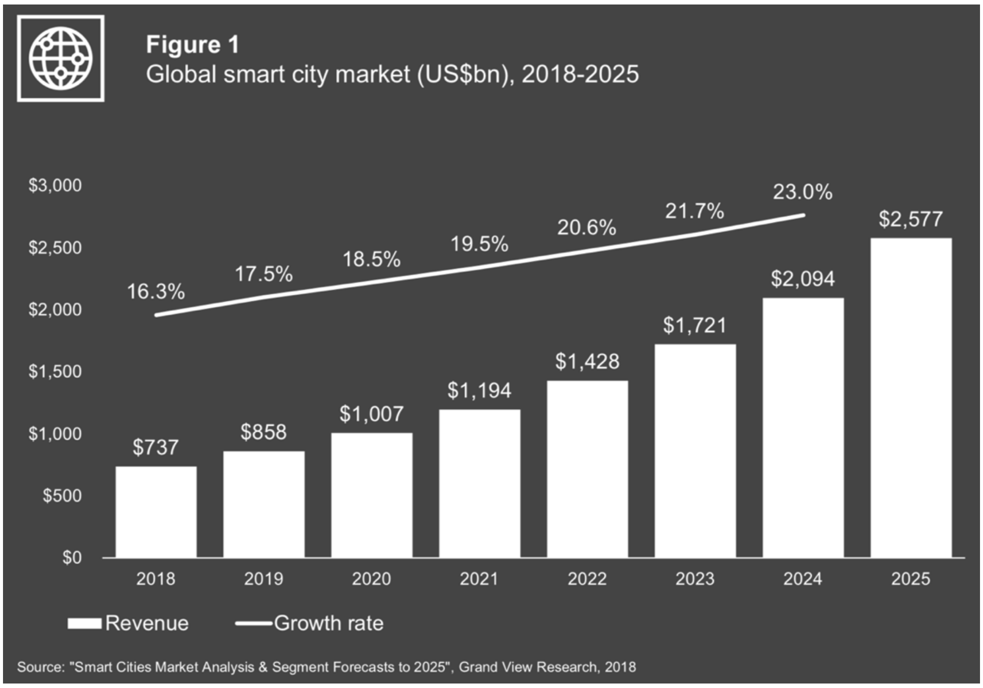

Figure 1.4 Projected growth rate of the global smart city market (PwC, 2019, p. 3)

In reformulating technological innovation around the notion of the city, tech companies and consultancies are not just following the trends in urban competitiveness but are actively advancing the importance of cities as main drivers of the world economy. For instance, McNeill's (2015a) analysis of IBM's smart city strategy describes how IBM, together with an increasing number of other corporations, is actively 'making "smarter" markets' (p. 566) where it can sell new and existing products. Analysing the 'twenty-first century's first new industry', Townsend (2014, p. 30) highlights the importance of a few key tech firms, describing for instance Siemens as the electrician and Cisco as plumber of the modern smart city (p. 63). Cisco, renowned for its expertise in networking, has been responsible for wiring up Songdo, a completely new-built smart city in South Korea, with a range of sensors, processors and other devices. As such, it is keen to emphasise its upgrade from its plumber imago, which it has been known for in historical accounts such as Townsend's: 'we used to be a plumber . . . but now we've moved from plumbing to being a platform for innovation' (John Chambers, chief executive officer at Cisco's global operations, cited in Halpern et al., 2013, p. 277).

In the meantime, Siemens has established its own showcase project at Victoria Wharf in London. Here it has built The Crystal, promoted as one of the most sustainable buildings in Europe, which serves as a museum for the role of technology in the future of the city in an urbanising world. One of its partners in constructing this building is engineering consultancy Arup, which also plays a prominent role in the corporate smart city movement. Similarly to IBM, it tries to apply its core business strengths to the domain of the city in its aspiration to become the 'prime city consultant':

> Arup is responding to the focus on city-wide challenges and opportunities by integrating our advisory services in strategy development, planning, finance, economics, consultation and operations with our key strengths in design, engineering and implementation – all delivered in a cities context. (*Arup in Cities*, 2015)

In collaboration with a range of city actors, it offers expertise across the themes of resilience, climate change, city life, economic growth, urban regeneration, 'host cities,' operations and digital cities, as spelled out in its Arup City Strategy Similarly, Microsoft's CityNext program revolves around 'more than 40 solution areas across eight city domains' which include Energy and Water; Buildings, Infrastructure, Planning; Transportation; Public Safety & Justice; Tourism, Recreation, Culture; Education; and Health & Social Services (*Microsoft CityNext: Technical Reference Model Overview*, 2013, pp. 6–7).

One of the most widely studied firms in this area, already mentioned above, is IBM, described by Townsend as having to ambition to be the smart city's 'choreographer, superintendent, and oracle rolled into one' (2014). As a pioneer on the corporate smart city market, IBM has been able to put a strong stamp on the smart city discourse, putting forward an elaborate framework of what it means to be a smart city. As part of its Smarter Planet program, which aimed to offer new solutions across a range of sectors through data analytics and technological innovation, it launched its Smarter City initiative, trademarked in 2011 (Söderström et al., 2014). Fundamental to this initiative was the Smarter City Challenge, trademarked in 2012, where the company deployed its consultants to a hundred municipalities per year, to advise city leaders on how smart technology could help address particular problems. While Paroutis, Bennet and Heracleous (2014) understand this as a key part of IBM's market orientation, as an attempt to better understand clients' needs, McNeill describes it as a way of shaping these same needs, which forms a core tenet of the firm's market making strategy.

According to a 2014 Leadership Report by Navigant Research (Woods & Goldstein, 2014), IBM is one of the firms that lead the way as global smart city suppliers. Likewise, a report by technology and market research company Forrester Research describes IBM as one of the few 'truly smart city service providers,' working across the board to 'to bring all the different pieces of the smart city puzzle' (Bélissent & Giron, 2013, p. 16). As a result, academic studies of the smart city also see in IBM a paradigmatic case for the development of the smart city market in a variety of ways. For instance, various studies focus on the way IBM takes a leading role in defining the nature and potential of the smart city, and the company's role in its realisation, through strategies of market making (McNeill, 2015) and 'corporate storytelling' (Söderström et al., 2014). Additionally, Paroutis et al. (2014, p. 263) describe IBM as an 'ideal case' (p. 263) to examine ICT companies' turn to city technology as a 'strategic option,' offering new insight into how business can respond to times of economic downturn. Finally, while these studies look at IBM's global strategy from the point of view of the firm, Wiig (2015) examines the fraught encounter between this global discourse and local city government practices through a case study of IBM's involvement in Philadelphia.

This central role of companies in propagating the smart city has led to criticism of the concept as being too corporate focussed. The 'stories' told by these tech firms are often claimed to be celebratory, utopian (Anthopoulos, 2017), 'self-congratulatory' (Deakin & Al Waer, 2011; Hollands, 2015b, p. 62) and ideological (i.e. neoliberal) (e.g. Cardullo & Kitchin, 2019a). For example, analysing documents from IBM and Cisco, Sadowski and Bendor (2019, p. 542) describe a corporate 'narrative according to which the smart city appears inevitable, the only reasonable response to an impending urban crisis.' Thus, while many smart cities rely on a set of concepts such as participatory, engaging, empowering, collaborative and transparent, the ways that these play out in practice are often characterised by a distinctly corporate, neoliberal motivation.

In their analysis of 61 smart city projects in Europe, Cardullo and Kitchin (2019a) found that despite rhetoric on the importance of the role of the citizen in the smart city, many of these initiatives followed a distinctly 'neoliberal blueprint'. Across these cities, citizen engagement was often reduced to tokenism, as projects revolved around 'marketization of service provision' rather than participation. In particular, this marketisation was manifest through technological solutionist approaches, focusing on technological solutions rather than on structural causes of problems; through nudging behaviours, aimed at educating citizens and promoting behavioural change; and through an emphasis on scaling and replication, where cities look at and implement solutions from other places (pp. 819-824).

Hollands similarly notes a 'lack of concern with democratic decision-making and real citizen involvement, participation and control' in many smart city initiatives, with citizens 'often cast as barriers in the corporate race towards the smart city' (2015b, p. 70). The most obvious examples of such corporate-led projects are large scale projects by multinational corporations, such as Songdo in South Korea, Masdar in the United Arab Emirates and PlanIT Valley in Porto, Portugal. In other cases, technology is used to develop novel approaches to advertising, in what Hollands describes as 'a trend whereby our cities are increasing becoming a backdrop to corporate advertising and the privatisation of public space' (2015b, p. 68). Underpinning all these smart city developments, however, is an attitude which relates to Cardullo and Kitchin's criticism of the smart city being technological solutionist mentioned above. As Hollands argues, 'many of our major urban problems are not technological, but social' (p. 73), yet 'serious urban problems like poverty, inequality and discrimination appear to be largely absent from these neo-liberal urban visions and projects, and there appears to be little or no recognition that smart developments might contribute negatively to social polarisation in cities' (p. 69).

Partnerships

As this smart city market has grown, more established companies as well as new start-ups have sought to join and take a share. In a process described as 'splintering urbanism,' a practice of 'unbundling infrastructures,' Graham and Marvin (2001, pp. 161–171) describe how the increasing demands on telecommunications, power and sanitation in advanced economies are addressed by the fragmentation of formerly public networks into the hands of a multitude of private interests. However, the business of cities extends well beyond the corporate realm. Certainly, in the context of smart cities, there is an important trend in new public-private partnerships and consortia between industry, local governments and academic institutions. As Claudel et al. (2015) describe, moreover, collaborations in smart city governance are often not only 'multipartner,' but also 'multicity.'

A report by Townsend (2015) gives a broad overview of how over the past ten years a number of research centres emerged in an effort to develop a scientific approach to the way cities work. The collaboration between actors spread globally across industry, academia and government, exemplified by centres such as CUSP, is prevalent model for these centres. For instance, the Future Cities Laboratory in Singapore is a research programme led by the Swiss Federal Institute of Technology in Zurich and the National Research Foundation of Singapore. In a similar fashion, the more recently established Amsterdam Institute for Advanced Metropolitan Solutions consists of an agreement between the city of Amsterdam and various partners located elsewhere, such as the TU Delft, Wageningen UR and MIT. Again, the large tech companies of IBM, Cisco and Accenture have a foot in the door, together with a number of regionally specific industry partners such as (Dutch telephone operator) KPN and Shell.

These partnerships are an important focus in studies of innovation. For instance, the Triple Helix model is used to argue that the triangle of 'university-industry-government relations' works to mobilise civil society around creativity and innovation (Leydesdorff & Deakin, 2011). Claudel, Birolo and Ratti (2015) from the MIT SENSEable City Lab argue for the importance of governments' involvement in developing smart city projects by supporting academic research and product development, and promoting 'the use of open platforms and standards' to 'speed up adoption worldwide.' However, the conflicting ideas, ideals and interests of the different actors mean that not all of these collaborative efforts will naturally enable successful innovation, standards or adoption. For instance, in a case study of the Future Cities Demonstrator Competition by the UK Technology Strategy Board (TSB), Taylor Buck and While (2017) describe a number of obstacles in the translation of smart city theory to practice. On the one hand, the aim of the competition was unclear, with some indications that the TSB focused more on 'external export opportunities' than actual improvement of urban service delivery. On the other hand, because of a lack of expertise due to, for instance, the outsourcing of IT capacity (Viitanen & Kingston, 2014) in the age of austerity, local authorities often too heavily relied on the same few consultancy firms, resulting in a rather narrow focus of innovation projects.

This drive towards new forms of partnerships is captured in the concept of epistemic communities, developed within the context of smart cities by Kitchin et al. (2017). With the proliferation of smart city initiatives across the world, a 'new smart city epistemic community' has emerged that consists of:

> a new set of urban technocrats (e.g., chief innovation/technology/data officers, project managers, consultants, designers, engineers, change-management civil servants, and academics), supported by a range of stakeholders (e.g., private industry, lobby groups, philanthropists, politicians, civic tech bodies), and events (e.g., various smart city expos, workshops, hackathons) and governance arrangements (e.g., smart city advisory boards). (Kitchin et al., 2017, pp. 2–3)

The smart city epistemic community consists of and actively promotes collaborations between these different actors and between the different sectors of government, industry and academia. These actors collaborate with a range of smart city interest groups to, together, form 'advocacy coalitions' operating, through a range of configurations of different actors and partnerships, on the global, supra-national, national and local levels.

This analysis of the smart city epistemic community is based on Haas's (1992, 2001) work in political science and public policy studies. Studying the themes of international cooperation and policy coordination in an uncertain and complex world, the concept of the epistemic community is defined as 'a network of professionals with recognized expertise and competence in a particular domain and an authoritative claim to policy-relevant knowledge within that domain or policy area' (1992, p. 3). This emphasis on networks enables an understanding of 'policy convergence' less dependent on formal agreement but rather on established 'patterns of cooperation' (p. 4) and the ability of different actors to influence each other. It offers a framework that emphasises 'the role of ideas, values, and technical understanding in shaping political outcomes' (Haas, 2001, p. 11578).

Likewise, for Kitchin et al., the concept of epistemic communities is helpful as it brings into view the complex ways in which the idea, or rather ideas, of the smart city are circulated among the different actors and across the various scales. However, as Kitchin et al. argue, the interests of the various smart city epistemic community members are not always aligned, as there is 'a blurred line between a smart city epistemic community and smart city vested interest groups' (Kitchin et al., 2017, p. 7). For this reason, they expand their discussion to include not only epistemic communities, but also a broader 'advocacy coalition.' This theme of misaligned interests will be explored in more detail in Chapter 4 on MotionMap.

Urban laboratories

One organisational format that provides a space for the various actors and stakeholders of the smart city to interact, collaborate and differentiate is urban laboratories. This format offers a language – with a vocabulary of experimentation, prototyping and testbeds – that can be shared by different actors, often meaning different things. Consider, for instance, Adibhatla's experience of developing an app which allowed bicycles to measure road surfaces in New York City:

> For me, it was more of a deliberate effort. I was prototyping, I was experimenting. It was this concept of using the city as an experiment, the city as a laboratory. What can I do with the city to reveal the city in a different way to me using the technology I already had as a citizen? (Interview with Varun Adibhatla, 6 June 2020)

This passage includes these different notions, referring to his own activities as experimenting and prototyping, but also to the city more generally as an experiment or a laboratory. Reflecting on this further, Adibhatla expands:

> there's experimentation and there's also a rapid prototype. Experimentation in the pure academic sense is to conduct a set of controlled experiments and test out a phenomenon, which is a very academic thing to do. That's where, I guess, CUSP somewhere there, versus rapid prototyping, which is experimenting a product or a way of solving a problem, but in a way that leverages technology, especially advances (…)

> when I say advances in technology, I'm talking more about the reduction in barriers to obtain this technology. (Interview with Varun Adibhatla, 6 June 2020)

This language may be used by companies to refer to product development; or by researchers to refer to processes of using data to understand the city better; or by policy makers to implement new initiatives.

Across this theme of urban labs runs a certain sense of uncertainty and futurity, allowing the deployment of different imaginaries of what the smart city is or should be. Indeed, Townsend et al. (2010) argue that as the potential of data to transform the city has become apparent, new tensions have emerged and 'battle lines' have been drawn with respect to what this potential entails and how it can be realised. In this context, the logic of prototyping is fundamental to figuring out what the new forms of data can actually be used for:

> Realizing the opportunity from urban data will require combinatorial local innovation: continuous, rapid, dirt-cheap cycles of prototyping. (…) These experiments will create new templates for commons creation, design, and planning, markets and governance at the scale of individual citizens, networks, and cities. (n.p.)

In this vision, every city will be turned into a 'civic laboratory,' where 'technology is adapted in novel ways to meet local needs.' The goal of this experimentation is to provide a 'catalyst for cooperation' (Townsend et al., 2010), bringing together top-down corporate forces with bottom-up activist voices to maximise technology's economic potential while preventing new forms of exclusion and promoting transparency, openness and participation.

Urban labs and experimentation underpin new urban research areas such as that of the new science of cities, but also product and service development by smart city providers and even new forms of urban governance. It plays out on a number of different levels: from experimenting with technologies, ideas, smart city applications and particular forms of collecting or analysing data, to conceiving the city itself as a laboratory. Many research centres involved with the smart city, urban informatics and the science of cities frame themselves around this notion of the laboratory. Among those centres that work on 'the most novel approaches to the study of cities,' for example, are the SENSEable City Laboratory at the MIT, the

Urban Informatics Research Lab at Queensland University of Technology in Australia, and the Future Cities Lab in Singapore (Townsend, 2015).

For the Future Cities Catapult in London, which will be discussed in Chapter 5 on Whereabouts London, experimentation was linked to innovation. Having since merged into the Connected Places Catapult, the Future Cities Catapult described itself as one of many 'smart city demonstrators.' Its role was to help accelerate the technological and commercial development of new smart city products, services and solutions:

> In a broad sense, demonstrators aim to de-risk the development and scale-up of innovative products, services and solutions that are not yet ready for the mainstream market. They do this by providing safe environments in which solutions can be developed, tested and proven. (Griffiths, 2019, p. 16)

In addition to individual demonstration projects, Griffiths (2019, pp. 16–17) identifies a range of 'underlying infrastructure or platforms' such as test beds ('physical or virtual infrastructure that enables experimentation, development or testing of products'); living labs ('user-centred, open innovation ecosystems that use a co-creation approach to solutions or service development in real-life settings'); proving grounds ('typically comprise open-access, private realm, controlled environment facilities to enable the testing of new solutions'); test networks (open-access communication networks, typically available for non-commercial purposes, to enable the prototyping of new products and services'); and virtual demonstration platforms ('digital representations of real locations that enable collaborative, virtual experimentation, improved planning and informed decision-making').

Similarly, for CUSP in New York, the notion of the urban lab is crucial, referring not just to experimental projects within the city but to the city itself as laboratory – as evident in its vision statement, in which it describes itself as:

> a unique public-private research center that uses New York City as its laboratory and classroom to help cities around the world become more productive, livable, equitable, and resilient. CUSP observes, analyzes, and models cities to optimize outcomes, prototype new solutions, formalize

> new tools and processes, and develop new expertise/experts. (Koonin, 2013, p. 8).

Thus, the Center contains a number of projects that fit the city with various sensors to measure its performance. One of its flagship projects is the Urban Observatory in which a camera takes a picture of the city every ten seconds from the top of a building in Brooklyn, in order to analyse the 'pulse of the city' ("NYU CUSP Unveils First-of-Its-Kind 'Urban Observatory' in Downtown Brooklyn," 2014). It is hoped that this information will help 'improve various aspects of urban life, including energy efficiency, detecting releases of hazardous material, tracking pollution plumes, aiding in post-blackout restoration of electrical power, and more.'

As Karvonen and van Heur (2014) point out, the conceptualisation of the city as laboratory has a long history, tracing it back to the Chicago School. One of the foundational texts of modern urban studies (Acuto, 2011) by Robert Park, for instance, ends with the conclusion:

> The city, in short, shows the good and evil in human nature in excess. It is this fact, perhaps, more than any other, which justifies the view that would make of the city a laboratory or clinic in which human nature and social processes may be conveniently and profitably studied. (Park 1925/1967, 46)

Gieryn (2006) gives a detailed account of how the various scholars in the Chicago School alternated between understanding the city as a field-site and as laboratory. While the former describes the researcher as immersed in the object of study, finding knowledge that exists out there and is place-specific, the latter is detached, universal and carefully (artificially) constructed. The concept of urban laboratories in the contemporary context is quite different from that of the Chicago School, in particular in regard to the blurring of this distinction between immersion and detachment. With the proliferation of urban interfaces, the city is increasingly the simultaneous object of research and the site of intervention.

The notion of the experiment has been described as fundamental to understanding the politics of cities' response to issues such as climate change. Indeed, as Bulkeley and Castán Broto argue, writing about the proliferation of localised, uncoordinated urban climate change initiatives, 'rather than occupying the margins of urban responses to climate change, such interventions can be regarded as *climate change experiments* that are central to the ways in which mitigation and adaptation are being configured and contested' (2013, p. 362 emphasis in original). These experiments are specifically linked to newly emerging partnerships between public and private institutions, blurring the lines between 'categories of producer and consumer, public and private, regulatory and economic' (p. 373). Similarly, Karvonen and van Heur describe the importance of urban laboratories in terms of the way in which they can 'strategically negotiate the boundary between inside and outside through the channelling of authors, data and resources' (Karvonen & van Heur, 2014, p. 388).

Similarly, the mega-project of building the smart city of Songdo, in South Korea, can be described an experimental city, in the sense of its purpose as a prototype 'for other cities to consider for future implementation while simultaneously acting as large-scale experiments for the incorporation of state-of-the-art technologies into urban landscapes' (Rugkhapan & Murray, 2019, p. 284). Songdo has been conceived as a 'new model of public-private cooperation including the formation of a public-private cooperation company (PPCC),' comprising of technology providers – most notably Cisco – and a number of private developers and public bodies (Halpern et al., 2013, p. 282). Its entire design is interlaced with technology – sensors, interfaces, control rooms – to improve the city's efficiency as well as its people's well-being. It is one of the first few new cities that have been entirely envisioned as a smart city from its conception. It is an experiment in smart city-building, serving as a model for smart urbanism globally. In addition, as a testbed, many of the technologies implemented here are prototypes for smart city technologies designed to eventually be sold in other smart cities across the world.

The language and practice of experimentation and prototyping can serve as a way into studying the wider social, political and economic trends in which the smart city takes place (Laurent & Pontille, 2019). This is evident in Halpern et al.'s analysis of Songdo as a testbed, not just in the sense of testing particular products or technologies, but as an experiment in smartness itself: it is 'a study into the possible ways modern digital technologies change the way we *will* inhabit our cities and the means by which these technologies *will* change our perception and experience of urban reality (Halpern et al., 2013, p. 292 emphasis in original). It is this last facet of Songdo's experimentalism which, considering the enormous size of the project, has been described as exemplary of a new epistemology of 'test-bed urbanism':

> a new form of epistemology that is concerned not with documenting facts in the world, mapping spaces, or making representative models but rather with creating models that *are* territories. Performative, inductive, and statistical, the experiments enacted in this space transform territory, population, truth, and risk with implications for representative government, subjectivity, and urban form. (Halpern et al., 2013, pp. 274–275)

The urban lab of the smart city, urban informatics, and the new science of cities is different from that of the Chicago School mentioned above. It is no longer a backdrop for studying and analysing and human behaviour. Rather, understanding through empirical deduction and observation is displaced by a logic of inductive description and intervention. The city of ubiquitous computing conceived in this way is a space of algorithmic governance, of continuous management, where norms, normality, are constantly recalculated against an ever-moving base line of data flows.

Focus on cities

An omnipresent theme in the literature on smart cities is what has been described by Brenner and Schmid (2014) as the 'urban age thesis:' that the urban population now globally exceeds the rural, for the first time in history, with the balance continuing to shift in its favour. This thesis, Brenner and Schmid describe, finds it origins in research into urbanisation by the United Nations which, having started in the 1950s, started to predict global urbanisation from the 1980s. Established as a recurring feature in a series of reports – in particular the regular World Urbanization Prospects and the Global Report on Human Settlements, the thesis has since become a 'seemingly omnipresent discursive trope' in a wide range of publications. Whether as 'framing metanarrative' or as 'branding device', it has been used to inform reports by international organisation, governmental and nongovernmental agencies, planners, consultants, technology firms, journalists and academics (2014, pp. 733–734). Thus, 'the urban age appears, in short, to have become a de rigueur framing device or reference point for nearly anyone concerned to justify the importance of cities as sites of research, policy intervention, planning/design practice, investment or community activism.'

As the start of this chapter illustrates, the importance of the smart city is explicitly located in this urban age thesis. Usually citing UN reports, almost every publication starts with it: from white papers of tech companies and consultancies trying to establish themselves in the smart city market, reports of research centres, articles by journalists commenting on these trends and papers by critical scholars analysing the movement.

> According to the United Nations Population Fund, 2008 marked the year when more than 50 percent of all people, 3.3 billion, lived in urban areas, a figure expected to rise to 70 percent by 2050 (UN, 2008) (…) The current scenario requires cities to find ways to manage new challenges. (Albino et al., 2015, pp. 3–4)

> Global trends towards urbanisation are associated with wide-ranging challenges, creating complex pressures on environments, infrastructures, buildings, networks, resources and people in cities and regions. Cities account for an estimated 60–80% of global energy consumption and 75% of carbon emissions (UN 2015) … Cities therefore need to develop the infrastructures, systems and services to help citizens live, work, play and travel. (Caird, 2017, p. 1)

> The unprecedented rate of urban growth creates an urgency to finding smarter ways to manage the accompanying challenges. (Nam & Pardo, 2011, p. 282)

> Between 2010 and 2050, the number of people living in cities is expected to increase from 3.6 billion to 6.3 billion. … This expansion in the urban population is already having a profound impact on the global economy, on demand for infrastructure and resources, and on new thinking about how cities are designed and managed. (Woods & Goldstein, 2014, p. 4)

As a framing device in the context of the smart city, the repetition of this thesis aims to convince readers – including policy makers – of the seriousness of the problems faced, the necessity of working towards radical solutions, and the inevitability of the role of the city in producing these solutions. While many articles and reports aim to demonstrate the value of new technologies in solving cities' problems, they often seem to take for granted the fact that these problems – and their solutions – must indeed be urban. By introducing every paper – 'mantra-like' (Brenner & Schmid, 2015, p. 156) – with this simple and impactful statistic, this becomes a premise so obvious that it hardly needs to be questioned.

Yet, as a number of critical scholars have remarked, it is important to question this premise, as its construction is intertwined with a number of ideological assumptions and implications. For Brenner and Schmid, the urban age thesis is a problematic basis for understanding contemporary process of urbanisation because it rests on incoherent definitions as to how to measure as well as how to conceptualise the city. It 'divides the indivisible' by maintaining an oversimplified distinction between the urban and the rural as a one-size-fits-all model. In so doing, it 'lumps together the unrelated and the inessential:' both categories contain such a wide range of phenomena and 'divergent conditions of population, infrastructure and administrative organization' that they cannot take account of the complexity of global urbanisation processes the thesis claims to cover (Brenner & Schmid, 2014, pp. 747–748). Urbanisation, they argue, is not simply a process of population movements that results in the establishment or expansion of a particular settlement type – i.e. cities. Rather, it is a global phenomenon that affects different places in different ways.

Thus, within the urban age thesis, the city becomes a concept that encompasses a diverse series of phenomena that vary across space and time. Departing from the same notion that there is a large variety in urban forms, Wachsmuth (2014) argues that while the city may be outdated as an analytical description, it has managed to persist as a category of practice – as 'plausible ideological representations of these processes' (p. 81) of urbanisation. While the heterogeneity of urbanisation makes the city unsuitable as a category of analysis for social science research, it endures as a practice of cognitive mapping, of making sense of contemporary urban experiences. On the one hand, it perseveres because cities 'continue to correspond to a common experience of urban society;' on the other, because 'the traditional concept of the city is ideological but adequate to urban elites' (2014, pp. 99–89). In other words, 'the city-as-a-representation is not neutral or innocent, but rather is *ideological*, in the sense that its partiality helps obscure and reproduce relations of power and domination that critical spatial theory seeks to expose and confront' (2014, p. 76 emphasis in original).

In the context of smart urbanism, too, the concept of the city has substantial persuasive power. For instance, McNeill (2015a) describes how, while the use of the label 'smarter' had become widespread in many of IBM's campaigns by the end of the 1990s, it was applied specifically to the domain of cities in the company's Smarter Cities strategy. Responding to a series of wider economic and technological developments – declines in hardware sales, emergence of a knowledge-based economy, the rise of big data, increasing complexity in urban management, lack of funding for innovation in service provision – IBM turned to cities through a strategy of 'remixing.' This strategy entailed the reframing of existing products, skills, expertise, business models and research to fit in the context of the city. By redeveloping many of its existing services and products from outside the field of cities to give them an explicitly urban focus and application, the city was used 'as a stable discursive signifier that can orient several vertically integrated elements of the firm's core business, enriched by acquisitions and research and development investment' (McNeill, 2015a, p. 564). Reshuffling its organisation so that it can build on its 'core competences' while sidestepping the '"traditional" urban professions' (p. 566), IBM carved out a global smart city market with itself at the centre.

Thus, smartness does not necessarily need to be urban. For example, Kar et al. argue that after smart cities, the next step in the journey towards smartness is the establishment of 'smart nations.' These are nations

> in which urban and rural citizens, governments, and businesses live in a digital society that interacts and generates value, which benefits all stakeholders. The concept of digital nations is broader and more encompassing than smart cities, as it covers an entire country. (Kar et al., 2019, p. 495)

However, by reorienting innovation towards the urban, the smart city is a strategy of territorialising technology. Following Angelo and Wachsmuth's (2014) notion of 'methodological cityism,' this suggests a technological cityism, as an 'analytical privileging, isolation and perhaps naturalization of the city' (p. 20) in technological innovation. While technological innovations could possibly result in geographic diffusion, the move from the smart city as analytic to strategic concept is a way of reinforcing the framework of competition and thereby maintaining and confirming the logic of urbanisation. The literature on global cities is rather separate from that on smart cities as this has not widely been studied in smart city research so far. However, it is important to understand these debates as it highlights the historical and political context of the construction of the smart city idea.

In the face of global issues such as climate change, the use of technology offers a way for cities to locate obstructions and inefficiencies. At the same time, it also constitutes a point of distinction for cities competing for a place in the ranks of smart cities (Giffinger et al., 2007). Thus, the adoption of advanced technologies, and in particular the ability to lead the way in innovation become focal points for ascending in the global hierarchy, and essential to surviving in the never-ending race between cities:

> Where does the future take us? It is easy to predict. Those cities that do not change, that do not forge ahead with the use of innovative urban planning, technological and governance models and intelligent use of resources, those that do not follow the concept of smart cities, will be left behind, with all the negative consequences for their population. They will lose financially, miss the best human talents and suffer economically and environmentally. (Gruen, 2013, p. 6)

In a framework where competition between cities is given, it is paramount for increasingly dense cities, in an increasingly uncertain world, to stay ahead of technological innovation in order to be able to (continue to) attract capital and human resources (Caragliu et al., 2011). To this extent, it is useful to 'consider the smart city as a new iteration of entrepreneurial governance strategies' (Wiig, 2015, p. 260). As cities compete to take advantage of global flows of capital, labour and information, only those that can steer and adapt to new technologies will be able to earn their spot in the hierarchy of cities.

Data and technology

In addition to a rise in prominence of the role of cities, the emergence of the smart city relies on the increasing importance of digital technology in society.

As developments in digital technology continue to make their mark across social and political life, there are a number of ways these have an impact on the smart city – both in terms of monitoring urban process and in generating new insights in how cities work. Large amounts and wide varieties of data are increasingly available for analysis, some captured specifically for urban management purposes, others as a by-product of everyday activity. While there is a longer history of big data sets, Batty (2016, p. 322) argues, 'only in the last 10 years has the computer revolution extended out to the city itself in the form of sensors being embedded in the fabric of the built (and natural) environment as well as being embedded as extensions of ourselves in smart phones and related digital devices.' The smart city's promise is that through a diverse range of technical applications cities can be more efficient, sustainable, resilient and safe. At its foundation is the increasing volume and variety of information about the way cities function and the growing ability to make sense of it.

In *The Data Revolution*, Kitchin (2014, p. 68) describes that big data is most commonly described in terms of their volume ('consisting of terabytes or petabytes of data'), velocity ('being created in or near real-time'), variety ('being structured and unstructured in nature'). Further, it is understood as exhaustive (capturing entire populations or large samples), high-resolution, relational ('enabling conjoining of different datasets) and flexible (being able to extend and scale). Aside from size or volume, one of the defining characteristics of big data is a shift 'from a focus on space to one on time' (p. 324). With the rise of real-time and ever-more granular levels of data, it is possible to draw pictures of cities at ever more detailed temporal scales. In particular, big data will be instrumental in understanding cities and their structures as functions, networks and patterns change over time, monitoring 'continual change over minutes, hours, days, weeks, months and so on' in order to 'reveal subtle changes in their form and function' (p. 325).

Batty (2016) gives a number of example of sources of big data in the city, including fixed and mobile sensors, remote sensing images, administrative demographic data and social media. In their systematic review of data science and software engineering studies of smart cities, Moustaka, Vakali and Anthopoulos (2018, p. 17) found that one of the most prevalent sources of urban data was the use of devices – either fixed ('located at specific places') or moving ('installed on a vehicle or other moving objects, or it is held by humans'). Other ways of generating data included network infrastructure (connecting devices), web and mobile applications, but also surveys, questionnaire, statistical records and reports. As people interact with a wide array of digital interfaces, they leave behind 'data trails.' These trails consist of 'digital footprints (data they themselves leave behind)' as well as data shadows (information about them generated by others)' (Kitchin, 2014, p. 167).

In addition to the notion of big data, the smart city also relies on the concept of open data. Historically, the use of data has often been limited to select groups of people, either because access has been restricted or because specialised tools are needed for analysis. In response, open data movements aim to widen access, both by making data publicly available and developing tools to engage with this data. These are based on principles such as 'transparency, accountability, participation, innovation and economic growth' (Kitchin, 2014, p. 49). As Ojo, Curry and Zeleti (2015, p. 2326) argue, 'Open Data initiatives are part of the efforts by governments at all levels to open up to enhance transparency, better empower citizens, foster innovation, and reform public services.' An example of such an open data initiative is the London Datastore, which will be explored in more detail in the case study of the Whereabouts London project. The London Datastore is a:

> free and open data-sharing portal where anyone can access data relating to the capital. Whether you're a citizen, business owner, researcher or developer, the site provides over 700 datasets to help you understand the city and develop solutions to London's problems. (https://data.london.gov.uk)

Such datastores have been prominent projects in many cities, including Milton Keynes (as will be discussed in the MotionMap case study) and Manchester. Other examples of smart city initiatives that include a prominent emphasis on open data are Smart Kalasatama in Helsinki, Apps for Amsterdam, Open Cities in Barcelona, Cook County Open Data in Chicago (see Ojo et al., 2015, pp. 2329–2330) and Bristol is Open. As Kitchin (2014, p. 56) describes, the argument for open data has been most well-developed in the context of public sector data, while business is often more reluctant to make its data accessible.

In New York, open data has been recognised as fundamental to developing smart cities and urban informatics, with New York City leading the way in making data available for the public. As Kontokosta explains, discussing the development of the smart city in New York:

> I think from the city perspective [open data] was the first piece of it. I think you can't do anything in terms of data analytics in a city until you have the data and then ultimately make it available and transparent. That's core to some of the foundational elements of what it takes for a city to actually be data driven. So, New York City was one of the leaders in doing that, first out of the box and having a very substantial open data polity and has now made massive amounts of information available. (Interview with Constantine Kontokosta, 8 June 2016)

However, Kontokosta continues, 'that's of limited usefulness to be honest.' Opening up the city's data sets for public use is a fundamental but insufficient first step. Both Kontokosta and Holland agree that a key issue in the ability to make use of this open data lies in the incompatibility of data sets of different agencies:

> the different data sets from different agencies don't speak to one another. They're designed for different purposes; they're defined and collected for specific purposes that aren't necessarily what may be most interesting. A lot of the interesting work comes from just integrating different data sets and finding patterns and correlations that one might not have thought. (Interview with Constantine Kontokosta, 8 June 2016)

Similarly, Holland argues:

> open data is a piece of that data part, but you actually want agencies to be making full use of their data or the municipal government's data whether it's open or not. Open data is going to be a small sub-set of all data within an agency for a wide variety of reasons and you want to make sure that the agencies are making the maximum use of that data that they already have on hand. It's a very valuable resource and it's grossly under-utilised and so developing the skills within our students to be able to do that and then developing that capacity and that understanding in the agencies as to how to do that, that's where the huge opportunity is. (Interview with Mike Holland, 8 June 2016)

As the case study chapters will show, this commitment to or interest in open data underpins the projects of the MotionMap and Whereabouts London. Both projects try to address this issue of incompatibility of different data sources, drawing together a wide range of data from different places in order to map and develop insights by finding correlations between them as well as to promote transparency and engagement.

As open-ness has gained importance across many spheres in contemporary, network society, so too has it become one of the fundamental principles for smart cities. In the process, it has become a concept that is often taken for granted. As Tkazc argues, 'once something is labeled open, it seems that no more description in needed. Openness is the answer to everything and it is what we all agree upon' (2012, p. 403). However, its precise meaning has remained elusive. Exploring the notion of the open in Popper's work, Tkacz describes how it is often described in terms of what it is not, rather than what it is. Indeed, to give a precise definition is to close the concept to what it could be: 'a precise truth of the open – is simultaneously the open's closure' (Tkacz, 2012, p. 402). This lack of clarity allows a wide range of organisations to describe themselves as open, mobilising associated concepts such as transparency, collaboration, competition and participation, without much opportunity for these claims to be scrutinised.

In addition to the existing administrative data referred to in these debates on open-ness, the smart city also generates and makes use of new forms of data, for instance via sensors and social media. As Holland argues,

> I think the bulk of what people talk about in terms of smart cities definitely comes out of the Internet of Things area of research. So, you've got dead cheap sensors that you put into your physical infrastructure and that produces a data stream that flows back somewhere and allows somebody to monitor the condition of some piece of infrastructure. (Interview with Mike Holland, 8 June 2016)

He continues:

> There's another piece that I would think of as much more opportunistic and so that is realising that you already have a lot of unintentional sensor networks in the city and the trick is to find them, pull the data, understand the limitations of those and what the shortcomings in those unintentional

> sensor networks are and then figure out how to use that data flow in an opportunistic sense. (Interview with Mike Holland, 8 June 2016)

Thus, 'new opportunities' are derived from various sources ranging from 'in situ' light, temperature and pollution sensors, to 'crowd sourced sensing' through the GPS of cell phones, social media feeds and blogs in addition to remote sensing and radio frequency (RFID) technologies (Koonin, 2013, p. 4).

These techniques are generally aimed at capturing everyday processes and the digital traces of routine behaviour of city dwellers, in order to monitor urban processes in real time. As these numerous sensors are connected in an Internet of Things (Perera et al., 2014), a 'digital skin' (Rabari & Storper, 2015) is formed, in which heterogeneous data sources combine in order to provide deep insight into the complexity of the city. Other analogies include that of the 'circulatory and nervous systems' of data (Townsend, 2009, p. xxvi) constituting the city not as static system, but more as a living, moving, evolving organism. This organism consists of buildings, infrastructure, data and, of course, people, which all are in continuous dialogue with one another. Here, hard- and software become linked in the urban fabric as interconnected systems of systems, through elaborate recursive processes of data generation, collection, mining and analytics and intervention, regulation and optimisation.

One example of implementing sensors in the urban space is the project of Hudson Yards, in New York City. Researchers of the Quantified Community neighbourhood informatics research initiative proposed fitting this US$25 billion development with an 'urban sensing platform' to 'measure and track localized environmental conditions, down to the individual street, block, or building' (Kontokosta et al., 2016, p. 1). Monitoring a wide range of variables such as 'air quality, noise, light levels, pedestrian counts, and temperature/pressure/humidity' and combining these insights with 'administrative, mobility, social media, and Wi-Fi usage data', the aim is to establish a neighbourhood profile, identify issues and – more generally – develop a better understanding of behaviour in the urban environment. As Kontokosta described:

> The idea is to try to do an intensive study of neighbourhoods to really understand how they work, how the neighbourhood environment impacts individual wellbeing, how it impacts health, how it impacts mobility and

> really trying to use the data and new sensors as a way to quantify and measure and understand how different decisions in the urban environment and different designs ultimately affect that human behaviour. It's all the things that sociologists and anthropologists and urban planners have been studying for decades. Instead of doing it anecdotally we're trying to figure out if we can begin to put measurements around this and actually look at where connections and causation actually exist. (Interview with Constantine Kontokosta, 8 June 2016)

This project has raised a number of unanswered questions, not least regarding the practicalities of installing sensors. Several years into the process of building Hudson Yards, the implementation of these sensors has been put on hold, being described as 'more aspirational than practical' (Nonko, 2019 n.p.).

Aside from practical issues, however, Mattern (2016) also raises a number of critical theoretical questions and concerns, around issues such as the notion of citizenship embedded in such a quantified community, privacy and consent, and 'surveillance and algorithmic governance.' The project is cast in terms of innovation and experimentation in the service of sustainability and liveability. However, Mattern argues, underpinning this are corporate concerns and behaviouralist ideas which can shape rather than reflect the behaviour of smart communities: 'the data we generate, based on determinist assumptions and imperfect methodologies, could end up shaping populations and building worlds in their own image:'

> From the observation deck atop 30 Hudson Yards, projected to be the highest in the city, residents and visitors will look out upon a dream made manifest: a clean, efficient urban machine; a carefully curated cultural experience; a Keller-fed, Equinox-toned, Coach-clad populace; a sustainable urban ecosystem; a harmonious community that behaves in accordance with the rules; a city that plays by the numbers. (2016 n.p.)

In Mattern's critique, the data and sensors in the instrumental city do not just measure the urban environment, looking at 'at where connections and causation actually exist,' as Kontokosta suggests above. Rather, they define what there is to be known and, in turn, the possible modes of agency, action and citizenship.

While there has been much coverage of the emergence of big data and the data revolution, Beer (2018) argues that 'we have so far given very little attention to the powerful role – both technical and rhetorical – played by the emergent industry of analytics that has come to fill this analytical space of social ordering' (p. 465). This emphasis on analytics in the smart city will underpin the case study of Whereabouts London, in Chapter 5. As analytics have become increasingly important in areas such as GIS and urban design, so too do they take a centre stage role within the smart city. Indeed, many cities include a data analytics programme in one form or another in their smart city strategies.

The London Datastore on which MotionMap is built, for example, is linked to London's City Data Analytics Programme. Its stated purpose is to 'support the development, commissioning and implementation of data science projects across different public sector organisations within the Greater London area,' but also to support 'the analytical capacity and technical development of borough data officers through a "City Data Academy"' (*City Data Analytics Programme*, 2020). Similarly, New York City has a Mayor's Office of Data Analytics (MODA), which 'applies strategic analytical thinking to data to help city agencies deliver services more equitably and effectively, and to increase operational transparency' (*About MODA*, 2020).

For Osman (2018, p. 620) the value of big data analytics in the smart city lies in their ability to draw connections and relationships between diverse sets of data, rather than the 'smartening' of individual city domains. In a literature review of the ways in which big data analytics are deployed in the smart city, Osman defines these analytics as:

> the entire processes and tools required for knowledge discovery including data extraction, transformation, loading and analysis; specific tools, techniques, and methods; and how to successfully provide results to decision makers. (Osman, 2018, p. 621)

The review gives various examples of the use of analytics in the smart city, as well as of attempts to theorise/formalise the relationship between the two. This emphasis on tools for data analysis is emphasised by Gardner (2014), who, writing on the blog of the London Datastore, argues that 2015 – as the 'year of open data'- would indicate 'a shift from how [data] is collected to how it is analysed and visualised with more tools becoming available to facilitate its effective use.'

Analysing a range of promotional material, Beer found 'a very specific data analytic imaginary in which the data analytics were presented as speedy, accessible, revealing, panoramic, prophetic and smart' (2018, p. 469). Here, analytics are instrumental in what Amoore and Piotukh (2016) describe as 'the twinned processes of data expansion and analysability.' These twinned processes involve an expansion both of what can be used as data and of the ways in which different types of data can be linked and analysed. In other words, analytics are on the edge of what Beer (2018, p. 467) calls the 'data frontiers', the 'boundary lines at which data-informed processes reach their limits.' These frontiers or boundary lines are both practical and political. On the one hand, it is through analytics that knowledge and meaning is extracted from and given to large sets of data. They make visible the patterns and relations that are hidden in the mess. On the other, by pushing 'the twinned processes of data expansion and analysability' the analytics industry promotes a particular image of a data-centred society.

The geospatial web, neogeography, VGI

The digital developments driving the smart city, described above, consist of both innovations in hardware and software. This can be understood in a wider context of the geospatial web, which arose as a research area in geography in the early 2000s. 'More commonly known as the *geoweb*,' the geospatial web:

> 'refers to the spatial *technologies* (hardware, software, APIs, databases, networks, platforms, cloud computing), *spatial content* (geo-referenced and geotagged data) and the internet-based mapping and location-based *applications/services* that they compose and enable.' (Kitchin et al., 2017b, p. 3 emphasis in original)

It describes a development in which geographical location becomes the index for organising all sorts of information. This relies on elaborate processes of geotagging – 'assigning geospatial context information' (Scharl, 2007, p. 5) of increasingly large amounts of data, which takes place both manually and automatically. Thus, the geoweb can be understood as 'the aggregate of geographically-referenced or 'marked-up' information that is increasingly used to organize and deliver content over the Web,' (Leszczynski, 2012, p. 72) understanding marked-up as 'annotated, or described, using a machine-readable syntax (e.g. XML)' (p. 86).

With the geoweb, geographic information has become increasingly linked to everyday life, in terms of capturing people's movements and behaviours, as well as their access to and interaction with this information. This has had significant implications on a variety of levels. This rise of the geoweb has sometimes been framed as a 're-emergence of the importance of geography within Web 2.0 technologies' (Hudson-Smith et al., 2009, p. 119), to counter previous ideas that the internet would diminish the importance of place. Web 2.0 refers to the transition of the internet from browsers where users can access information held in databases, to 'sites that were almost entirely populated by user-generated content, with very little moderation or control by the site's owners and very little restriction on the nature of content' (Goodchild, 2007, p. 2005; see also O'Reilly, 2005).

This emphasis on user-generated geographical information within the context of the Web 2.0 has been developed in a new type of geography: "neogeography," referring to 'a new geography based on a digitally connected world at whose core lies citizen-created data organised at an increasingly fine geographic scale' (Hudson-Smith et al., 2009, p. 118). According to Batty et al. (2010, p. 2), it is based on 'a set of at least six powerful ideas that are changing the way people interact digitally,' namely: 'individual production and user-generated content, harnessing the power of the crowd, data on an epic scale, architecture of participation, network effects, and finally openness.' Neogeography does not refer to a particular approach to the academic discipline of geography, but rather indicates 'a new way of *doing* small-g geography that stresses the personal and individual' (Goodchild in Wilson & Graham, 2013a, p. 11 emphasis in original). It indicates a 'blurring of traditional distinctions between experts and non-experts' (Byrne & Pickard, 2016, p. 1506).

Considering this emphasis on 'citizen-created data,' neogeography has often been discussed in conjunction with the concept of Volunteered Geographic Information (VGI), first coined by Michael Goodchild as a 'special case of the more general Web phenomenon of *user-generated content*' (2007, p. 212 emphasis in original). VGI emerged in the context of a number of applications, such as WikiMapia where people can add descriptions to locations; Flickr, which allows users to upload photos linked to specific places; OpenStreetMap, where volunteers work together to 'create a free source of map data' (p. 213); and Google Earth and

Google Maps, which enables users to 'superimpose geographic information from sources distributed over the Web' (p. 214). What these applications have in common is a reliance on geographical information contributed by interested users.

There has been some debate on the distinction between VGI and neogeography (e.g. see Parker, 2014, p. 12). For Andrew Turner, VGI is a central component of neogeography, referring to the 'collection of data and input from individuals' while neogeography indicates 'the personal interaction of individuals with spatial information in personal ways' (Turner in Wilson & Graham, 2013a, p. 11). In response, Goodchild argues that 'with respect specifically to data practices I think neogeo and VGI are identical. But as a new paradigm for the interaction between people and geography I think neogeography provides a much broader perspective' (p. 12). Looking at the two terms together, Kitchin et al. argue that they 'refer to the new relations and practices of geographic production and consumption that are created by the rollout and use of the geoweb' (2017b, p. 4).

In particular, the practices described by neogeography and VGI constitute a shift away from experts and professionals as sole producers of geographic information and an emphasis on notions such as democratisation and participation. As Goodchild describes:

> Neogeography implies a reinventing of geography, in which the traditional roles of expert producer of geographic information and amateur user have broken down, with the amateur becoming both a producer and user—or what some have termed a prosumer. (Goodchild in Wilson & Graham, 2013a, p. 10)

Thus, with neogeography and VGI not only the boundaries between experts and non-experts are blurred, but also those between the production and consumption of geographical information, giving rise to terms such as prosumers and 'produsers' (Coleman & Georgiadou, 2009). Moreover, putting the development of the geoweb in political economy context, Leszczynski has argued that that the changes in producing geographic information cannot be understood 'solely in terms of enabling technologies that transfer data-authoring capabilities to everyday cartographers,' but constitute fundamentally new regimes of production that make the 'prosumption' of geographic information valuable' (Leszczynski, 2012, pp. 75–76). Within the smart city, the use of crowdsourced data plays an important role.

For example, Arun Adibhatla describes a project of his time as a student at CUSP, where researchers installed sensors on bicycles to measure the “bumpiness” of road surfaces in New York City:

> We created this thing called SQID, Street Quality Identification Device, which takes a picture of the streets every second and we tested it with the city and we were able to collect 400 miles of data in a week. So then you can open up the possibilities, but we’re always confronted with this, “Oh, wouldn’t this be great if citizens did it?” (Interview with Varun Adibhatla, 6 June 2020)

Such data could be used to inform the city authorities about the state of the roads so that potholes could be quickly repaired. However, as Adibhatla described, this raised the question of what the role of citizens should be in the smart city:

> So, we chose to say that the citizen should not [be] reporting potholes, that’s not the function of a citizen. The citizen should be living their lives in the city. It’s the government that should be able to make use of tools in a way that optimises service delivery much better. (Interview with Varun Adibhatla, 6 June 2020)

Similarly, describing a pothole project in the city of Boston, Zook (2017, pp. 5–6) argues that rather than an example of ‘nuanced and engaged involvement in urban governance,’ the reliance on citizens to collect such data reduces people to sensors. It reinforces existing inequalities as the users and raises concerns about bias as the users – ‘younger and wealthier individuals—are likely to be clustered in certain neighborhoods.’

These reflections links into wider critical arguments of the use of VGI and the extent to which this can be understood as a shift towards democratisation (see Byrne & Pickard, 2016). On a practical level, Wilson and Graham argue that ‘central concern is how in very few cases this potential has been transformed into actual practice’:

> the power geometries of mapped knowledge are complex, as more than a decade of critical GIS scholarship have demonstrated. Despite the reshaping, decentralisation, and distribution of networks of geographic information, the movement of content from production to consumption,

> for the most part, remains in the hands (and devices) of a relatively small (and often elite) group of people. (Wilson & Graham, 2013b, p. 4)

The shift away from experts or professional geographers to non-experts or amateurs as producers of geographic information has often been welcomed and described as a process of democratisation. However, rather than taking this for granted, Kitchen et al. (2017b, p. 14) argue that 'the extent to which the practices of neogeography are democratising and replacing established, curated geographies' is crucial to the changing knowledge politics of the geoweb.

Similarly, reviewing the discussions about the democratising potential of neogeographic technologies, Haklay (2013, p. 56) asks 'what is the nature of this democratisation and what are its limits?' Despite the many technological innovations, Haklay argues, many of the inequalities associated with access to the internet persist that undermine 'the claim for democratisation and the recurring theme of 'anyone, anywhere, anytime"' (p. 62). The main problem, Haklay (p. 66) claims,

> in the core argument of those who promote it as a democratic force is the assumption that, by increasing the number of people who utilise geographic information in different ways and gain access to geographic technology, these users have been empowered and gained more political and social control.

To understand the democratic potential of neogeographic technologies, Haklay proposes a 'hierarchy of hacking' – different levels of engaging with and taking control and ownership of these technologies. These range from 'meaning hacking' where information is reinterpreted and 'use hacking,' the adoption of existing systems for a new purpose; to shallow and deep 'technical hacking,' where users manipulate the code of applications to create something new. 'As we go up the scale,' Haklay describes, 'the level of intervention in and change of technical codes required becomes more significant, and the number of people who have the necessary skills and knowledge, the interest in making the changes, and the time and resources to carry them through, decreases' (pp. 64-66). As a result, while the web 2.0 and VGI are based on increased access to the production and consumption of geographical information, the level of skill required to meaningfully engage with these technologies have solidified rather than destabilised pre-existing inequalities.

Crampton et al. (2013, p. 138) have argued that much geoweb research has been limited to 'simple mapping and analysis of user-generated online content tagged to particular points on the earth's surface.' Firstly, they claim that the explanatory value of big data has often been taken for granted, resulting in studies that 'are naive in the way their insights are extrapolated to make sweeping statements about society as a whole' (p. 132). Secondly, an 'overreliance on geotags' perpetuates a 'fairly simple spatial ontology' that ignores the 'multiplicity of ways that space is implicated in the creation of such data' (p. 132). Thus, while they recognise the potential value of geoweb and neogeographic research, they argue that a critical approach needs to be informed by theoretical and empirical contextualisation, by thinking 'beyond the geotag.'

In addition, while their argument focuses on the best ways of engaging with user-generated geospatial data, Crampton et al. also recognise that 'broader social, political, economic, and institutional forces remain important in structuring how big data relates to the world that it supposedly describes (2013, p. 138). Such a recognition forms the basis of Leszczynski's critique, who has described how geographers have tended to approach these issues with an emphasis on 'instrumental rationality' at the expense of 'examining the broader social implications of the framing of Web-based geographic information technologies as neo, and from assessing the work that discursive-material practices around the newness of spatial media do in the world' (2014, p. 75). In particular, she argued that the leveraging of newness as a discursive tactic—whether as proliferation and profit, rationalization of the social consequences of spatial media, or depoliticizing device—has broad social implications.'

This argument chimes with the critique of the use of the urban as a framing device (Brenner & Schmid, 2014, p. 734), as well as with the criticisms of the instrumentalist approaches to technology in the smart city. What these approaches have in common is a wariness of the purported inevitability of scientific progress and the promises of technology to solve social problems. Similarly, the debates around neogeography, VGI and the geoweb resemble or prefigure many of the discussions on smart cities described above. In particular, they can be characterised by a distinction between advocates for the positive effects of widening access to geographical information on the one hand ('boosterish' (Wilson & Graham, 2013b, p. 4)), and more critical perspectives on the other. Thus, it has been argued that ‘the corporations, technology start-up companies, and technology enthusiasts that are creating the neogeographic landscape are all adopting the instrumentalist point of view, while ignoring the deeply embedded values’ (Haklay, 2013, p. 62).

Digital mapping

In many of the centres identified by Townsend (2015) above, mapping and visualisation takes a central place in their research projects. One such project, developed as a collaboration between New York University and CUSP, is that of the TaxiVis (see Figure 1.5) which uses the origin-destination data of 520 million taxi trips to build an interactive map as a tool to explore journey data and identify any significant patterns in people’s movements. The aim of this project was to ‘support the exploration of large, spatio-temporal [origin-destination] data, and provide visualization services that are both usable and efficient’ (Ferreira et al., 2013, p. 2150). These aims entail two features that are important for digital mapping in the smart city more generally. Firstly, the researchers emphasise the importance of being able to analyse the taxi data set as a whole, rather than having to cut it up into smaller sections which may be representative or not. Secondly, the project focuses on exploration of and interaction with this data in order to generate new rather than confirm existing hypotheses.

Figure 1.5 The TaxiVIS project, demonstrating the various user interface components. (A) Time selection widget, (B) Map, (C) Tool bar, and (D) Data summary (Ferreira et al., 2013, p. 2152)

As another example, The MIT SENSEable City Lab is particularly interested in 'technologies for sensing the material world and the novel kinds of interactions they can enable with the city' (Townsend, 2015, p. 14). In order to enable such interactions, many of these sensing technologies include a mapping element. For example, one of these technologies is the City Scanner, a 'mobile sensing platform for smart city services' (Anjomshoaa et al., 2018). It consists of modular sensors which can be installed on vehicles driving through the city, such as taxis, buses and trash trucks. Its first trial was in Cambridge, MA, where sensing platforms that included sensors for WIFI, acceleration, thermal imaging, GPS, air quality, temperature and humidity were installed on trash trucks. These sensors generated a total of 1.6 million data points, which were mapped in 'near real-time' and made publicly available on the City Scanner website (see Figure 1.6). Developing this technology, the team envisioned ‘a paradigm of modular sensing components and their corresponding cloud services for data visualization, data integration, and advanced data analytics that enable cities to create elaborate applications for their inhabitants in a cost-effective manner’ (Anjomshoaa et al., 2018, p. 10).

Figure 1.6 City Scanner (Anjomshoaa, 2018, p. 11)

While these examples cited above are aimed at general exploration of the city through data, other mapping projects are developed to address very specific problems. For example, in the Netherlands researchers of the TU Delft, in collaboration with the Amsterdam Institute for Advanced Metropolitan Solutions (AMS), developed the Social Distancing Dashboard. This dashboard, covering the cities of Amsterdam, Rotterdam, The Hague and Delft is an interactive map with which residents and policy makers can check how accessible streets and neighbourhoods are while observing COVID19 social distancing measures (Figure 1.7). The map pulls together various records from government and the Bureau of Statistics and automatically visualises these using OpenStreetMap. This is published online via SocialGlass, a platform by the TU Delft and the AMS to generate interactive, explorative maps and data visualisations.

Figure 1.7 Amsterdam Social Distancing Dashboard (https://covid19.social-glass.tudelft.nl/#14/52.37199/4.89888)

This notion of the dashboard, along with the control centre, constitutes an important way in which maps and visualisations find their way into the smart city as spatial support devices to assist decision-making. A commonly cited example of this is IBM's Rio Operations Center, with its mission 'to consolidate data from various urban systems for real-time visualization, monitoring and analysis' (*City Government and IBM Close Partnership to Make Rio de Janeiro a Smarter City*, 2010). Indeed, McNeill (2016) identifies the dashboards of the Rio Operations Center as a crucial element in IBM's Smarter Cities strategy, precisely because of the 'enhanced visuality' it enables. Other cities, such as London and Dublin also have publicly accessible dashboards developed on online platforms.

As more and more cities adopt dashboards on smaller and larger scales, Mattern (2015 n.p.) has labelled this the 'age of Dashboard Governance.' She traces a history of the urban dashboard from Bloomberg terminals in the world of finance in the 1980s, to the rise in popularity of the dashboard in the corporate world in the early 2000s and a range of city dashboards in the US, 'driven by a "new managerialist" approach to urban governance.' Through dashboards, maps and other visualisations present a real-time overview of the state of the city and its constituent processes and systems, in order to facilitate flow and afford intervention when disruption looms. As monitoring devices, dashboards – defined as interactive data visualizations.' are used to simultaneously represent and direct, for 'knowing' and 'governing' (Kitchin et al., 2015), the city. Thus, in dashboards, maps are clearly linked not only with visualising and representing, but also with action.

Maps have become part of a diffuse landscape of dashboards, analytics, models and visualisations. As Rossetto argues, 'in light of the current intensification of media convergence and the growing ubiquity of digital mapping, we should acknowledge that the borderlands of cartography are much more porous and perhaps indefinable' (2019, p. 49). To capture this 'porous and perhaps indefinable' area of cartography, Crampton proposes a broad definition of digital mapping as:

> The art and science of using digital technologies to deal with geospatial data. I say 'deal with' to include digitally mediated processes of collecting data, transforming them, weeding them out and combining them with other geospatial data. And beyond that, sharing and passing forward maps or mappable digital spatial data. Digital mapping may involve the production of maps, whether on a computer screen or displayed on mobile devices – although they may or may not be the ultimate product. (Crampton, 2017, p. 35)

Along with these many new kinds of maps, their role in the context of big data and the smart city is manifold. Crampton's definition refers to a multitude of ways in which maps relate to the data they represent, ways in which they are used and produced, and formats they may take. In this context, Crampton suggests thinking of digital maps as spatial media, referring to the ways in which 'geospatial information can be produced, shared and analysed to create value and to act as media for communicating other information' (pp. 35-36).

Through this concept of spatial media, these trends in digital mapping can be understood in the wider context of digital geography, the geospatial web, neogeography and VGI as discussed in Chapter 1. Indeed, as Crampton (2009, p. 91) remarks with reference to these various terms: 'all of these activities are based around and dependent on mapping.' For Batty et al. (2010, p. 2), the use of the concept of neogeography in relation to mapping 'addresses the fact that it is now possible for users other than professional geographers, geographic information scientists and cartographers to create their own map content, and this has the potential to broaden the domain of interest and applications quite radically.'

In congruence with the discussion on neogeography in Chapter 1, spatial media signify a trend towards more diverse ideas around the production and consumption of geographic information, away from professionals, and for a wide variety of applications. Crampton describes several key themes that signify this shift towards deprofessionalisation with relation to digital mapping. For example, the use of free and open-source software has enabled users to experiment with various types of map mashups – 'the combination of geographic data from one source with a map from another source (eg, Google or Yahoo) using an application programming interface (API)' (Crampton, 2009, p. 93). In addition, crowdsourcing and geocollaboration entails the collaboration of large numbers of users in different places to create new maps (pp. 95-96).

Similarly, Batty et al. (2010, p. 2) argue that mashups, with the map mashup as 'exemplar par excellence,' are in many ways synonymous with the GeoWeb and should be considered as 'the true definition of Neogeography.' Writing in 2010, when the availability of data and software accessible to non-experts was only just taking off, they identified an increasing number of map mashups in a field described as 'inchoate.' These could be categorised along a spectrum (p. 3) ranging from 'basic portals that provide maps as a backcloth which users can customise' (e.g. Google Maps), to applications built on these basic platforms and secondary software providing 'methods for tiling or layering the backcloths provided by basic portals' (e.g. GMapCreator, MapMaker) to 'basic software (…) that lets users themselves create content' (e.g. OSM). These developments raise a range of technical question with regards to issues such as 'standards, formats, security, privacy and confidentiality' (p. 4).

Crucially, the trend towards these map mashups and the concept of spatial media has been used to mark a distinction with Geographic Information Systems (GIS). The emergence of the concept of spatial media can be understood in a context in which '"old school" Big GIS with black-boxed proprietary software is less dominant' (Crampton, 2017, p. 40). The relationship between GIS and spatial media has been conceived in a variety of ways. 'The "ordinariness" of spatial media' is often contrasted to 'GIS, which remains a specialized technology often the preserve of trained experts' (Leszczynski, 2015, pp. 746–747). On the other hand, Sui and Goodchild (2011) identify a 'convergence of GIS and social media,' where online mapping sites are increasingly social' (p. 1737), while simultaneously social media is 'increasingly location-based' (p. 1739).

Rather than focusing on the differences between traditional GIS and spatial media, Ricker claims that 'spatial media are a form of GIS that permeate our lived experiences and influence our experience in place, which often go unnoticed to a consumer or producer of spatial media' (Ricker, 2017, p. 26). Describing a shared history of GIS and spatial media, she argues that these new media rely to a large extent on the technologies developed under the label of GIS. Understanding this trajectory as a continuum rather than a big break with the past is helpful, Britta suggests, as 'doing so enables us to draw upon the energies and efforts (and progress) made by interventions created by critical GIS. By acknowledging the significant social, ethical and political interruptions created by GIS and spatial media, we might create a richer, more inclusive and safer environment for those involved (knowingly or unknowingly) with the creation and analysis of our spatial-mediated future' (p. 32).

In addition to these trends towards the deprofessionalisation described above, this increasing diversity of mapping technologies and applications also raises new questions of what maps do in relation to the places they depict. As analytic tools, the main role of these digital maps, and of data visualisations more generally, is often framed in terms of making complex data intelligible through the recognition and making visible of patterns and relationships. As Halpern (2014, p. 21) describes, 'visualizations, according to current definition, make new relationships appear and produce new objects and spaces for action and speculation.' Similarly, Dodge et al. (2008, p. 3) identify the power of geographic visualisations as their ability to 'augment the human capacity in order to analyse and understand the world,' describing three 'broad epistemological classes' of visualisations: those that simply display information, those that allow visual exploration, and others that let the user question relationships within the data through probing and manipulation.

However, in addition to their roles as analytic tools, within the context of digital mapping, Kitchen et al. (2017b, p. 8) have argued, the post-representational approaches to cartography covered above gain particular importance:

> While such thinking was initially applied to traditional maps it is clear it has much resonance for how to make sense of mapping within spatial media. In large part, this is because spatial media are inherently fluid, transitory, contingent and context-dependent. While a traditional map gives the impression of a fixity and a totalising and universal perspective, spatial media are constantly being updated (added to, edited) and regenerated (e.g. refreshed through zoom, panning, turning on/off features/layers, during movement), and are contextually filtered in delivery – individually (with respect to search history), temporally (results change over time), socially (based on social networks) and geographically (based on present location)

Here, the view of maps as analytic tools can be understood as an offshoot or continuation of the communication model of cartography mentioned above: the map as a neutral instrument in making complex patterns intelligible to the map user. Understanding digital maps as spatial media emphasises the many roles they can play beyond being analytic tools. It underscores the ways in which they can change and be changed, afford particular interactions and are dependent on the contexts in which they are used.

Thus, Kitchen et al. (2017b, p. 9) argue, 'the relationship between map and territory is being altered,' in particular in relation to one of the 'fundamental conventions' of cartography that 'the map is not the territory but rather a representation of it': 'spatial media are transforming the production of space and the nature of spatiality' as they are 'more and more mediating how space is understood and the interactions occurring within them' (p. 9). Digital cartography, Kitchen et al. argue, emphasises the way in which maps do not just represent but are active participants in the mediation and production of space. Within this context, Crampton (2017, p. 36) argues for the use of the idea of assemblage to understand digital mapping, in order to explore the question: 'how do a wide variety of actors, institutions and knowledges form and reform and what work do they do in the world?' Assemblage theory, Crampton claims, offers 'two useful ideas.' Firstly, it draws attention on the external relationships of digital mapping, emphasising how it is 'nested and interrelated with other issues.' In addition, it helps focusing not so much on the properties of digital maps, their technical components, but rather on their 'capacities' and the 'work they do in the world.'

Lammes (2017, p. 2) similarly focuses on mutability and context-dependency to distinguish between traditional – i.e. paper – and digital maps, describing how 'digital map users do not just read a map – they constantly influence the shape and look of the map itself.' In contrast to traditional maps with their static map images, in which map-makers make the decisions regarding what is included, she argues that:

> Digital maps no longer entail or promote such objectified and static representations of space. Whether it is a map on a navigational device that adjusts its route-display according to where the driver chooses to go or a map in a computer-game that is partly created by players, maps have become interactive to the point that they are co-produced by their users. At home, at work and while we are travelling, maps have become more personal, transforming while we navigate with and through them.

She describes how different mapping applications, such as TomTom, Waze and OpenStreetMap, provide different levels of trade-off between reproducibility, inscription, and the level of control users can exert. On the one hand, users may have more freedom to personalise or alter map images. On the other, they remain entangled in networks of immutable mobiles such as proprietary databases, satellites and Wi-fi access points which are 'immutable, asymmetrical inscriptions over which users have little control' (p. 12).

This raises new questions regarding the nature of map and how its continuity can be understood when the map image is constantly changing. For Lammes, drawing on a Latourian terminology, this mutability of the image is in turn made possible by 'a network consisting of an assemblage of plural immutable mobiles' (p. 2). Graham (2017) explores this same question within the context of the role of maps in the production of 'digitally augmented geographies.' What is different from previous forms of spatial media, he argues, is the way in which 'contemporary spatial media are able to easily separate content from its containers and attach it to places' (p. 50). As more and more data become georeferenced, it becomes attached to places such that it can be accessed independently through different interfaces. Data becomes part of places rather than of media, so that 'the map is indeed becoming part of the territory' (p. 44).

As this discussion on digital mapping demonstrates, developments in mapping technologies require and provoke new ways of conceptualising maps and their relation to space, place, user and producer, media, format and application. While it does not provide a specific new theoretical paradigm, it raises a number of issues on the changing nature of maps and signposts a few of the ways different authors have started to theorise this. The diversity of formats, uses, and ways of interacting with these maps calls into question definitions of what constitutes a map and, consequently, ideas on how it should be studied. It highlights the problematics of the relationships between the map and the territory, between data and the map image, and between representation and intervention, knowing and governing. In raising such questions, the study of maps is able to engage with many of the concerns around the study of smart cities introduced in this chapter.

Conclusion

This chapter has outlined some of the key debates on smart cities, highlighting a number of the fault lines that run across these debates, dividing and connecting the different participants. Firstly, the discussion of the concept of the smart city gave an overview of the different ways in which this has been defined and studied. This section highlighted a complex and sometimes confusing mix of ideas and interests, with malleable alignments between multinational corporations, public policy makers, new urban scientists and critical scholars. Secondly, the chapter has sought to unpick the way in which the smart city has been constructed as the apparently inevitable outcome of the intersection of technology and urbanisation, examining how not only smartness, but also the "city-ness" of the smart city can be problematised. Next, it focused on some of the ways in which the different actors – e.g. governmental, corporate, activist, academia – relate to one another in the construction of the smart city and the smart city industry.

The chapter then focused on various ways in which technologies and data have been deployed in the smart city, ranging from big and open data to the use of sensors and data analytics. This discussion of data and technology were put in a wider context of debates in social theory and geography on the geospatial web, neogeography, and Volunteered Geographical Information. These debates address the increasing importance of data in people's everyday lives and the new opportunities for people to engage with the use and production of this data. Finally, this discussion of technology and data highlighted the changing landscape of digital mapping in the smart city and the different theoretical approaches that have been developed to address these changes.

To be sure, there are many more concepts and debates that could be covered in the study of smart cities. For example, the way smart cities have been spread in uneven ways across the world and the ways in which this has led to new inequalities both within and between nations is an important area for discussion. The issue of citizenship – what it means to be a citizen in the smart city – has been woven through this chapter but could certainly be unpicked further as a topic on its own. The selection featured in this literature review has been made on the basis of two criteria. Firstly, these are topics that expose many of the fundamental differences between the ideas of the various smart city stakeholders. Secondly, they have been selected because of their relevance to the case studies and their capacity to inform the analysis of the MotionMap and the Whereabouts London.

All of these themes run across the two case studies. However, each case will place an emphasis on particular themes. For the MotionMap, in Chapter 4, the notion of the prototype is at the heart of the analysis. This chapter will therefore especially draw on concerns around prototyping, experimenting and urban laboratories. It will include discussions of the types of data and technology used in the project and explore the way this has been envisioned in reference to ideas around citizen participation. Developed by a consortium, the role of partnerships will also be a key part of the discussion, examining the way different actors have different values and interests within the same project. The Whereabouts London chapter will also look at the use of data in the smart city, connecting to the debate on open data and highlighting issues around participation, but also about transparency and inclusiveness. By providing an overview these debates, this literature review serves to raise an awareness of some of these key issues that will inform the analysis of the case studies.

2. Maps as objects

In March 2014, Steven Koonin, director of CUSP, and Nigel Thrift, then Vice-Chancellor of the University of Warwick, celebrated the partnership of CUSP and the Warwick Institute for the Science of Cities (WISC). Here, they discussed the rise of big data and its promise and pitfalls for better understanding and organising the city. Thrift concluded the conversation by arguing that:

> One of the things that these developments are producing is of course a new representation of things and the thing for me as a geographer that is exciting is that right at the centre of all these developments if you like is mapping. And I can remember twenty years back people thought that mapping was just kind of boring, and we'd done it all. And now, you know if you look, new kinds of maps are appearing all the time – maps that are genuinely an analytic tool. You've got to be able to see the problem to begin with. And I think it's a really exciting time actually, in terms of precisely these kind of things. And what I like about it, it's both an analytic tool and at the same time these maps are brilliant aesthetic tools. (*Urban Informatics: A New Science for Better Cities*, 2014)

Mapping, Thrift argued, is at the centre of developments of the smart city and urban informatics: they offer a 'new representation of things,' they help us visualise the problems, functioning simultaneously as analytic and aesthetic tools. What makes the emergence of smart cities and urban informatics an 'exciting time' for Thrift is the development of 'new kinds of maps' that didn't exist previously. The growing availability and prominence of data requires new tools for analysis and making this information accessible. Maps are able to draw together different forms of data such as sensor outputs, administrative records and social media information in order to make connections, visualise patterns, and generate novel insights. There are a number of technological innovations that converge in the smart city that generate an increasing availability of data that can be visualised and mapped – as touched upon in Chapter 1.

Over the years, maps have been a fascinating subject to a wide variety of audiences. People use maps to navigate, to mark their territories, to tell stories. From an academic perspective, the map attracts scholars from geography, but also from disciplines as history, sociology, anthropology, political science and philosophy – to name a few. Unsurprisingly, therefore, there are many ways of thinking about and studying maps. They have been used for navigating, to document new trade routes, as instruments of power and oppression, as tools for protest and subversion. They have been refined as technological devices, drawing on the latest scientific advances, and experimented with as works of art. Indeed, in the smart city, the digital map has become a familiar figure. As the technologies available to produce and use maps develops, so too does our thinking about the roles they play in society.

This chapter will trace the recent history of current cartographic theory in order to describe a clearer picture of the context in which maps can be and haven been analysed. In particular, it will discuss this context from an angle of the concept of representation, and the way in which this has been central to understanding the relationship between the map and the world. Key to this history is the relationship between cartographic thought on the one hand and developments in scholarly debates in its associated disciplines. In the latter half of the 20th century, much of the research on mapping, under the influence of quantitative geography, focused on the use of new computational techniques to improve map design and communication. In response to this approach, which has become known as the communication model to maps, critical cartography originated in the 1980s, drawing on thinkers such as Foucault, Barthes and Derrida to question the neutrality of maps' representations. Having discussed the fundamentals of this critical cartography, the chapter will look at more recent ideas in cartography that developed around notions such as non-representational theory and performativity.

After this history, this chapter tries to extrapolate this relationship between cartography and wider social-theoretical trends by considering the implications of object-oriented ontology for thinking about maps. In so doing, this chapter will discuss what it means to think of an object-oriented cartography. What does it mean to treat maps as objects? What are the implications for how maps can be studied? What kind of questions does this theoretical approach allow us to ask? Firstly, the chapter will describe some of the fundamental principles of OOO, with Harman as key protagonist. Secondly, it will discuss what this thought means for understanding maps as objects and how such an understanding differs from the other approaches to cartography discussed previously. Finally, it will reflect on some potential lines of enquiry an object-oriented cartography might take, which will serve as a starting point for analysis in the case study chapters.

Approaches to studying maps

Critical cartography

The first point of departure in looking at different ways of studying maps in this chapter is the field of critical cartography. This term refers to a specific school of thought which arose in the late 1980s with authors such as Brian Harley, Denis Wood, John Fels and John Pickles. It is taken here as point of departure most importantly because it constitutes a reference point for many of the later approaches to cartography which this chapter will discuss. As this section will describe, critical cartography represents a research agenda that focuses on epistemology, the (inter)textual, representation and interpretation. All of these have come under attack over recent years with various twists and turns such as those of the performative, the non-representational and the ontological. Understanding these points of difference will help build on the insights produced through these turns while being attentive to the debates that have preceded them.

Moreover, critical cartography can be understood as the start of a systematic attempt to study maps not just as analytic, but also as aesthetic, rhetorical tools. Drawing on insights from social theory – in particular, post-structuralist thinking – critical cartography was an intervention that questioned the scientific view of maps simply as tools of communication of geographical data that had become prevalent with the surge in map-making techniques under the quantitative revolution in geography from around the 1950s. Research within this communication paradigm focused primarily on how to improve this transfer of information, for example through enhanced map design (see, for instance, A. Robinson, 1952). Within this paradigm, various models of cartographic communication were proposed (see Board, 2017), but throughout, maps were generally understood as neutral, scientific tools to enable the transfer of knowledge.

In contrast to this communication paradigm, Harley, in what became a foundational (e.g. see Rose-Redwood, 2015) text within critical cartography, 'Deconstructing the map,' argued that:

> For historians of cartography, I believe a major roadblock to understanding is that we still accept uncritically the broad consensus, with relatively few dissenting voices, of what *cartographers* tell us maps are supposed to be. In particular, we often tend to work from the premise that mappers engage in an unquestionably 'scientific' or 'objective' form of knowledge creation. (Harley, 1989, p. 1 emphasis in original)

As Crampton and Krygier (2005) describe, critical cartography as a school of thought should be understood in a historic context of an ongoing struggle of on the one hand cartographers, making maps and trying to establish map-making as an academic discipline, and on the other hand geographers and philosophers arguing for the impossibility of thinking maps without conceptual, theoretical and philosophical grounding (see also Edney, 2015). Within this context, Kitchin, Dodge and Perkins (2011, p. 4) argue, Harley's impact was crucial in that he added to discussions of the social, political and economic aspects of map circulation through a focus on 'the power of maps and the power invested in maps.'

For Harley, maps were like texts, always serving to – implicitly or explicitly – tell the author's story. Critical cartography's intervention in this respect was to draw attention to the limits of representation, problematizing the view of maps as mirrors of the world. Instead, it argued, maps are always the result of processes of selection and abstraction, and of the design and rules which were produced within the social and political cultures of the map makers. The inherently subjective nature of representation itself was stressed to describe how maps, as instruments of both communication and persuasion (Wood & Fels, 1986, p. 99), could be central to political struggles. Accordingly, many of the cases scrutinised under this research agenda concerned government and propaganda maps (e.g. Crampton & Wilson, 2015; Harley, 1988; Pickles, 2011; Wood & Fels, 1986) that exemplified the use and abuse of power through cartography. At the same time, critical cartographic practice has focused on counter-mapping, challenging and revealing the hidden assumptions in maps, through forms such as protest mapping, map art, map mashups and indigenous mapping (Perkins, 2018, p. 82).

In particular, Harley himself saw his main contribution as distinguishing between the external and the internal power of maps. While the former described the 'familiar sense of power' that describes the power exercised '*on*' and '*with*' cartography (1989, p. 12 emphasis in original), the latter relates to political dimensions of the map making process itself. It questions

> the way maps are compiled and the categories of information selected; the way they are generalized, a set of rules for the abstraction of the landscape; the way the elements in the landscaped are formed into hierarchies; and the way various rhetorical styles that also reproduce power are employed to represent the landscape. (p. 13)

Accordingly, Crampton describes critical cartography's approach to maps, contrasting it with that of the communication paradigm's view:

> Critical cartography and GIS however conceives of mapping as embedded in specific *relations of power*. That is, mapping is involved in *what* we choose to represent, *how* we choose to represent objects such as people and things, and *what* decisions are made with those representations. In other words, mapping is in and of itself a political process. (Crampton, 2010, p. 41)

Building on Foucault and Derrida, Harley's aim was to deconstruct the map in order to reveal it as a 'specific set of power-knowledge claims' (Crampton & Krygier, 2005, p. 12). Similarly, Wood and Fels (1986) drew on Barthes' work on myths in order to consider how social constructions can become seen as naturalised truths. For mapmakers, pre-occupied with maps as analytic tools, the biggest concern was the ability to produce better maps by understanding issues such as information loss in the encoding/decoding process or optimizing design for understanding and interpretation of data. Critical cartography, in contrast, sought to demonstrate how these processes and decisions were in fact always bound up with politics of power and knowledge.

This conceptualisation of maps also entailed a certain set of methodological orientations as focus shifted from determining the most efficient methods for communication of spatial data to examining how power finds its expression in maps. Wood and Fels (2011, pp. 258–259), reflecting on the impact of their seminal 1986 paper 'Designs on signs: Myth and meaning in maps,' describe the basis for their collaboration as a mutual interest in semiology or semiotics, to be elaborated by readings in linguistics, 'deconstructionism' and phenomenology. Through these influences they developed a methodological approach that consisted of ‘semiological analyses’ and ‘close readings.’ Harley, on his part, found a cartographic methodology ‘derived directly from semiotic… too blunt for specific historical enquiry.’ Instead, he proposed a theoretical and methodological framework based on

1. literary criticism: conceptualising ‘maps as a kind of language’ to ‘identify the particular form of cartographic discourse.’
2. iconology: ‘to identify not only a “surface” or literal level of meaning but also a “deeper” level, usually associated with the symbolic meaning in the act of sending or receiving a message.
3. the sociology of knowledge: focusing on the relation of knowledge with power, in particular through citing Foucault, to better understand map knowledge as a ‘social product.’ (Harley, 1988a, pp. 278–279)

Together, these methodological building blocks formed a framework for deconstruction, in which the close and critical reading of maps could lead to the deciphering of the political contexts in which they were produced. Harley described this approach as ‘deliberately eclectic,’ acknowledging that ‘in some respects the theoretical positions of [Foucault and Derrida] are incompatible’. Nevertheless, being concerned more with ‘a broad strategy’ than with a ‘precise method or set of techniques,’ together they might be able to help ‘devise a scheme of social theory with which we can begin to interrogate the hidden agendas of cartography’ (1989, pp. 2–3).

However, this eclectic construction of different theoretical vignettes, each with their own commitments, agendas, strengths and weaknesses, has not been without its problems or criticism. As Belyea argues (1992), the alignment of sometimes incompatible concepts in combination with a reluctance to engage directly with the works of Derrida and Foucault implied an often superficial discussion, failing to develop a coherent, developed narrative. Consequently, Harley’s critical cartography has been criticised for consisting of a series of theoretical arguments without a solid empirical grounding. As Edney (2015, p. 9) describes, *Deconstructing the map* testifies to Harley increasingly ‘being liberated from empiricist strictures,’ leading to the inclusion of various theories and concepts without attention to their differences and incompatibilities.

From the way Harley's work has since been taken up by other scholars, it seems that it was not so much the methodological guidance that was of value, but its vibrancy and the appeal of its 'highly effective polemic' (Edney, 2015, p. 9). As Pickles recalls:

> I was similarly drawn to hermeneutics as a methodology for opening up a way of critiquing correspondence theories of truth. So in that sense for me that was part of a broader critique of logical positivism and empiricism. It was part of a turn to hermeneutic phenomenology, to provide a much broader critical resource for dealing with the representational logics, not just in cartography and the way in which propaganda maps were used, but around some of the claims being made about spatial analysis and around economic geography at the time. (Pickles in Crampton & Wilson, 2015, p. 29)

Thus, critical cartography has been fundamental in bringing into question the scientific views of maps as analytic tools, as neutral instruments of communication – a critique that 'is as urgent today as it was' when Harley first published his essay (Edney, 2015, p. 11). It has enabled a link between the critical analysis of maps and wider critiques of power. While the extent to which it offered specific techniques of analysis remains a topic of debate, key to its approach was the examination and interpretation of the visual surface of maps, questioning the use of particular symbols and colours, and the selection of geographical information.

Non-representational cartographies

More recently, critique of critical cartography has come from a different direction, as it has been accused of reinforcing the realist or objective worldview that it sought to undermine. Critical cartography's main project was to delegitimise the scientific, technical understanding of maps as communicational tools, to look beyond their silences (Harley, 1988b) and question their neutrality. However, in so doing, it has been argued that it did not necessarily question the idea of maps as mirrors of the world. As Kitchin and Dodge have argued, 'Harley believed that the truth of the landscape could still be revealed if we took account of the ideology inherent in the representation' (2007, p. 332). Consequently, alternatives to dominant forms of mapping focused on representing the previously unrepresented, making visible the silences, rather than questioning the representational or communicative nature of maps as such.

Thus, Del Casino and Hannah (2006) argue, much of critical cartography can be criticised for reinforcing a series of binary oppositions that underpinned the views of maps it sought to critique. They argue that while the semiotic and hermeneutic methodologies allow map users to read maps in different ways, to turn a map into 'multiple maps' and to challenge the mapmaker's assertions, 'there remains in this work a lingering emphasis on authoring, production, and writing' (p. 40). In order to make mapmaking more democratic, they call for this emphasis to be subverted by bringing into question established binaries such as 'representation/practice, production/consumption, map/space' (p. 35), as well as 'design and use, representation and practice, objectivity and subjectivity' (p. 45). Specifically, such questioning entails turning 'attention toward how maps and mappings are practiced beyond the productive moments of making a map or constructing various mappings' (p. 42).

In a similar vein to this critique, various new directions of cartography have emerged that go beyond critical cartography, drawing on terms such as performative, processual, and non- and post-representational. These cartographies suggest more complex or dynamic relationships between maps and the landscapes they represent, their users and producers, and the several other binaries identified by Del Casino and Hannah. They entail more flexible, creative arrangements in terms of theoretical conceptualisations, methods, types of maps studied, and types of questions that can be asked.

For instance, in a progress report on the state of cartographic research, Perkins (2003, pp. 344–346) noted, besides ongoing studies concerned with 'Harleyan notions of maps as élite discourse', there had also been a turn to 'maps as performance'. This notion of performance invoked attention to maps not as finished products, delivered by the producer to the consumer, but as processes – foregrounding the activity and creativity of various practices of mapping. Perkins in particular highlighted such a shift in the work of artists who problematised 'relationships to the world by using mapping in their work' and emphasised 'the complex and nuanced ways in which the power relationship in mapping practices is exercised.' As part of a 'philosophical shift away from representation and towards action' these performative understandings of mapping also entailed an increased interest in ethnographies of mapping practices (Perkins, 2004, p. 385). Additionally, with this attention to the activity of mapping, participatory mapping has become a key area of research and practice.

Associated with the popularity of the notion of performance in the social sciences and humanities, Gerlach (2017) argues, is its use in the study of maps across disciplinary boundaries, expanding views on the definitions of mapping, and troubling straightforward theoretical and methodological frameworks. The concept of performance allows a questioning of previously stable identities, of how maps serve to enact the world they claim to represent: 'a focus on mapping as performance disabuses us of the caricature of the map as a technology of capture and instead prompts a recognition of the generative, emergent and politically enactive qualities of cartography' (2017, p. 99).

Along with performance, and the way in which this term allows a look beyond the visual, another notion that has gained traction within the social sciences and humanities is that of the non-representational. Non-representational theory, developed most notably by Thrift, has been described as 'the geography of what happens' (Thrift, 2008, p. 2) and is interested in practice, experience, sensation, becoming and the everyday. It privileges movement, uncertainty and the processual over stable representations and identity. A non-representational perspective does not necessarily mean that the representational is not important, or that maps do not represent. Rather, it allowed cartographic studies to turn to situations – 'encounters' (Gerlach, 2017, p. 96) – between maps, space, map makers and map users.

Kitchin and Dodge similarly focus on maps as mappings, formulating a theory in opposition to both the communication paradigm and critical cartography, viewing maps 'not as mirrors of nature (as objective and essential truths) or as socially constructed representations, but as emergent,' or 'ontogenetic' (2007, p. 340). Both map makers and critical cartographers presumed a stable notion of the map as a geographical representation, as communicative and analytic tool. In contrast, for Kitchin and Dodge maps should be viewed as processual – only emerging in the continual practices of their production and use, through activities such as 'recognizing, interpreting, translating, communicating, and so on' (2007, p.

335). They are made anew on each occasion and always depend on the context in which they are used. They are not ontologically secure with a fixed or constant identity, but should be understood as a 'spatial representation understood as a map' or '*transformed into* a map by individuals' (2007, p. 338 emphasis in original). Accordingly, critical cartographic research should focus not so much on if and how maps represent their territories, but more on how they are 'brought into being through practice (embodied, social, technical)' (p. 335).

While Del Casino and Hannah distance themselves from the notion of non-representational theory, their approach is sympathetic to those described above. Similar to the proposal of maps as ontogenetic, they propose the concept of 'map space' (2006). This concept serves to consider the ways in which space is performed through fluid, processual and contested intersections of map production and consumption, visual representation and bodily practice and interaction. Map space centres on the specific situations, encounters, in which maps are put to use. On each occasion, the map is made anew, undermining the theoretical distinction between map consumption and production. In map spaces – rather than 'maps and spaces' (p. 37) – experiences, practices and performances intersect with wider historical, cultural and political contexts.

While these various concepts and theories described thus far share similar aims in terms of focusing on the practice and performance of mapping, this does not mean they form a coherent body of thought. For example, as Del Casino and Hannah claim, 'it is not necessary to conflate all theories of practice and performance with nonrepresentational theory' (2006, p. 43). In particular, they argue against non-representational theory as developed by Thrift, for its privileging of practice and performance over representation. Rather than doing justice to the complex, co-constitutive relationships between maps and spaces, this privileging reinforces actually serves to 'reinscribe the binary logic of representation and practice that limits our theoretical possibilities' (ibid). In addition, Gerlach (2017) describes how the multiplicity of approaches to studying maps cannot be captured in a uniform, overarching theoretical framework.

Moreover, the differences between representational and non-representational forms of cartography is not always as straightforward as may seem, with various theoretical positions bridging this divide, and with a proliferation of overlapping concepts such as post- and more-than-human cartography muddling these distinctions (see Rossetto, 2015). Nevertheless, what they have in common is a departure from a critique of the problems of representation and opening up the research agenda to the complexities of cartographic practice.

Object-oriented cartography

As discussed in the previous sections and in Chapter 1, in the trajectory of cartographic thought, the separation between the map and its territory has become increasingly blurred or dynamic. In this context, Crampton poses a key question:

> what is the relationship between the map and the territory if it is not the territory itself and yet is of it? (Crampton, 2001, p. 239)

This project reflects on this question by turning to wider developments in the social sciences, humanities and philosophy, where questions of ontology, performativity, affectivity, materiality and explanation displace longstanding concerns with epistemology, representation, meaning, ideology and interpretation. The brief history of different cartographic approaches shows how the study of maps has often developed in harmony with wider trends in the social sciences and humanities. Critical cartography, as it emerged in the 1980s, relied heavily on then popular concepts of post-structuralist thought from thinkers such as Foucault, Derrida and Barthes. Similarly, later approaches were articulated in accordance with various theoretical approaches formulated in response to such scholarship, with a focus on the non-representational, performative and processual.

This project aims to extrapolate this harmony, looking at recent developments in social theory and philosophy to see how these can further challenge the study of maps. In particular, it will draw on philosophical ideas from object-oriented ontology (OOO) to explore how this can prompt new ideas in thinking about and studying maps. In doing so, the aim for exploring an object-oriented cartography is not necessarily to find a new framework to replace all existing ones. Although the different cartographic approaches discussed above have been dealt with in chronological order, it should not be assumed that each new approach replaces a previous one. To some extent, all of these models are still in use today. For example, the view of maps as tools for communication – and also as analytic tool – is a common one, not least for data scientists. Similarly critical, performative and non-representational approaches are still being used in current research.

In following this line of thought, this thesis shares some of the aims of a recent book, *Object-Oriented Cartography: Maps as Things*, by Tania Rossetto (2019). This study engages with the literature on OOO to appraise how it can generate new ways of researching maps. The 'objecthood' of maps, Rossetto argues, has been of interest to cartographic thinking in a variety of forms, drawing attention to a wide range of questions around materiality, design, and practices of mapping and engaging with maps. Acknowledging these different approaches, she argues that:

> by proposing a piece of tentative object-oriented map thinking, I do not want to introduce a new paradigm in cartography by slavishly following a philosophical school of thought. Instead, I would like to propose an additional perspective and add a layer to the effervescent arena of contemporary map studies. (Rossetto, 2019, p. 22)

Her engagement with OOO is thus intended to build on and expand, rather than necessarily replace previous frameworks, describing her project as explorative, experimental and tentative in nature. 'Embracing the objecthood of maps,' she poses the question 'of the object as a question of the life of cartographic objects, including maps within the universe of things to which OOO directs our attention' (p. 26).

This thesis is similarly explorative, asking how considering maps as objects can help understand smart cities. This chapter, as a piece of tentative thinking, explores how perspectives from OOO can help produce new ways of conceptualising maps by identifying points of contrast with other cartographic ideas as discussed above. It will therefore not give a comprehensive overview of the entire field of object-oriented ontology and associated fields such as speculative realism, vitalism, correlationism, new materialism and so forth. These complexities and nuances of the different standpoints of the various scholars are subject to ongoing debate which is beyond the scope of this project. However, some of the key philosophical themes and arguments will be introduced before discussing their applicability to the understanding of maps.

Object-oriented ontology

The origins of OOO can be understood in the wider context of a 'speculative turn' (Bryant et al., 2011) and alongside other philosophical currents in continental philosophy such as new materialism (Dolphijn & Van der Tuin, 2012). As noted above, in-depth discussion of the similarities and differences between OOO and these associated fields will be beyond the scope of this thesis. However, one of the key points of speculative realism – namely, the critique of correlationism – does require some discussion as it forms one of the cornerstones of OOO.

Speculative realism, as developed by French philosopher Quentin Meillasoux, departs from a criticism of what it calls correlationism, which is argued to be manifest in a wide range of philosophical standpoints throughout history. Correlationism marks the privileging of the human subject as a defining element of the nature of reality. It refers to 'the idea according to which we only ever have access to the correlation between thinking and being, and never to either term considered apart from the other' (Meillassoux, 2008, p. 5). Correlationism is not a philosophical standpoint in itself, but rather denotes two seemingly contradictory positions across a varied body of thought. As Bogost (2012, p. 4) graphically argues, 'the speculative realists share a common position less than they do a common enemy: the tradition of human access that seeps from the rot of Kant.'

Meillasoux argues that there is a spectrum of correlationist thought. On one end, strong correlationist positions do 'not even admit that we can know that there is an "in-itself" and that it can be thought.' At the other end is weak correlationism, also described as subjectivism, or subjectivist metaphysics. Here, the in-itself is in fact the 'correlate,' the relationship between thinking and being. While strong and weak correlationisms are often considered as opponents, what they have in common is their refusal to acknowledge the possibility of grasping an in-itself independent of any relationships, and in particular independent of the knowing, human subject; in other words, '"what is asubjective cannot be"' (Meillasoux in Dolphijn & Van der Tuin, 2012, pp. 72–73). In contrast, speculative realism argues for the existence of an objective nature, an absolute, that exists outside the correlation with human thought. It is this argument of speculative realism that forms one of the fundamental principles of OOO. Objects exist in and for themselves, independent of their relationships to other objects and independently of people's ability to perceive them.

However, as these objects exists in and for themselves, a crucial issue arises in terms of our access to and knowledge of these objects. This is not only a problem of the relationship between knowing subjects and knowable objects, between thinking and being, but also of relationships between objects. As Gratton argues, 'real objects relate "asymmetrically" to their others through sensuous qualities, and this is just as true for the coffee grinds and a filter as it is for the human relation of knowledge to things themselves' (2014 n.p.). As objects encounter each other, they grasp one another always only partially, their full being remaining fundamentally withdrawn, or hidden. Morton describes this in terms of translation:

> Objects encounter each other as operationally closed systems that can only (mis)translate one another (…). Causation is thus vicarious in some sense, never direct. An object is profoundly "withdrawn"—we can never see the whole of it, and nothing else can either. (Morton, 2011, p. 165)

Relationships between objects, allow certain features of these objects to come to the fore. Yet, this is always a selection of all the features of these objects that are relevant to that particular moment. None of these encounters are able to include all object qualities. This notion of vicarious causation referenced by Morton is a key concept developed by Harman. Focusing on causation, Harman argues, is a way of look at relations between objects rather than the relationship between people and objects. The emphasis on vicarious, meanwhile, refers to the idea that 'relations never directly encounter the autonomous reality of their components' (Harman, 2012a, p. 189).

In addition to what these object-oriented thinkers discussed here have in common, there are certain differences between the various object-oriented thinkers. One of such crucial differences relates to terminology – in particular the use of the term "object." Harman defines objects as 'unified entities with specific qualities that are autonomous from us and from each other' (Harman, 2011a, p. 22). In this definition, Harman is not interested in the distinction between objects and things, which has been important for many other philosophers, including Heidegger, who is one of the fundamental figures in Harman's thought:

> Heidegger's own distinction between "objects" and "things" is irrelevant for our purposes; we can use the single term "object," simply because that was the term used by phenomenology when it first revived the philosophical theme of individual things. (Harman, 2012b, p. 187)

While this distinction is irrelevant for Harman's purposes, others – such as Latour and Bennett – do argue for a preference for the term "thing." For Latour – one of Harman's key influences, also drawing on Heidegger, the distinction between the two terms is at the heart of his argument on matters of fact and matters of concern. Objects correspond to matters of fact, statements that describe that what can be found empirically. Things, on the other hand, correspond to matters of concern. They describe not just what exists, but also why it matters. They are 'gatherings,' of 'gods, passions, controls, institutions, techniques, diplomacies, wits' (Latour, 2004, pp. 235–236). They form arenas constituting a space not just for analysis and description, but also for debate.

Similarly, Bennett, whom Harman (2018, p. 240) considers to be a 'fellow traveller,' has a clear preference for the term "thing", or in some instances "body," as opposed to "object." Specifically, this preference relates to the way in which the notion of the object also suggests a subject.

> I find the term "thing" or "body" better as a marker for individuation, better at highlighting the way certain edges within an assemblage tend to stand out to certain classes of bodies. (…) "Thing" or "body" has advantages over "object," I think, if one's task is to disrupt the political parsing that yields only active (American, manly) subjects and passive objects. Why try to disrupt this parsing? Because we are daily confronted with evidence of nonhuman vitalities actively at work around and within us. (Bennett, 2010, p. 231)

In particular, she argues, things and bodies are more adept than objects to the context of ecological and environmental issues. Bennett's concern is with cultivating an ethical awareness in a way that is inclusive of both human and nonhuman subjects; an awareness that replaces a paradigm of caring (by humans) for the environment with one of a 'vital materiality' that takes into account the force of things. Such an awareness engenders a 'greater appreciation of the complex entanglements of humans and nonhumans' and, crucially, 'reminds humans of the very *radical* character of the (fractious) kinship between the human and the nonhuman' (Bennett, 2010, p. 112 emphasis in original).

In addition, Bogost, whose *Alien Phenomenology* draws heavily on Harman's work, introduces yet another term: the unit. Bogost (2012, pp. 22–29) finds various problems with the term "object:" the concept "object-oriented" may lead to confusion due to its specific meaning in computer programming; it implies a subject, which in turn hints at correlationism; it implies materiality, in a way that limits what can be counted as object. Likewise, the "thing" is problematic because it has a 'charged history' in philosophy and critical theory; and it emphasises 'concreteness' over abstractions and relations. In contrast, Bogost argues, the term "unit" is able to denote a wider range of things or objects because it is ambivalent and indifferent. Units can deal with objects and things at different scales, taking account of them as they come together to form larger objects, or break down into smaller parts, or as they enter into different relationships altogether. Moreover, the unit opens up a focus on unit operations – which will be discussed below – the ways in which units act on and relate to others. For this same reason, Bryant advocates talking about "machines," rather than objects: a machine is a system of operations that perform transformations on inputs thereby producing outputs' (Bryant, 2014, p. 38).

Thus, across these related bodies of work, there is variety in the terms used to denote more or less the same concept: objects, things, bodies, units, machines. This thesis will mainly use the term object, as this is the most commonly used within the OOO literature. "Things," "units" and "machines" will be used where the discussion engages specifically with texts that revolve around these terms. This facilitates what Rossetto (2019, p. 139) has described as 'theoretical hybridisations.' In other words, making use these different terms facilitates the choice of useful arguments of the various thinkers and determine how these may apply in the study of maps. In this way, this chapter explores thinking of maps as objects that contain their own capacity to act and affect; whether material (e.g. as paper map) or virtual (e.g. digital maps, data visualisations) or both (e.g. as screens, interfaces, dashboards); engaging with other objects through particular unit operations.

Maps as objects

Before considering which lines of enquiry an object-oriented cartography might follow this section discusses what it means to approach maps as objects and how this differs from the previous cartographic approaches outlined above. Harman positions OOO explicitly in contrast to two distinct and opposing tendencies, 'reductive strategies' (Harman, 2013, p. 43) evident throughout a wide range of philosophy and critical thought. These are broadly described as '*anti*-object-oriented standpoints' (2011a, p. 22). On the one hand, in a process described as undermining, is the tendency to explain objects by considering the elements of which they consist (2013, pp. 43–44). Here, the strategy is to:

> say that objects are a shallow fiction of common sense, and that the real action happens at a deeper level: whether it be tinier components discovered through the sciences, some sort of "pre-individual" realm, an outright blob-like *apeiron*, a vaguely defined mathematical "structure", or some other variant of one of these options. (Harman, 2011c n.p., emphasis in original)

Examples of such thought are pre-Socratic debates envisioning the world as consisting of 'immortal elements,' or smaller particles, as well as scientific understandings of objects as 'conglomerates of molecules, atoms, quarks and electrons, or strings' (Harman, 2011b, p. 171). In the case of cartography, undermining descriptions, explaining maps in terms of their constituent elements, or 'tinier components,' could be identified in the attempts under the communication model to improve map design by optimising its various components. Indeed in this model, the 'real action' happens at the level of the various cartographic elements that make up a map, such as their lettering, composition, design and colour (see Robinson, 1952).

In contrast to undermining, overmining means explaining objects not downwards, in terms of smaller elements, but upwards through forces, structures and relationships. Examples of this strategy are idealism, the various types of social constructivism, as well as Actor Network Theory and a long list of philosophers including Anaxagoras, Levinas, Nancy, Simondon, DeLanda, Bergson (see Harman, 2011a, pp. 22–23, 2013, p. 45). While this list contains a diverse range of philosophical positions, they are united, according to Harman, in holding that:

> objects, they say, are useless fictions, or at least forever unverifiable. All that is real are the contents of consciousness, the constructions made by society, the workings of language – or relations, effects, and events more generally. Or perhaps what we call "objects" are merely "bundles of qualities" (David Hume). (Harman in Kimbell, 2013, p. 107)

Overmining privileges the relationships in which objects are engaged, understanding the object as defined by these relationships, or by the effects it has on other objects. With social constructivism high on Harman's list, critical cartographers such as Harley, Wood and Crampton could be classed in the group of overminers. It can be identified in strong statements such as: '*there is nothing natural about a map*. It is a cultural artefact' (Wood & Fels, 1986, p. 65 emphasis in original). Here, maps are not taken seriously as objects in the way that Harman advocates. Rather, they are considered as expressions of the mapmaker's culture, ideology, consciousness and so forth. What is real is not the individual maps, but the larger structures that produces them.

However, while these two strategies diminish the object in two opposite directions, both can also be combined when they go together in a third process named 'duomining' (Harman, 2013). To the duomining strategy Harman ascribes a number of philosophical currents, perhaps most notably 'the whole of modern science' because it 'aims both to reduce objects downward to the most basic constituents *and* to claim that these things are, in principle, knowable through mathematization.' Maybe, Harley's combination of Foucault and Derrida should be understood as a case of duomining. On the one hand, drawing on Foucault, Harley (1989) argues for a view of maps as forms of power-knowledge, which for Harman would constitute a strategy of overmining. On the other, he draws on Derrida's framework of deconstruction to call for a close reading of map surfaces, thus undermining the map by focusing primarily on the way it is composed. Similarly, Wood and Fels (1986), via Barthes' work on myths, look at how maps gain authority and particular social and cultural contexts by developing a framework for analysing the various 'codes' (e.g. thematic, topic, iconic, linguistic; see p. 73) deployed to produce them.

In contrast to these various 'anti-object' approaches, Harman argues, in OOO objects are more than both their constitutive elements and their effects. They are both more than the sum of their parts and exist independently of the relationships in which they find themselves:

> On the one hand objects are autonomous from all the features and relations that typify them, but on the other they are not completely autonomous, for then we would have a multiverse of utterly disconnected zones that even an occasionalist God could not put back together again. In other words, we need to account for the difference between objects and their qualities, accidents, relations, and moments, without oversimplifying our work by reducing objects to any of these. For all of these terms make sense only in their strife with the unified objects to which they belong. (Harman, 2011a, p. 24)

Thus, following an object-oriented perspective, maps should be conceptualised as more than the cartographic elements, the colours and symbols, topographic content and codes of which they consist, but also as independent from the relations and situations in which they are produced and circulated.

While the constructivist approach of critical cartography challenged the idea of neutrality of representation as formerly presupposed by the communication model, an object-oriented cartography contributes to altogether questioning, or expanding on, the communication function of a map. It describes how maps may operate in all sorts of ways besides merely conveying geographical information, interacting with its territory rather than – or in addition to – representing it. Such a framework is sympathetic to the post- or non-representational and performative approaches described above in that it focuses not so much on what is and what is not represented, but rather on 'how mappings emerge, circulate and do work in the world' (Kitchin et al., 2012, p. 483).

However, these approaches can also be criticised from an OOO perspective for not properly acknowledging the map as object. In Kitchin and Dodge's (2007) ontogenetic approach, maps are brought into existence in specific situations. This only considers the map to the extent that it emerges in a particular context or encounter, brought into existence by the practices of the map makers and users, outside of which, it is not a map at all: 'without these practices a spatial representation is simply coloured ink on a page' (2007, p. 335). Indeed, Kitchin et al.'s specific objective of their ontogenetic view is to question maps' 'ontological security,' shifting from 'ontology (how things are) to ontogenesis (how things become) – from (secure) representation to (unfolding) practice.' From an OOO perspective, such a stance does not do justice to the map as object. In contrast, writing about the materiality of rocks, Harman argues: 'the rock does not exist because it can be used, but can be used because it exists' (Harman, 2012b, p. 199). Similarly, an object-oriented cartography would argue that a map does not exist because it can be used but can be used because it exists. They are not just temporary arrangements but persist independently of the occasions in which they are used.

In this way OOO distinguishes itself from ontogenetic or performative approaches. It draws on a critique of what Bogost describes as 'the obsession with Deleuzean becoming, a preference for continuity and smoothness instead of sequentiality and fitfulness.' While for Bogost the 'familiar refrain of "becoming-whatever" (it doesn't matter what!) suggests comfort and compatibility in relations between units,' the premise of OOO is incompatibility, disjunction and the individuality of objects (2012, p. 40). Becoming, in other words, emphasises the partial ways in which objects relate to each other, the surfaces of translation in any interaction between objects. In so doing, it misses the point of OOO, which is the withdrawn nature of objects – that which does not come into the equation when two (or more) objects meet.

Both strategies of under- and overmining, Harman argues, are limited. Firstly, undermining approaches are unable to 'account for emergence' (Harman, 2013, p. 47): 'what this argument misses is the phenomenon known as emergence, in which new properties appear when smaller objects are joined together into a new one' (Harman, 2018, p. 30). While objects consist of smaller parts, their objecthood consists of something larger, a sum that is bigger than its parts. Undermining philosophies do not explain how the parts that make up an object are summed up into this bigger whole. They 'fail to recognize the autonomy and power of objects at many different scales other than the ultra-tiny or ultra-basic one' (Harman in Kimbell, 2013, p. 107).

Overmining, on the other hand, 'cannot explain change' (Harman, 2013, p. 47, see also 2018, p. 49). If the significance of an object is determined by the relationships in which it finds itself, what would drive things to change? If there was not a certain withdrawn essence left inside of objects, 'everything would be identical with its current and actual state of relations with everything else. Reality would be exhaustively deployed in its present state, with no hidden surplus or reserve that might surge forth and generate novelty' (Harman, 2013, p. 47). Finally, duomining amplifies both of these problems, producing accounts that can explain neither emergence nor change.

OOO entails a view of objects such that they cannot be dissolved either upwards or downwards. An object-oriented cartography thus must assert that maps are more than the cartographic elements that constitute them, or than the relationships, situations or spaces in which they find themselves. This entails not the combination of undermining and overmining but abandoning both. In doing so, it is hoped, it will be able to account firstly for the emergence of maps. What is it that makes cartographic elements cartographic? How do these elements together constitute a map? At the same time, this approach aims to explain the ways in which maps are able to affect change. How are maps able to shape the way we see the world? How do they exert power and control? These two themes of change and emergence will be revisited throughout the two case studies as well as in the Conclusion, which will reflect on how the object-oriented approach has enabled the cases to provide an account of how maps produce change and emergence in the smart city.

Studying maps as objects

How can the principles of OOO be translated into practice to guide cartographic research? As will be described in the final part of this chapter, the central theme that will be developed in the case studies pertains to the way OOO understands the relationship between what things are and what they do. Indeed, these two aspects can be distinguished in Harman's two complementary texts, *Tool-Being* (2002) and *Guerrilla Metaphysics* (2005), which laid out the foundations of his thinking. The first argued that 'objects exist in utter isolation from all others, packed into secluded private vacuums;' while the latter focused on showing 'how relations and events are possible *despite* the existence of vacuum-sealed objects or tool-beings' (2005, pp. 1–2 emphasis in original). The various lines of enquiry described below, and those followed in the case study chapters later on, all aim to address these two aspects of object-oriented thought in one way or another. In fact, the relationship between these two aspects will be the main motif in both case studies.

Applying the philosophical debates of OOO and speculative realism to concrete ideas on studying maps as objects is not straightforward. As Bogost describes in relation to the larger project of speculative realism, discussion has largely been confined to 'philosophies of first principles,' rather than practical implementation:

> even if we accept the rejection of correlationism as overtly, selfishly anthropocentric, how do we deal with things that are also complex structures or systems crafted or used by humans? And even more so, how do we as humans strive to understand the relationships between particular objects in the world, relations that go on without us, even if we may be their cause, subject, or beneficiary? (Bogost, 2012, p. 29 emphasis in original)

Indeed, thinking non-anthropocentrically or non-correlationally becomes particularly difficult when applied to objects such as maps, which are created and used by people. For Latour, this reflects a more general problem for philosophers who 'use in their arguments an inordinate quantity of pots, mugs, and jugs – to which, sometimes, they might add the occasional rock.' Such objects, however, Latour argues, are not complicated enough – 'more precisely, they are never simultaneously *made* through a complex history and new, real, and *interesting* participants in the universe' (2004, p. 234 emphasis in original).

This distinction goes to the heart of the difficulty of "applying" a complex philosophy such as OOO to a concrete area of research such as cartography. While the OOO literature also include its share of objects such as rocks (e.g. Harman, 2012b, p. 199), maps, of course, are both made through complex histories and constitute interesting participants in the universe. Rossetto's discussion on object-oriented cartography proposes conceptualising maps as 'cartographic aliens' (Rossetto, 2019, p. 54), in order to capture, through speculative, aesthetic counter methods, their inner life, independent of the human subject. For Rossetto, the value of using object-oriented philosophy to inform map studies is that it generates new questions concerning the possibilities of knowing the essence of maps. Thus, Rossetto proposes the use of 'aesthetic counter methods to allude to the being of maps' (2019, p. 26). In so doing, she particularly draws on Bogost's alien phenomenology: 'by exploring the alien phenomenology of maps, and therefore decentring but not denying the inescapable anthropocentrism of any intellectual practice, I aim to grasp maps 'in person' (Rossetto, 2019, p. 35)

One example of OOO dealing with the kind of complicated objects as Latour suggests can be found in a debate between Harman (2012b), Morton (2012a) and Bennett (2012) on literary theory, which may suggest some useful lines of inquiry for its application to cartography. Firstly, Harman positions his thoughts on an object-oriented literary criticism in opposition to various 'prominent currents in twentieth-century literary theory' (2012b, p. 184). All of these, Harman argues, are guilty of either under-, over- or duomining texts in one way or another. In response, he proposes that OOO can provide a *counter* method: 'instead of dissolving a text upward into its readings or downward into its cultural elements, we should focus specifically on how it resists such dissolution' (2012b, p. 200 emphasis in original). 'For the sake of time,' he only elaborates on 'resistance in the downward direction' (p. 200). This approach interrogates the boundaries of objects such as texts, by manipulating them to find out at what points they fall apart or change into something else.

For example, texts can be modified by changing sentences, words, spellings and punctuation. They can be lengthened or shortened. Their stories can be set in a different time or place. Applying this to maps, a counter method could entail changing the various cartographic elements such as design, colour and scale, or that places them in a different country or city altogether. By considering 'the resulting consequences and lack of consequences' (2012b, p. 202), this can demonstrate how objects are more than the elements of which they consist or the form they to take. The objective of such counter methods is not so much to provide insight into the inner being of maps – something that Harman would argue is fundamentally impossible. Rather, it is to test OOO's argument that objects are irreducible to their components or entanglements.

An example of such a counter method can be found in Rossetto's case study of a You-Are-Here map in the city of Padova. She describes how engaging with the map's surface can be understood as a counter method. The map, a physical object in the street, is marked by people tracing routes with their fingers, by the weather, and by objects such as leaves. Resting on this surface, she argues, testifies of the resistance of the map as object to be dissolved upwards or downwards. It is 'a space where we meet or interact with objects, but not exhaust or fuse with them. It is a space from which we can acknowledge that something lies in reserve, that there is a degree of surprise, and some 'resistance' from the object' (Rossetto, 2019, p. 46).

Secondly, Morton bases his 'object-oriented defense of poetry' on the difference between what an object – be it a poem or a map – is and how it appears. Causality, he argues, is aesthetic, by which he 'simply' means 'having to do with appearance' (2012a, p. 205). Thus, to study poetry:

> is to see how causality itself operates. A poem directly intervenes in reality in a causal way. As literary scholars we are familiar with ascertaining the significance of a text. An OOO approach to poetry shows how poems do something as physical as what happens when my car scrapes the sidewalk. (Morton, 2012a, p. 206)

To argue that to study a poem is to study causality, Morton claims that for OOO space and time are not external to objects, but is produced by them through their inherent withdrawal from the world, and even from themselves: 'time, space, and causality float "in front of" objects: they just are ways in which an object appears' (p. 214). An object is never what it seems; that is, there is always more. Its essence remains withdrawn. The qualities with which it appears to something are that something's translation of the object. Change in space and time is produced through the object's capacity to be something other than what it appears to be at any given moment. Thus, objects produce time and space: every object has 'its own way of "timing" and "spacing"' (p. 216).

Morton equates an object's past with its appearance, and its future with its essence. The object's appearance consists of its trajectory of encounters with and between objects in the past. Its essence remains withdrawn in the future, which does not denote a '"time in which" the object "resides"' but rather 'the pure possibility of the object as such' (p.221). The present of any object, Morton argues, is the tension – a rift – between its past and its future, between its appearance and its essence, between pretence and openness – respectively. New objects are the result of trauma, as 'irruptions of transformation' (p. 215). The end of an object is the collapse of its essence into appearance – 'if it is forced to speak nothing but the truth, destruction ensues: the rift collapses' (p. 221). In this way it can be argued that to study the aesthetics of a poem – its appearance – is to study causality.

To study poems as objects for Morton entails studying this field of causality: to interrogate its present as the intersection of how it appears and what it is. It considers how the poem changes and produces change, through vicarious causation, and gives rise to new objects:

> to write poetry is to perform a nonviolent political act, to coexist with other beings. This coexistence happens not in some eternal now, or in a now-point, however expansive or constrained. The "nowness" of a poem, its "spaciousness," is the disquieting asymmetry between appearance and essence, past and future.' (Morton, 2012a, p. 222)

Similarly, the presence of maps might be framed as a rift between its appearance, as its past, and its essence or being, as its future. Thus, to map is to 'coexist with other beings.' If 'to write poetry is to force the reader to coexist with fragile phrases, fragile ink, fragile paper' (p. 222), then to map is to force the map user to coexist with lines and symbols, but also with interfaces and algorithms, prototypes and little analytics, sensors and satellites, terrain, territory, borders and people. Studying maps as objects in this way entails studying this field of causation and maps' capacity to produce change, to affect and be affected. It is this framework of 'nowness' or spaciousness' of an object understood in terms of its relationships between appearance and essence, past and future that will underpin the analysis of the case study of the MotionMap in Chapter 4.

It is hard to summarise Harman's and Morton's thought neatly into a practical guide. Indeed, Bennett, responding to both, describes her experience reading these articles:

> they induced a dizziness—they were overfull. This was an alluring, slightly compulsive dizziness, like the kind you got when you were a kid doing dizzy circles. Or maybe the texts' affectivity is better described as like that of a shadowy thicket whose fast-growing vines begin encircling your legs as

> soon as you enter, but instead of hightailing it out of there, you are drawn further in. (Bennett, 2012, p. 225)

On the one hand, this experience testifies to the difficulty of applying the complex conceptual arguments of OOO to the study of objects such as texts or maps. It is easy to get lost in the discussions on subjects, objects, people and things, access and being, ontology and epistemology, essence and relations, aesthetics and causality. In their efforts to emphasise the object independent of any relationships, Harman and Morton rigorously and intentionally break with large bodies of contemporary – and less contemporary – thought. Bennett, however, is less committed to discarding all 'contemporary materialisms (inspired by Deleuze, Thoreau, Spinoza, Latour, neuroscience, or other sources) that affirm a vitality or creative power of bodies and forces at all ranges or scales [and which] also cut against the hubris of human exceptionalism' (2012, p. 230).

On the other hand, Bennett's dizziness serves to underscore an argument about the affectivity of such objects. Developing the concept of 'thing-power,' she shares OOO's insistence on dealing with things beyond the way they appear to people. She proposes a theory of 'vibrant matter,' which sees things not as passive matter, waiting to be used by humans, but as being able to act, as 'forces with trajectories, propensities, or tendencies of their own' (2010, p. viii). In doing so, she expands her previous work on enchantment (Bennett, 2001) to direct it toward both the 'humans who *feel* enchanted' and toward 'the agency of the things that *produce* (helpful, harmful) effects in human and other bodies' (Bennett, 2010, p. xii emphasis in original). In this vein, with regards to the relationship between text and the things within stories, she argues that 'poetry can help us feel more of the liveliness hidden in such things and reveal more of the threads of connection binding our fate to theirs' (2012, p. 232).

Thus, while there are various differences between Harman and Morton's OOO and Bennett's thing materialism, they share a common ground which can be used for a rethinking of maps. Applying their thinking to an object-oriented critical cartography entails raising the question of how maps can add to the vibrancy of the things they represents and how they can 'help us feel more of the liveliness' (Bennett, 2012, p. 232) of their territories. In agreement with the principles of OOO, the human – those who *feel* enchanted – become part of the same flat ontology as things. A thing-materialist critical cartography explores the particularity of a map not to isolate it from its environment, but paradoxically to more adequately understand its place in it and its relationships to other objects. It considers the agency of the map itself so that it is neither a product of larger regimes of power, nor purely emergent from the context in which it is produced.

Another cue for using OOO to think about objects more complicated than rocks and mugs can be taken from Bogost's work on video games. In particular, this thesis will – in the Whereabouts London case study in Chapter 5 – draw on the theory of unit operations, developed within the context of OOO in turns by Bogost (2006, 2012) and Bryant (2014). It can be defined as 'the logics by which objects perceive and engage their worlds' (2012, p. 29), emphasising that 'things are not *merely* what they do, but things *do indeed do things*. And the *way things do* is worthy of philosophical consideration' (p. 28, emphasis in original). While a description of how a unit operates does not define what it is, understanding what it does is fundamental for Bogost's wider project of alien phenomenology, as it tries to capture how objects experience other objects. This project is concerned with the experience of the thing in a way that does not start from that thing's relationship to a human subject. Its purpose is to ask of things: 'what do they experience? What's their proper phenomenology? In short, what is it like to be a thing?' (Bogost, 2012, p. 10 emphasis in original).

Bryant (2014, p. 40) similarly argues that 'the being of a machine is defined not by its qualities or properties, but rather by the operations of which it is capable.' Here, he distinguishes between what a machine, an object, is capable of – its 'powers' which constitute its 'virtual proper being;' and the actual exercise of those powers through operations. These operations in turn produce 'local manifestations' – 'the product of the operation of a power on a particular input' (p. 42). In keeping with Harman's OOO, the object thus consists of its withdrawn interior, a virtual proper being with powers which it may or may not exercise, and the way it appears to other objects, through local manifestations produced by its operations. By focusing on inputs and outputs, Bryant develops a theory of unit operations to understand the world of objects as a 'post-human media ecology' (2014, p. 15), which explores how objects interact with and are 'structurally coupled' to one another.

Accordingly, the purpose of focusing on unit operations is to help 'determine the flows to which a machine is open, as well as the way that machine operates on these flows as they pass through the machine' (Bryant, 2014, p. 62). This idea of the post-human media ecology links in with Bogost's crucial distinction between units and systems: 'unit operations are modes of meaning-making that privilege discrete, disconnected actions over deterministic, progressive systems' (2006, p. 3). For OOO, systems, described in many different ways, such as assemblages and post-human media ecologies, do not prescribe or regulate their constituent parts. Rather, they emerge from their parts – units – and the way these perceive, operate on and relate to one another: they 'derive meaning from the interrelations of their components' (2006, p. 4).

Crucially, for Bogost, unit operations do not just relate to one unit's actions on another, but also helps understand the unit's own unity. Inspired by Badiou, Bogost sees units as sets: each unit consists of, takes part in and combines with further units. Every unit or object is itself both a multiplicity and takes part in yet larger multiplicities:

> The container ship is a unit as much as the cargo holds, the shipping containers, the hydraulic rams, the ballast water, the twist locks, the lashing rods, the crew, their sweaters, and the yarn out of which those garments are knit. The ship erects a boundary in which everything it contains withdraws within it, while those individual units that compose it do so similarly, simultaneously, and at the same fundamental level of existence. (Bogost, 2012, p. 22)

Consequently, Bogost argues, 'if everything exists all at once and equally, with no differentiation whatsoever, then the processes by which units perceive, relate, consider, respond, retract, and otherwise engage with one another—the method by which the unit operation takes place—is a configurative one' (2012, p. 26). In other words, unit operations are configurative in distinguishing a unit from the other units in the system or ecology in which it takes part. Examining an object's unit operations, therefore, entails simultaneously studying that particular unit, and the way it engages with other units and the system.

Conclusion

This chapter has laid the foundations of a theoretical framework for thinking maps as objects. It has given a brief overview of recent schools of cartographic thinking, starting with the field of critical cartography which emerged in the late 1980s. This discussion reviewed a collection of other approaches revolving around notions of performance and the non-representational. Having covered this brief history of cartography, this chapter has tried to extend this resonance with social theory to explore the possibility of an object-oriented cartography. This draws on OOO's outspoken positioning against the theoretical underpinnings of previous modes of cartographic thinking.

OOO emphasises the autonomy of objects, arguing that these cannot be understood in terms of their constituent parts, their apparent qualities, or the relationships and contexts in which they are embedded. They engage with other objects, but in doing so only reveal themselves partially, with part of their being always remaining withdrawn. The last section of the chapter explored some of the implications of these arguments for studying maps. In particular, this focused on investigating the relationship between the independence or autonomy of objects on the one hand, and the ways in which they are able to influence, relate to and affect the other. The works of the authors described in this context offer different perspectives on thinking in an object-orientated way about things such as texts and maps.

These perspectives are not incompatible. Rather, they provide different potential lines of enquiries made possible – demanded – by a shift towards ontology and objects. Harman's argument focuses on interrogating the integrity of the object and on demonstrating that it cannot be dissolved either upwards or downwards. Morton pushes this forward by linking the withdrawn nature of the object to its capacity for producing change. Bennett is similarly interested in the ability of things to affect other things, in thing-power. Bogost and Bryan's ideas on unit operations also focus on objects' abilities and capacities, and crucially link this to the way objects configure themselves as distinct entities.

The common ground between these arguments can be considered in terms of entanglement, which allows us to 'maintain the irreducibility, heterogeneity, and autonomy of various types of entities while investigating how they influence one another' (Bryant, 2011, p. 32). Indeed, the balance of these two aspects of objects will be at the core of the case study analyses in Chapters 4 and 5. Using an object-oriented perspective, the two case studies in this thesis will explore how these different emphases on irreducibility, heterogeneity and autonomy on the one hand and influence on the other may challenge and inform cartographic thought and research.

3. Exemplifying

This research is based on two case studies: MotionMap in Milton Keynes and Whereabouts London. Through these cases, the research will explore and interrogate some of the theoretical assumptions of OOO as discussed in Chapter 2, in order to examine if these could help us understand maps in the context of the smart city. This chapter will set out the thesis' methodological approach, putting forward a case study methodology to discuss the specific role these case studies will play in addressing the research questions. In particular, this case study methodology will be understood through the concept of exemplifying, constructing the two studies as examples of how maps can be approached as objects.

The chapter will start with outlining some of the critique of case studies in social research. In response to these criticisms, it will use the concept of casing to open up different ways of thinking about case study methodologies and of defining what cases are and how they relate to theory or knowledge. Subsequently, the notion of the example will be developed as a particular type of casing. Conceptualising case studies as examples will help to understand how single cases can help generate knowledge about their wider context. While single cases may be criticised for not being representative or generalisable, as examples they have a different role in developing knowledge and understanding.

Examples are concerned with the relationship between the general and the particular, moving away from generalisability as a primary concern and instead focusing on analogy and intelligibility. This helps us think of the case studies as examples that make intelligible different ways of thinking maps as objects in order to understand what it means for a city to be smart. In addition, the chapter will reflect on the relationship between this and the previous chapter, asking how the exemplary case study methodology relates to the discussion on objects. It will ask: what makes the case study methodology suitable for exploring an object-oriented methodology? Finally, the chapter reflects on the selection and casing of the two case studies.

Before proceeding, it should be noted that this is a chapter on methodology, rather than on method. Whilst these two terms are obviously connected, it is important to make this distinction in order to understand the purpose of this chapter. As Howell (2013, p. ix) argues, method and methodology ‘are regularly used to denote methods when the term methodology is required or methodology when the writer actually means methods.’ Hammersley (2011, pp. 25–27) similarly describes an ‘ambivalence towards methodology,’ identifying three different ‘genres’ of methodological literature: methodology-as-technique. methodology-as-philosophy, and methodology-as-autobiography. In response, various authors have attempted to clarify the concept of methodology and its distinction from method. For instance, Harding (1987, p. 2) calls for disentanglement of method, methodology and epistemology, respectively defining these as ‘evidence-gathering techniques,’ theory and analysis ‘of how research does or should proceed;’ and theories of knowledge.

Thus, methodology is often defined in terms of strategy and design, while method refers to techniques and procedures:

> methodology is not just – and is often *not very much at all* – a matter of method, in the sense of using appropriate techniques in the correct way. It is much more to do with how well we argue from the analyses of our data to draw and defend our conclusions (6 & Bellamy, 2012, p. 17 emphasis in original)

Conceived in this way, methodology becomes the link between methods on the one hand and the theoretical assumptions and conclusions on the other. Through this link, methodological discussion can contribute to developing ‘intellectual craftsmanship’ as put forward by Mills:

> Be a good craftsman: Avoid any rigid set of procedures. Above all, seek to develop and to use the sociological imagination. Avoid the fetishism of method and technique. Urge the rehabilitation of the unpretentious intellectual craftsman and try to become such a craftsman yourself. Let every man be his own methodologist; let every man be his own theorist; let theory and practice again become part of the practice of craft. (Mills, 1959, p. 224)

Methodology is not just a study of methods, but a study or discussion of the ‘alternation between (empirical) intake and (theoretical) assimilation’ (Mills, 1959, p. 74). It allows for a way out of the tendencies of social sciences both towards ‘grand theory’ and towards ‘abstracted empiricism’ – the criticism of which is central to Mills’ argument. The purpose of this chapter is to establish a methodological framework to facilitate a discussion that argues from the findings of the case studies in Chapters 4 and 5, and that is able to draw and defend conclusions.

Casing

There is a large body of literature on using case studies in social science research, describing the different ways cases are used to demonstrate arguments or generate hypotheses. Alternatively, studying a particular case can be important because the case itself constitutes a significant social, political, economic etc. event, situation, or process. This is a point made by Bryman (2012, pp. 68–69), who, describing the difficulties in defining a case, 'would prefer to reserve the term "case study" for those instances where the "case" is the focus of interest in its own right.' In this view, theory can be employed to explain the case and to provide a better understanding of what is happening, but the case findings cannot be in turn used to generate new theoretical insights. To do so would technically constitute a case study not as the 'unit of analysis' or 'object of interest', but rather as 'little more than a location that forms a backdrop to the findings.' Thus, the case in a case study methodology is something that should be explained – not something that can explain. It is *interesting*, not necessarily *of interest*.

The understanding of the nature of case studies as expressed by Bryman is characterised by Flyvbjerg as part of the 'conventional wisdom of case-study research' (2006, p. 220), which denies or at least limits the potential of single cases to be of relevance for anything other than themselves. Here, studying a single case is not properly scientific as it cannot meet criteria of rigour, control, external validity and reliability, and leaves too much room for the researcher's personal views, error and interpretation. In this line of thinking, examining MotionMap and Whereabouts London could at most serve to generate some new hypotheses about how maps can be framed as objects. Using these cases to think about the potential value of OOO to cartographic theory and research as this thesis seeks to do would not properly count as case study research, as the 'focus of interest' reaches beyond the cases themselves.

Central to much of the criticism of case studies is the problem of generalisation and generalisability. Indeed, Platt (2007 n.p.) argues that a 'major area of controversy is that over how case studies may contribute to empirical generalization or to general theory.' Sarantakos (2012, p. 113) defines generalisability as 'the capacity of a study to extrapolate the relevance of its findings beyond the boundaries of the sample,' concluding that 'obviously, the higher the generalizability, the higher the value of the study.' As Flyvbjerg argues, however, this conventional wisdom is one of several misunderstandings of case study research that do not do justice to the potential of cases in human learning and in social research. Not only are there a number of ways – most notably falsification – in which single cases can contribute to the development of theory, formal generalisation itself, Flyvberg proposes, is 'overvalued as a source of scientific development, whereas "the force of example" is underestimated' (p. 226).

Likewise, Moriceau (2010) questions generalisation as the sole purpose of research. He describes how generalisation, or generalisability, is a key concern for the social and natural sciences alike, and is dealt with in various ways, depending partly on discipline, partly on philosophical commitments: 'some researchers devote much energy to ensuring generalizability; others propose the reader is responsible for applying case study results to other case studies; and still others shrug off the question of generalizability, asserting its irrelevance for case study research.' Accordingly, different 'ontological assumptions' of for instance grounded theory, critical realism and postmodernism enable different kinds of 'generalization strategies.' Most importantly, Moriceau concludes – like Flyvberg – that perhaps generalisability does not need to be the primary objective of case study research. Instead, he suggests that 'the generation of rich knowledge of a given phenomenon' or the discovery of 'other kinds of insights' may be more important.

Alternatively, Latimer and Munro (2018) propose not necessarily getting rid of generalisation as such, but reimagining and repurposing the concept. Criticising the idea that the accumulation of parts can produce an accurate general picture of a whole, they argue that the breaking down of phenomena into ever-smaller instances always results in a loss that cannot be restored by putting these parts back together. Instead, they turn to the practices of 'world-making' as a way of thinking about case study research beyond emphasising the representativeness of cases. Generalisation thus imagined entails attention to agency, attachments and extensions to describe how persons and things, ideas, experience and practices hold together to make worlds possible for longer or shorter periods of time.

In contrast to Bryman's limited role for the case study as a methodology, Ragin (1992b) puts forward an understanding where case-study research can take many forms ranging from the intensive study of a single case to large-scale comparative analyses of many cases. Indeed, the term "case" has been used in a multitude of ways across and within academic disciplines and has, in the process, gained a variety of sometimes contradictory meanings. For instance, the case study is sometimes conflated with qualitative research, with quantitative research instead taking a perspective across many cases at a time (Ragin, 1992b, p. 4). According to Platt (2007 n.p.), this conflation is partly due to the case study's history in American sociology where it was seen as representative of qualitative research and opposed to statistics. In this line of thinking, case study methodology implies the in-depth study of the richness and complexity of one or a limited number of cases, to which quantitative methods cannot do justice.

However, both Ragin and Platt argue that research can take a case study approach regardless of it being qualitative or quantitative. It is a question of methodology, rather than method. Thus, Platt (2007) describes a number of ways case studies have been deployed in various disciplines, such as experimental case studies, medical case histories, ethnographies and comparative case studies. Across these different uses of case study methodology there is a wide variety of definitions of cases, of their use and purpose, of their value and their relationship to theory.

Considering the many ways in which cases can be used, determining both the nature of the case and what it is a case of within any study are difficult tasks and ongoing challenges that are at the heart of doing research. This process is captured in what Ragin calls 'casing:' a research tactic that is 'invoked at many different junctures in the research process, usually to resolve difficult issues in linking ideas and evidence' (Ragin, 1992a, p. 217). It describes the researcher's processes of 'making something into a case' (p. 218), including defining or delimiting what should be counted as the case, what it means to be a case for any particular study, and what the case is a case of. A useful way of thinking about casing is offered by Ragin (2009, pp. 523–524):

> Empirical evidence is infinite in its complexity, specificity, and contextuality. Casing focuses attention on specific aspects of that infinity, highlighting some aspects as relevant and obscuring others. (…) Different casings provide different blinders, different findings, and different connections to theory, research literatures, and research communities.

What is relevant to a case depends on the particular casing – which is a result of a study's research questions, but also of elements such as theoretical framework, the literature it engages with, and the community or discipline in which it is located. Depending on these issues, the same material may be cased in a variety of ways. In other words, the activity of casing includes deciding what aspects of a case are of relevance and why.

Thus, the nature of a case is not a given, but something that needs to be constructed throughout the course of a research project:

> From this perspective, no definitive answer to the question "What is a case?" can or should be given, especially not at the outset, because *it depends*. The question should be asked again and again and researchers should treat any answer to the question as tentative and specific to the evidence and issues at hand. Working through the relation of ideas to evidence answers the question "What is a case a case of?" (Ragin, 1992b, p. 6)

Casing mediates between the evidence and the research question. It entails sifting through the research results and continuously reflecting on the relationship between the findings and the objectives. It facilitates a link between the empirical and the conceptual – the primary requirement for Mills' intellectual crafts(wo)man. While 'the details, no matter how numerous, do not convince us of anything worth having convictions about' (Mills, 1959, p. 55), the process of casing can help connect these details to the conceptual, to issues and concerns, making a case and showing why it is not only interesting, but also of interest.

The example

The concept of casing entails the idea that there are many types of cases, many ways in which a case study methodology can be used. This chapter develops the example as one such type of casing; that is, the example is one answer to the question of “what is a case?” For some, exemplification is understood akin to illustration, which, when posited as a possible function of the case study, refers only to the ‘presentational or rhetorical features of how the material is written up,’ rather than to a study’s methodology (Platt, 2007). However, a more substantial role for the example is envisioned by Flyvberg (2006), who argues for the potential of case study research in terms of the ‘force of example.’ Similarly, Latimer and Munro, claim that:

> The true value of the illuminating example comes not only from evading the trap of making the example hold as a particular ‘representation’ of a universal truth or ‘social fact’, or from the rigour of the researcher’s cross-checks and balances alone. Good examples are much more profound: they are about grounding the part in the fabric of relations and associations, connections and disconnections that makes the particular possible. (Latimer & Munro, 2018, p. 308)

Generalisation, making the example hold as a particular ‘representation’ of a ‘universal truth’ or ‘social fact’ is here understood as a trap, as the ‘re-synthesis’ (p. 307) of the parts or instances that make up the whole is inherently problematic. The value of the example, therefore, is not to provide an accumulation of representative cases. Rather, Latimer and Munro argue, it is about demonstrating how the single instance is made possible by revealing the things, ideas and beliefs to which it attaches itself.

Although generalisation can be an important and valuable aspect of research, the use of the example as put forward here has the ability to shift attention away from generalisability to alternative sources of validation for the selection and study of cases. Its value, in this context, is not its capacity to be generalised, as a representative case, but its capacity of making intelligible, of enabling connections, of extending (Gambs, 2013) beyond itself into a wider context. The example conceptualises the relationship between universality, generality and the whole on the one hand, with particularity, singularity and the part on the other. Its relationship to the general is complex and paradoxical: examples both produce and are governed by that what they exemplify. Likewise, the “exemplified” simultaneously exceeds and is defined by any concrete instances in the process of exemplification.

In other words, what is at stake in the process of exemplification, according to Lowrie and Lüdemann (2015, p. 2), is the tension between ‘flat and hierarchical methods of ordering,’ which defines ‘whether the radical singularity of the thing or person exemplified, or its conceptual subsumption is privileged.’ One the one end of this spectrum, marked by flat methods of ordering, the singularity of particular examples is emphasised. On the other end, under hierarchical methods, the significance of the particular is defined by the conceptual. The tension between these two methods of ordering is unstable: too much towards the horizontal and the example loses its capacity to extend beyond itself, it is left on its own; too much towards the vertical and the example becomes just an instance, generalizable, fully defined or governed by the conceptual.

Consequently, Lowrie and Lüdemann (2015, pp. 2–3) argue, there are different ways of exemplifying. They link configurations of ‘flat and hierarchical methods of ordering’ to specifically disciplinary commitments. In other words, what defines a discipline is not so much, or not only, its shared examples, but also its mode of exemplification: ‘many of the disputes in the history of thinking about examples turn on the competition between flat and hierarchical methods of ordering.’ The way in which this balancing is eventually played out, it is argued, differs per discipline. For example, they describe how in the discipline of case law general rules are shaped by individual cases, while in modern science and philosophy examples have often been ‘demoted to the mere didactic illustration of general concepts for those unable to understand them without assistance from concrete cases or instances’ (p. 4). Similarly, Højer and Bandak (2015) describe how anthropology has sometimes been criticised for privileging ethnography of specific peoples over the formulation of general principles. Thus, different disciplines have different preferences towards the flat or the hierarchical. In the same way that disciplines’ have different generalisation strategies (see Moriceau, 2010), so too do they value different exemplification strategies.

Another theory of the use of example as method is put forward by Agamben, in his work on the paradigm – used as synonymous with the example. The paradigm steers the example away from the vertical towards the flat or horizontal method of ordering described above. In particular, Agamben's notion of the paradigm is intended to address his concern with dissolving the dichotomy between the universal and the particular, between the general and the singular (see Meskin & Shapiro, 2014, pp. 423–425). Rather than a 'binary logic' of the general and the particular, the paradigm designates a 'force field traversed by polar tensions' (2009, p. 20):

> in the paradigm, the generality or the idea does not result from a logic consequence by means of induction from the exhaustive enumeration of the individual cases. Rather it is produced by the comparison by only one paradigm, one singular example, with the objects or class that the paradigm will make intelligible. (Agamben, 2002 n.p.)

Thus, rather than thinking of the relationship between data and theory in terms of either inductive or deductive the paradigmatic approach suggests an alternative approach of analogy and abduction. By linking the paradigm to abduction, understood as 'an ampliative and generative form of reasoning,' it can be framed in terms of fostering a 'basic inquisitive stance or mind-set, (…) characterized by openness, curiosity, exploration, humility and creativity' (de Melo, 2018, p. 91).

Crucially, as a paradigm, the example shifts the focus from generalisability and representativeness to intelligibility or knowability. What is at stake, according to Agamben, is not a question of the transformation of the particular into the general, of a case into knowledge, but of the relationship between 'a singularity (which thus becomes a paradigm) and its exposition (its intelligibility)' (Agamben, 2009, p. 23). This exposition – which should be understood in the sense of an exhibition, a demonstration, rather than an uncovering – of the case as paradigm involves showing the conditions under which it can come to be known as a paradigm for, or example of, something. These conditions are not external to the case, where the question would be if the case meets the conditions to qualify as a case of something but are 'immanent' (p. 31) to the example. In other words, an example is not first found ready before being analysed: 'in the paradigm, intelligibility does not precede the phenomenon; it stands, so to speak, "beside" it' (p. 27).

Methodologically an example, as paradigm, is not selected to prove a particular point that is known in advance. It involves a somewhat messy or blurry process in which what is exemplified only becomes clear gradually. Both the general and the particular, are constructed, uncovered and exhibited together, slowly and iteratively. Indeed, the importance of the example is that it suspends and problematises its relation to what it exemplifies, so that the unexpected, the incompatible and the unresolved can become of value to the researcher. This is a process of validation in which both that what needs to be validated and the criteria against which the validating will need to take place hang in the balance.

This emphasis on intelligibility, or knowability, also brings into view a particular temporal dimension of exemplifying. In response to Agamben's discussion on the paradigm, Samuel Weber draws attention to Benjamin's concept of the 'now of knowability' (see Agamben, 2002) – the moment, or space-time in which the example's knowability is developed. This now, in its exclusive inclusion, its suspension of the normal function, is a 'cut' – a moment of separation in which 'what is involved (…) is not so much the act of [knowing] as the virtuality of (…) becoming-[knowable]' (paraphrasing Weber, 2008, pp. 50–51):

> Such a now is an *Augenblick*, the *glance* of an *eye* whose sight is always split between what it is and what it sees. In such an instant, what becomes possible is not simply knowledge as reality, but knowability as ever-present possibility.

What is important for Weber's reading of Benjamin is the distinction between knowability and knowledge, and the importance of the former term in its own right.

> Such "knowability" is not, for Benjamin at least, simply a preface to its realization as full-fledged knowledge. It has its own dignity, precisely as potentiality, and above all, it has its distinctive structure. It is this structure alone – which is that of *awakening* as distinguished both from consciousness and from unconsciousness – that explains how and why knowability, whose manifestation is inseparable from its vanishing, cannot be reduced to the positive knowledge it both makes possible and relativizes. (pp. 168-169)

The now of knowability is therefore not simply a snapshot, holding the object of investigation still. It takes a structure of awakening, which should be understood as a process of positioning, of gaining a sense of direction in both time and place in the world.

The temporality of the methodology of exemplification, therefore, is not about the trajectory from example to knowledge, but about the now of knowability which has its own space and time; which has a movement of itself or rather, which is movement in itself. This is what Weber (2008, p. 171) writes about the spatial and temporal ('the one conditions the other') characteristics of awakening:

> The (person) awakening never wakes up in general, but always in and with respect to a determinate place. The locality in turn is never closed upon itself or self-contained, but opened to further relationships by the iterations that take place "in" it. To be sure, such iterations are never infinite, they will always *stop*, but that stopping will never amount to a conclusion or a closure. Rather, it will be more like an interruption or a suspension. A cut.

As a methodology, the process of exemplifying is tasked with expanding the now of knowability. Paying attention to this now of knowability means asking not whether the case is representative of the phenomenon it exemplifies, but how, as a paradigm, it facilitates a particular mode of knowing – as a form of positioning, determining direction, an extension beyond itself. It is this now that seizes on the example's ability to 'to proliferate, connect, and absorb,' in which 'exemplification multiplies, makes connections, and evokes (the one becomes many)' (Højer & Bandak, 2015, p. 12).

Thus, the example is used across many different academic disciplines for its ability to define the relationship between the general and the particular, between theory and evidence. The methodological framework employed in this thesis draws on this ability in order to formulate what it means for the two case studies to exemplify some of the different way maps can be thought of as objects. As will be discussed, this methodology of exemplifying makes use of the capacity of the single instance to produce knowledge. It opens up its own space/time in which the part and the whole become known together. Unlike with generalisation, with the example the whole does not exist independently of the part. Højer and Bandak (2015, p. 11) describe this distinction between generalisability and 'the power of the example':

> With exemplification, the question of veracity and validity – that is, of finding proof ('What is this phenomenon proof of?') – turns into a question

> of how to produce imagination and potentiality ('What can this example evoke?'). The move from evidence to exemplification is thus a move from the passive provision of evidence from an already established viewpoint in a disciplinary tradition ('We know what we are looking for but can we find it?') to the active making of convincing connections *from within* the example ('Can we find other things by (imaginatively) using what we have found?').

These questions of veracity and validity should not be understood in terms of the external validity of generalisation. This would be a purely vertical method of ordering that privileges the conceptual at the expense of the singular. Rather, exemplifying as discussed here is a methodology of drawing connections, of extending and orientating:

> The notion of exemplification, then, points to pattern 'extension', the analytical strength of a particular example being how much it is able to proliferate, connect, and absorb. In line with this view, evidence 'makes evident' or 'recognizes' (in something outside itself) and can be gathered (the many become one), whereas exemplification multiplies, makes connections, and evokes (the one becomes many). (Højer & Bandak, 2015, p. 12)

This understanding of exemplification shifts away from the vertical method of ordering to more of a horizontal approach. The example, Højer and Bandak argue, 'does not invert the vertical analytical movement but rather points to a 'lateral' rethinking of the relation between the particular and the general, ethnographic material and theoretical reflection' (2015, p. 6).

This emphasis on multiplication, proliferation and connection resonates with a project of critique not as deconstruction of existing narratives, but as construction, as addition to and elaboration of these narratives. This, Massumi argues, is the value of the example: not the application of existing concepts, but the adding of detail:

> As a writing practice, exemplification activates detail. The success of the example hinges on the details. Every little one matters. At each new detail, the example runs the risk of falling apart, its unity of self-relation becoming a jumble. Every detail is essential to the case. This means that the details

> making up the example partake of its singularity. Each detail is like another example embedded in it. A micro-example. An incipient example. A moment's inattention, and that germ of a one-for-all and all-in-itself might start to grow. It might take over. It might shift the course of the writing. Every example harbors terrible powers of deviation and digression. (Massumi, 2002, p. 18)

Thus, the example, the exemplifying case, implies a methodology that adds to rather than subtracts from. It avoids the application of concepts as would be the case with deductive and inductive models. Rather than solving issues, it has the potential to multiply them, create new ones – to make a mess (Law, 2003). As examples, maps are able not only to simplify, but also to complicate, not only to render more concrete, but also to make more abstract, not only to make more comprehensible, but also to leave 'readers with a very special gift: a headache. By which I mean a problem: what in the world to do with it all' (Massumi, 2002, p. 19).

Exemplifying object-oriented cartography

The notion of the example helps to understand the way in which the case studies are set up to explore if OOO may be used to inform cartographic theory and research. There are, moreover, a number of affinities between OOO as outlined in the previous chapter and the exemplifying case study methodology as described here. Firstly, it can be argued that the questions raised in object-oriented and thing-materialist debates is particularly suited to the in-depth study of single cases. As Bennett writes, 'vital materialists will thus try to linger in those moments during which they find themselves fascinated by objects, taking them as clues to the material vitality that they share with them' (Bennett, 2010, p. 17). Similarly, the case study methodology based on exemplification is about curiosity and fascination, looking for clues and following them wherever they may go. With its focus on occupying and expanding the now of knowability, the example allows the case study to linger in the moment. Building a case into an example requires the accumulation and activation of detail. Just as every object is unique, so too is every case. The example provides a methodology for demonstrating this uniqueness as the same time as extending beyond itself into a wider context.

In doing so, moreover, the conceptualisation of examples in this chapter is quite similar to that of objects in the previous as both share a primary interest in the singularity of individual things, while also acknowledging their complicated relationship to their wider contexts. The study of objects involves simultaneous attention to their 'secluded private vacuums' (Harman, 2005, pp. 1–2) and to the way they relate to and affect other objects around them. Similarly, a case study methodology as proposed here is interest in the uniqueness of a case, but also in the way they relate to a wider context, without being necessarily representative of such a context. Finally, both cases and objects are inexhaustible and can never be known or encountered in their entirety. Here, the process of casing is instrumental in deciding whatever details of a case are of interest, emphasising certain aspects while temporarily ignoring others.

Next, one of the features distinguishing an object-oriented cartography from the school of critical cartography can be understood in terms of their attitudes towards maps and map makers and their conceptualisation of critique. Within critical cartography, maps and map makers have often been treated with a sense of suspicion. Indeed, as referenced in Chapter 2, the starting point for Harley's 'deconstructing the map' was the problem that 'we still accept uncritically (…) what *cartographers* tell us maps are supposed to be' (1989, p. 1 emphasis in original).Critical cartography's goal was to deconstruct or demythologise maps in order to reveal and expose the map's 'second text' (Marting Dodge & Kitchin, 2000), the map makers' true intentions, or their position in a wider field of power relationships.

Likewise, the methodology of exemplification is not one of deconstructing, but of constructing. It is about the ability to 'find and create the good paradigm' (Giorgio Agamben, 2002). It entails making intelligible, drawing connections, enabling movement, activating detail. It is sympathetic to notions of critique as suggested by Latour, who asks what critique would do 'if it could be associated with *more*, not with *less*, with *multiplication*, not *subtraction'* (2004, p. 248 emphasis in original). It is

> affected by a different mood, namely, one that echoes the fascination with objects which oozes from object-oriented literature. A diametrically

> different intellectual posture, more inclined towards aesthetics and wonder and less prone to denunciation and distrust (Rossetto, 2019, p. 27)

This methodology of affirmation and experimentation rather than deconstruction and interpretation, resonates with the theoretical/philosophical concerns of OOO. Indeed, throughout his writings, Harman expresses his debt and affinity to Latour's work on things, materialism, ontology and critique and positions himself strongly in opposition to critical theory – as set out in Chapter 2. He criticises approaches of deconstruction as cases of overmining, explaining objects through the structures and networks in which they are found. None of the strategies of under-, over- and duomining, Harman argues, do justice to the object. They divert attention elsewhere. In contrast, the methodology of the exemplifying case study enables an object-oriented cartography to focus on the map itself as object of interest.

Finally, the example can be understood in response to a critique of OOO – more specifically of (speculative) realist writers such as Latour, Harman and Meillassoux (Galloway, 2013). While object-oriented and speculative realism are often posed as provocations against established schools of thought, Galloway claims that there is in fact a problematic congruence with the contemporary, hegemonic forms of reasoning and governance. There are a number of problems or risks associated with this congruence, or coincidence, Galloway argues. Most poignantly in relation to OOO, the critique of social constructionism risks replacing projects of understanding how various categories are socially constructed with a new 'system of "objective" essentialism (an unmediated real, infinity, being as mathematics, the absolute, the bubbling of chaos)' (Galloway, 2013, p. 356). As a result, the turn to ontology risks becoming a turn away from critical fields such as feminism, postcolonialism and identity politics. While many of the new materialist or speculative realist thinkers are clearly political, Galloway argues, 'the question becomes more pressing however when a philosopher uncouples Being from politics in order to withdraw from the project of political critique altogether' (p. 358).

Inspired by Catherine Malabou's writings on plasticity, Galloway poses the question: 'what should we do so that our understanding of the world does not purely and simply coincide with the spirit of capitalism?' (2013, p. 352). The paradigmatic case study methodology proposed here can be understood as offering a potential way of avoiding such coincidence. The paradigm is not about withdrawing from the project of political critique. Expanding the now of knowability, it is characterised by movement, not coincidence. It allows for reflection, orientation and determining direction. By lingering in the moment, activating detail, and stimulating multiplication and extension, the paradigm provokes established ways of thinking and allows for things to be imagined differently. As philosophical debates, OOO and speculative realism are not particularly specific in terms of prescribing how object-oriented research should be conducted. The paradigm offers a methodology in which these concepts can be linked to methods and data in an iterative manner – leaving space for reflection in which these concepts can themselves be scrutinised and tested.

Casing MotionMap and Whereabouts London

Through the discussion on casing and the example, this chapter has aimed to formulate a response to the question of what a case is – that is, what it means to be a case of something. This final section will address the selection and casing of the two case studies of MotionMap and Whereabouts London, which will be discussed in Chapters 4 and 5. The cases were selected based on a number of criteria to engage the different pieces of the puzzle that comprise this thesis, in order to address the research question: *can object-oriented ontology be used to inform cartographic theory and research?* As set out in the Introduction, the research started from an interest in the smart city because of the way in which this provides a context for examining the changing nature of maps. The case selection process therefore focused on finding mapping projects that were based within smart city initiatives. I went through a wide range of websites of smart city initiatives and research centres across the world – many of which have been mentioned in Chapter 1, reviewing their recent publications and projects, identifying those pieces of work that revolved around mapping.

In the early years of smart city research, case studies often focused on large-scale infrastructural projects such as Songdo in South Korea and Masdar City in Abu Dhabi in (e.g. Halpern et al., 2013; Halpern & Günel, 2017). These were often discussed as the result of the work of research centres pioneering a new science of cities are in prestigious universities in global cities such as the CASA in London, the Future Cities Lab in Singapore, and CUSP in New York (see Townsend, 2015); and of a select group of large multinational technology firms such as IBM, Microsoft and Cisco (McNeill, 2015b). However, the potential of technological solutions for all sorts of urban problems has pervaded cities of all scales. For example, there have been various smart city initiatives in smaller cities throughout the UK such as Future City Glasgow, Bristol is Open, and Milton Keynes's MK:Smart. For this research project, I wanted to ensure to look at a range of different types of smart city initiatives.

A crucial element in the eventual case study selection was availability of and access to information for each of these projects. While most smart city programmes include various mapping examples, many of these are only short-term projects and provide limited additional information regarding their background, goals, methodology and people involved. Often, the map or mapping platform is made available only as a finished product. In this respect, both MotionMap and Whereabouts London stood out as they both were associated with a variety of published resource that made it possible to explore the maps in more depth.

For example, for MotionMap there were a number of relevant scholarly articles published by the MotionMap team as well as by academics involved in the wider MK:Smart programme. These include articles describing the citizen engagement and prototyping workshops for MotionMap (Cook et al., 2019; Valdez, Cook, Langendahl, et al., 2018; Wolff et al., 2017), its aims and ambitions (Valdez Juarez & Potter, 2014), the MK:Smart Data Hub (d'Aquin et al., 2015; Daga et al., 2016) and the MK:Smart programme (*MK:Smart*, 2017; Valdez, Cook, & Potter, 2018). In addition, following an initial interview with Professor John Miles at the University of Cambridge, everyone from the team turned out to be very approachable and available for interviews, providing a wide range of perspectives on the project.

Meanwhile, for Whereabouts London the developers had been proactive in making a lot of important information on their BitBucket repository, later transferred to GitHub. This repository includes background information about the project's goals and development, as well as a tutorial and the algorithm's code. This technical information was supplemented by an interview with Alan Waldock, Data Visualisation Designer at the Future Cities Catapult, who worked on the project.

As an explorative study examining the potential value of OOO for cartographic thinking, the two cases were not chosen because they were thought to evidence any particular claim or argument in advance. Rather, the two cases together were selected largely because they were, initially at least, unlike one another. They are from different cities – London and Milton Keynes, apply to different sectors – public administration and transport, and have different aims and ambitions.

Each case involved a different approach to mapping. MotionMap is a wayfaring map helping people navigate their way across the city through information about transport and business, using real-time data gathered from sensors and cameras. Whereabouts London is an interactive map that offers a novel description of London's demographics and allows for comparisons between different areas. It is based on the analysis of publicly available data from a range of sources, made available through the London Data Store 2.Also, the cases were from two different types of initiatives. MK:Smart was a smart city programme that involved grassroots organisations and private companies but was primarily driven by the Open University in Milton Keynes. The Future Cities Catapult was an organisation mainly focused on supporting and developing businesses in the innovation sector.

By looking at different kind of maps, these case studies offer different opportunities to reflect on what mapping entails in the context of the smart city. Both cases raise questions that have been pertinent throughout the trajectory of cartographic research: questions around map users and producers, of the process of production, representation, participation and more. The objective was not to ensure that the projects are representative of or generalisable to the smart city movement as a whole. Indeed, there are many different types of maps and mapping projects that could have been selected: from citizen science and grassroots projects, to large-scale dashboards by multinational technology firms. Rather, the hope is that the case studies could focus on different aspects of maps, smart cities, and of OOO with the aim of capitalising on the particularities of the cases to prompt different ways in which an object-oriented perspective can be applied to cartographic thought and research.

While both cases were selected because of the availability of contextual information, for each the type of resources were of a different kind. As a result of these different types of material available for analysis, each case study used their own specific research methods to analyse this material, which will be covered in more detail in Chapters 4 and 5. For each case these different methods simultaneously enable and are enabled by an analytical framework based on particular socio-theoretical concepts – the prototype and the little analytic, respectively. These concepts facilitate the analyses and link the empirical findings to an OOO-based framework. They help "case" the two projects as cases that explore the potential contribution of an object-oriented approach to cartography. To this purpose, each of the case study chapters will follow a similar structure: they will start with a description of the map and the background of the project; followed by a description of the empirical material collected, framed by a consideration of either prototyping or the little analytic; and finally a discussion that explores relevant texts and arguments from the OOO literature in relation to this material.

For MotionMap, the interviews, the prototyping and citizen engagement workshops, and the academic literature all revolved around the development process of the map: the aims of the project, its success and failures. This focus on the development process was simultaneously supported by and in support of the concept of the prototype, which in turn facilitated the object-oriented analysis. As described in the literature review in Chapter 1, the language of prototyping, experimentation and urban laboratories can be found throughout the smart city literature. Indeed, it was a central theme within the MotionMap project itself. In the case study, the concept of the prototype enables a discussion of the way in which the map mediates between failure and success, present and future. This framing allows the case study to reflect on object-oriented concerns of the distinction between essence and appearance and the link between the object for itself on the one hand and causality on the other, as will be explained in full in Chapter 4.

For Whereabouts London, the material from the online repository enabled a process of reverse engineering that produced a description of the mechanisms underpinning the map's approach to classification and visualisation. The analysis of the underlying mechanisms in the case study was carried out in conversation with Amoore and Piotukh's (2015) concept of the little analytic to facilitate the case study's analysis in terms of OOO. The little analytic as put forward by Amoore and Piotukh addresses the question of how maps are able to make sense of and visualise large and complex data sets: how are meaningful patterns hidden in large bodies of data singled out for attention? In doing so it resonates with a concern with the importance of data analytics in the smart city as highlighted in Chapter 1. Within the case study, moreover, the concept facilitates a link between a technique of reverse engineering and the object-oriented concern with unit operations. By focusing on Whereabouts London's unit operations, the case study will reflect on the distinction between what an object is and what it does and, crucially, the relationship between these two.

Using these two different concepts will allow for different tenets of OOO to be explored. It enables a questioning of the principles of OOO and reflection on the extent to which these principles are helpful for and applicable to cartographic research. They serve to facilitate a link to the specific methods, the evidence-gathering techniques, used for analysis, as well as a link to wider debates and the context of smart urbanism and big data. The notion of exemplification helps to explain *how* the cases function as examples. The concepts of the prototype and the little analytic further build on this by elaborating on *what* they exemplify – namely, different elements of object-oriented thought applied to thinking about maps. The prototype scaffolds an analysis that revolves around the map's movement into two opposing directions – its moving forward toward potential futures and at the same time its refusal to go anywhere, making itself known through friction and failures. Meanwhile, the little analytic offers a way of tracing a map's steps, its unit operations, and in doing so untangles the way that it configures itself by way of acting on other objects. Together, these two concepts are instrumental in the casing of the two maps as they help 'resolve difficult issues in linking ideas and evidence' (Ragin, 1992a, p. 217) and develop the cases as examples of what an object-oriented cartography might look like.

Conclusion

This chapter has set out the methodology of exemplifying that provides the framework for relating the case studies of the next two chapters to the research question. First, it explored a common criticism of the use of case studies: the problem of generalisability. Acknowledging that there are problems with generalising the findings of single case studies to larger populations, of external validity, the chapter has used the concept of casing to elaborate the various ways of making sense of case study research. In particular, the notion of the example has been developed as a different way of casing that draws on the individuality of a single case. The example as discussed here enables a move away from generalisability and instead focuses on intelligibility and knowability, on the way a single case can extend beyond itself by making connections, activating details, evoke and provoke the sociological imagination.

In setting out these methodological tenets, the chapter has made a distinction between methodology and method. It has argued for understanding methodology as a link between a study's theoretical assumptions on the one hand, and its practical methods, procedures for gathering evidence, on the other. It has enabled a link between the research question set out in the Introduction, the context of smart cities described in Chapter 1, the theoretical framework developed in Chapter 2, and the empirical findings of the case studies in the next two chapters. In doing so, it has argued that the exemplifying case study methodology is well-suited to construct a framework for the cases in which object-oriented approaches to cartography can be explored. Thus, connecting the case studies to the theoretical concerns of OOO, it is hoped that this methodology will help cultivate not just a sociological imagination, but an object-oriented imagination.

4. MotionMap

The smart city often conjures images of seamless integration of technology in urban space. People are able to move through the city effortlessly, having real-time access to information on the various tenets of its transport system. Authorities use data to understand routines and movement patterns. Transport providers are able to respond flexibly to changes in demand, leading to overall reductions in congestion and pollution. In reality, however, a lot of work needs to be done to enable these smart approaches to transport. It requires the physical instrumentation of roads and vehicles with sensors, mechanisms for the collection and making available of different data sources, agile teams of software engineers to build the algorithms to make sense of this data, and the building of coalitions of groups that manage and use these new ways of doing transport. Not to mention, given the conflicting ideas of what it means to be smart, as explored in Chapter 1, there is no guarantee that these groups agree on what the problems and solutions are in any given city. Soon, the images of a smooth space of smart transportation make place for rather messy patchworks of incomplete flows of data, malfunctioning apps and misaligned interests.

This chapter will present a case study of MotionMap (see Figure 4.1), a wayfinding app created by a team at MK:Smart, the smart city initiative in Milton Keynes between 2014 and 2017. This project struggled with many of the issues described above. Indeed, as will be discussed, one of the team's fundamental tasks turned out to be how to mediate between the different ideas of the project's stakeholders: academics, technologists, entrepreneurs and residents. All of these had slightly different expectations of and hopes for the map. The chapter will start with an introduction to the project, outlining the context of smart city developments in Milton Keynes and the range of stakeholders that were involved. Next, it will discuss the process of developing the MotionMap, facilitated by the concept of the prototype. The importance of prototyping, experimentation and urban laboratories has already been covered in the literature review of Chapter 1. This chapter will build on that material to examine how these ideas play out in this particular case.

Specifically, in this case study, the concept of the prototype is used to tease out some of the potential lines of enquiry of thinking maps as objects as set out in

Chapter 2. It enables an analysis of the map's rhythm of two distinct mechanisms and temporalities. On the one hand, it signals and promises a future of a properly working technology, of a new way of doing things. On the other, it produces a space for the emergence of unanticipated failures, problems and issues. These two distinct gestures generate a rhythm of speeding up, promise and multiplicity, alternated with slowing down, risk and failure. Crucially, they map onto the two lines of inquiry opened up by OOO, as outlined in Chapter 2: the emergence of the map as object and the ways in which this particular object may relate to, affect and be affected by other objects in its environment. By following both of these lines, opened up by the concept of the prototype, the case study addresses the central research question of whether and how object-oriented ontology can be used to inform cartographic theory and research.

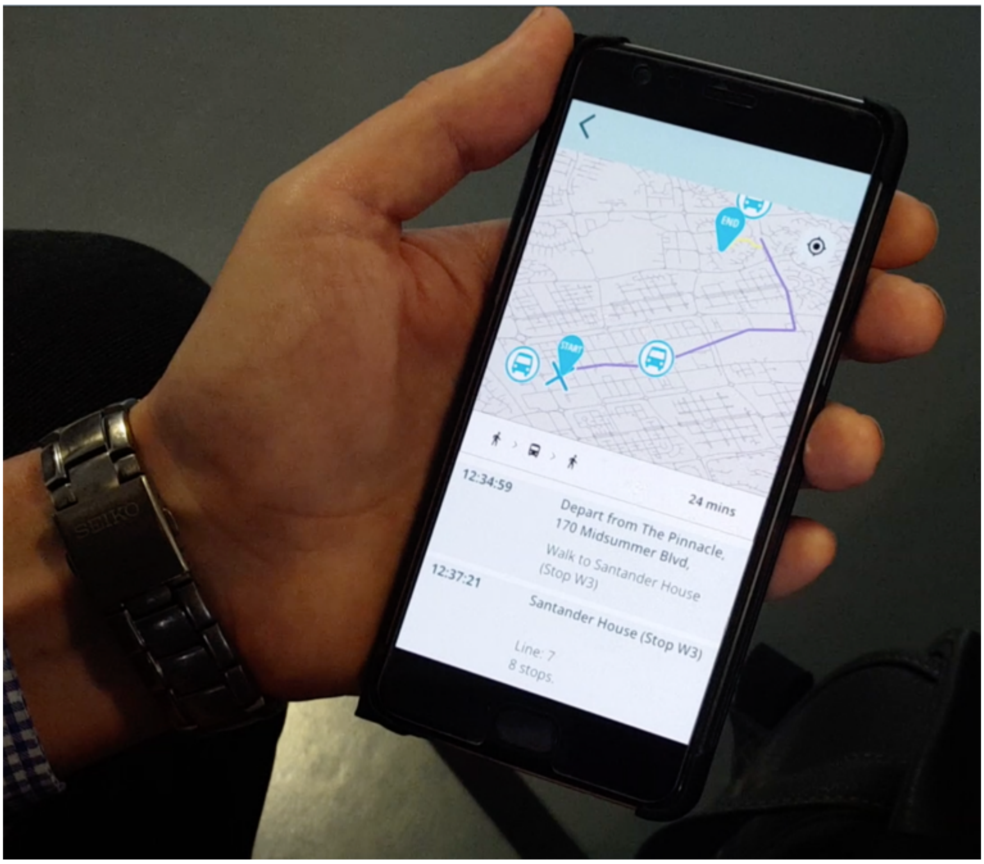

Figure 4.1 MotionMap in action. Picture taken at one of the testing workshops in Milton Keynes (own photograph, taken 24 April 2017 in Milton Keynes)

As a researcher, I came across the MotionMap project when I was looking through the various smart city programs throughout the UK. This was at quite an early stage of the application's development, long before a final product was ready.

Even towards the end of my study, the map was still of limited functionality and only released in a beta-version. From April 2016 to October 2017, I conducted a series of semi-structured interviews with the main project members. These include John Miles, from the University of Cambridge, Alan Miguel Valdez and Stephen Potter, both from the Open University, and Ernst Kretschmann and Daniela Krug from Building Intellect. Through these interviews I questioned the development process of the map, asking interviewees to reflect on the project's goals, its successes and its obstacles. I used themes explored in Chapter 1 of this thesis to explore different views on issues relating to smart city, data and technology.

In addition to these interviews, I attended two testing workshops in April 2017 – one at the Open University, and one at the Transport Catapult offices in Milton Keynes. In these workshops, participants teamed up with members from the project team to walk through the app. Using a questionnaire, participants had to explain to the project team members what they liked and did not like about the app. As an observer, I filmed one of these sessions. Stills and transcriptions of this material are used in this chapter to describe the user experience of the app, and in particular the issues encountered from a user perspective.

Finally, my analysis also relies on information contained within a series of research papers from Valdez, Potter and others at the Open University. These reflect in more detail on various aspects of the development of the project, such as the gamification for the promotion of citizen engagement (Wolff et al., 2017), and the process of organising the workshops and prototyping the map (Valdez et al., 2015, 2018).

The project of MotionMap

MK:Smart was the first smart city initiative in Milton Keynes and ran from 2014 to 2017. With a £16 million budget, it was:

> a large collaborative initiative, partly funded by HEFCE (the Higher Education Funding Council for England) and led by The Open University, which is developing innovative solutions to support economic growth in Milton Keynes. (*About*, n.d.)

It comprised of a number of different strands, looking at Data, Energy, Water, Enterprise, Citizens and Education (see Figure 4.2), which constituted the focus for its various projects.

Figure 4.2 Different strands of MK:Smart. Screenshot of http://www.mksmart.org/

Like many smart city initiatives, the rationale of MK:Smart is framed by the urban age thesis, discussed in Chapter 1, and its associated crises such as congestion and climate change, as can be seen from some of the initiative's promotional material:

> As citizens continue to migrate to cities, these urban areas face a broad range of challenges. Milton Keynes is no exception and, as the fastest growing city in the UK, faces serious challenges in several areas, including transport, energy and water, housing, health, and education. (*MK:Smart*, 2017, p. 2)

Indeed, various of the publications coming out of the programme start with this premise of urbanisation – either in general or specifically in Milton Keynes (Hudson et al., 2016; Wolff et al., 2015). As MK:Smart's brochure highlights, this has a particular impact on the town's transport capacity. With the population of Milton Keynes set to grow, its traffic volume is expected to rise significantly:

> according to an analysis by Milton Keynes Council, given the current rate of growth, by 2026 there will be a 57% increase in travel demand at peak times, including a 25% increase in car journeys. (*MK:Smart*, 2017, p. 2)

With the town estimated to be able to 'only provide an extra 25% capacity through junction improvements and other measures' (Valdez et al., 2018, p. 145), technologies of the smart city constitute an appealing avenue for tackling these issues. Indeed, as will be discussed in more detail later in this chapter, reducing congestion on the roads was among MotionMap's various aims.

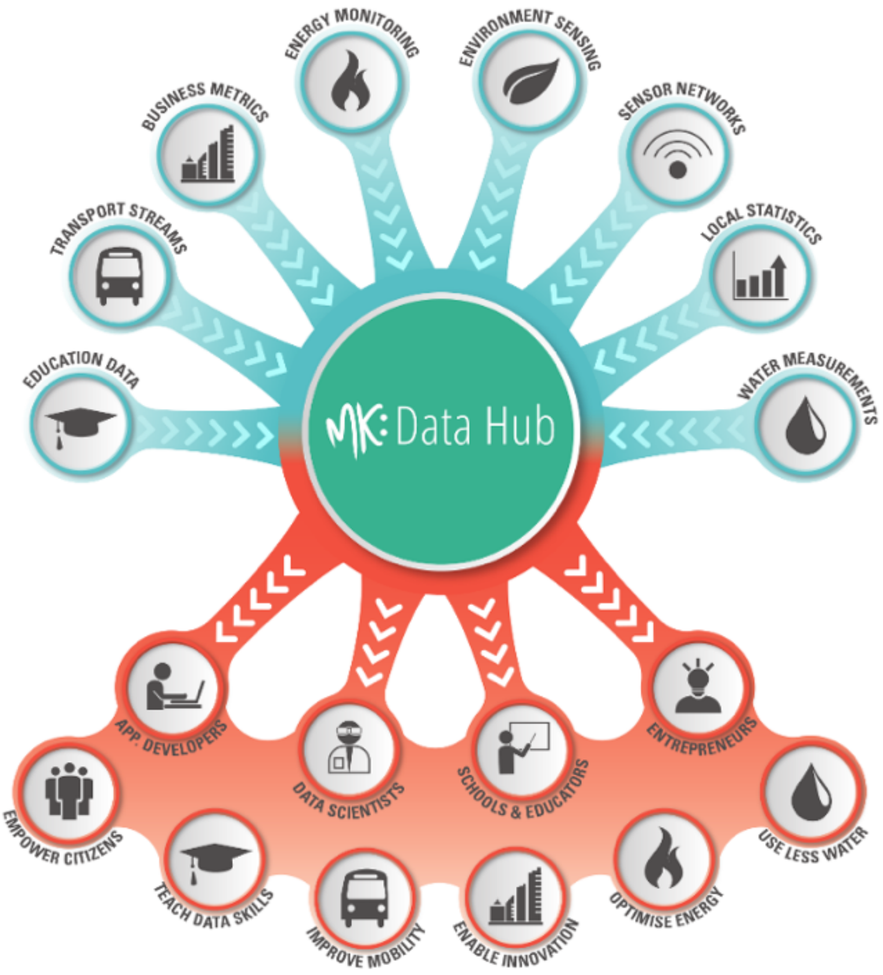

*Figure 4.*3 *The Data Hub at the core of MK:Smart (Data, n.d.)*

One of the main objectives of MK:Smart was establishing the Milton Keynes Data Hub to support the development of all smart city activities, as depicted in Figure 4.3. This data hub was designed 'to support applications that combine different city data in innovative scenarios' (Daga et al., 2016, p. 1). It is a repository for data from a number of sources: 'local and national open data, data streams from both key infrastructure networks (energy, transport, water) and other relevant sensor networks (e.g. weather and pollution data), data crowdsourced from social media and mobile applications, etc.' (*Data*, n.d.). In addition, private companies are able to provide data, all of which can be extracted and combined for projects when needed. Crucially, the data is not stored with a specific application in mind:

> contrary to traditional approaches, the data management infrastructure of such a smart city data hub isn't built to support the requirements of a specific set of applications, services, or access patterns. The point of

> systems such as the MK Data Hub is to enable innovation, by making data available in a homogeneous, inexpensive, and flexible manner, supporting applications that might not be specified yet. But the data's value isn't entirely known at the time and by the people who are building the infrastructure to share, use, and consume it. (d'Aquin et al., 2015, p. 67)

Indeed, as Professor Miles explains, outlining the context of the idea for MotionMap:

> There will be data for health care and data for transport and data for water and data for energy – you know data for all these different stripes. But it's meant to be curated in such a way that you can take a horizontal cut across it. So you can get access to any of the data, so if you want to build an app, for any purpose at all in Milton Keynes, based on the reality of you know what's going on in Milton Keynes right now? You should be able to zoom in on the hub and pick up on data of all these different aspects and make your app. So that's the basic premise. (Interview with John Miles, 11 April 2016)

Supervised by a Data Hub Manager, it is an intermediary between data providers and consumers, curating the data's different formats, licences, rights and policies so that it becomes manageable and 'exploitable' (Daga et al., 2016).

Thus, building on this platform provided by the Data Hub, the MotionMap project was conceived to make use of – "exploit" – the Data Hub's various data sources. As a local wayfinding app MotionMap aimed to give residents in Milton Keynes real-time insight into the busyness of the city, integrating different modes of transport such as walking, driving, cycling and public transport. In this way, the map would enable people to make smart transport choices and would, as a result, reduce congestion in the expanding town. To some extent, it resembled existing applications such as Google Maps and Citymapper. However, the idea behind the project was that, as an app developed locally and with input from the town's residents, it would be provide a more bespoke map that better suited the specific situation of Milton Keynes. In particular, unlike these large-scale maps by global tech firms, MotionMap was 'intended to also contribute to public policy objectives, providing a platform for exploring a variety of approaches to mobility in the city' (Valdez et al., 2018, p. 148).

While the Data Hub was the conceptual starting point, MotionMap also made use of data from a number of places. The basis of the real-time traffic data in Milton Keynes was provided by INRIX, a big data company that sells data garnered from mobile phones. The map also made use of GPS data of buses, providing real-time information on where all the buses are. Next, computer vision cameras were used to determine the number of people, the busyness, in shopping centres and in parks. Other sensors monitored the number of cars in the car parks and indicated the number of remaining available spaces. It also included information from specific modes of local transport such as the town's bike sharing system.

As discussed in the literature review, smart city programmes often involve a wide range of heterogeneous actors and stakeholders, described with the concept of the smart city epistemic community (Kitchin et al., 2017). In the age of big data, every city administration is instilled with the great potential of new technologies to transform urban government and improve the delivery of services, in order to respond to the looming crises caused or exacerbated by large-scale urbanisation. However, existing local city governments themselves might not be able to make the most of these technologies. As the Department for Business Innovation & Skills (2013, p. 6) sets out in a background paper on smart cities in the UK:

> The complexity and the pace of change, combined with the need for integrated and systemic solutions, are presenting a major challenge to local authorities who, traditionally, have developed responses in a "siloed" fashion.

In response, local authorities increasingly draw on those innovation officers, consultants, engineers and so forth as identified by Kitchin et al. (2017). Collectively, these promise to provide administrators with new insights into how the city works –'to take us beyond today's imperfect and often anecdotal understanding of cities to enable better operations, better planning, and better policy' (Koonin, 2013, pp. 1–2).

This emphasis on complexity and change, the need for integrated solutions and working across siloes was important for MK:Smart, which started in 2014 and ran for 3 years until it came to an end in 2017. With a total programme value of almost £17 million, it was funded for £8 million by a Catalyst Fund of the HEFCE

(*Open University*, 2014), while the rest was made up by industry partners. This Catalyst Fund was intended to:

> drive innovation in the [Higher Education] sector, enhance excellence and efficiency in HE, and support innovative solutions at a time of changes to funding and regulation. Funded projects will normally be collaborative, bringing together support from other partners including business, universities and colleges, and other public agencies. (*Catalyst Fund*, 2014)

Led by the Open University, the MK:Smart consortium consisted of a number of partners, including other universities (the University of Bedfordshire in Milton Keynes and the University of Cambridge), governmental and public sector organisations (Milton Keynes Council, the Satellite Applications and Transport Catapults, and Community Action:MK), and industry actors (BT, Anglian Water, HR Wallingford, Fronesys, Graymatter and Playground Energy). In addition to these partners, there were also 'associate partners' including E-on, Huawei, Tech Mahindra, Samsung, the Future Cities Catapult, ThingWorx, Privitar and Comarch (see *MK:Smart*, 2017, p. 11).

Moreover, this interdisciplinary and cross-sectoral emphasis of MK:Smart also shaped the MotionMap project. The driving force behind the creation of the MotionMap project came through university researchers, in particular Professor John Miles, Chair of Transitional Energy Strategies at the Department of Engineering of the University of Cambridge. Working together with Professor John Miles were Stephen Potter (Professor of Transport Energy) and Alan-Miguel Valdez (Research Associate), both at the Open University in Milton Keynes. Together, they became involved with the transport stripe of MK:Smart through a previous project on electric vehicles in the town.

This project laid much of the foundations for their thinking on MotionMap, as it focused on what Stephen Potter described as the 'social understanding of new technologies' and the 'socioeconomic' aspects of implementing these. Indeed, both Potter and Valdez were particularly interested in 'smart city systems as enablers for active, participatory co-creation of value by citizens' (Valdez Juarez & Potter, 2014). Criticising many existing smart city projects and narratives for being overly technocratic, they were hoping to explore the democratic potential of MotionMap, as will be unpicked in more detail below.

In addition to these researchers, much of the hands-on work was carried out by technology start-up Building Intellect. Based in Cambridge, Building Intellect was set up in 2011 by Daniela Krug as a research consultancy in the built environment sector. Via Professor John Miles, the company got involved with the MotionMap project and subsequently refocused itself as a software company in 2014. Thus, the development of Building Intellect was very much intertwined with that of MotionMap. And so was its future: as MK:Smart came to an end in 2017, Building Intellect took over responsibility of MotionMap.

As the company took sole control of the project, it gradually shifted its attention from Milton Keynes to Cambridge, where its headquarters are based. While it still aimed to release MotionMap in Milton Keynes, the app itself was mainly developed further in Cambridge, whose council provided a new form of revenue. This means that, as the project was handed over from a collaborative partnership between academics, software technologists and private industry, the future of MotionMap in Milton Keynes was uncertain. When my engagement with the project ended in 2017, the application was only released as a beta version. Since that time, not much news has been published and it does not appear that it is operational. While this may be seen as a disappointing result, it also fits the MK:Smart's model of initiating projects that will then be taken further by industry. As its final brochure reads:

> new exciting initiatives are planned for the sector work packages (transport, energy and water), aimed at scaling up and consolidating the solutions pioneered by MK:Smart. In particular, the transport work package has produced two new start-ups and we expect commercial spin-offs of the work carried out in MK:Smart to reach the market before the end of 2017. (*MK:Smart*, 2017, p. 10)

This focus on producing commercial spin-offs relates back to the idea of the city as a laboratory, a space where new products can be prototyped and developed. The case study presented in this chapter will focus on the project's development in Milton Keynes, although towards the end some of the team had already started to shift their attention towards Cambridge.

Prototyping

The previous section has outlined the context of the MotionMap. The rest of the chapter will go into more detail about the process of developing MotionMap. This process or developing can be usefully described as a process of prototyping, a concept which has a range of connotations across the domains of product and software development, smart urbanism, and the social scientific literature, as outlined in Chapter 1's section on urban laboratories. In the context of MotionMap, one helpful way of thinking about what prototypes do is offered by Lezaun et al. (2016, p. 211), who describe how collaborative experimentation can:

> serve multiple purposes all at once: they mediate between institutions and communities, bring diverse actors together (sometimes to dramatize their differences), produce hands-on solutions, pilot unorthodox technologies, and, last but not least, test new ways of articulating issues.

Indeed, as will be seen in this chapter, MotionMap played all of these roles – it mediates different visions of the smart city, brings together stakeholders, produces hands-on solutions and articulates issues.

The importance of the notion of prototyping for the case study emerged from its prominence in the smart cities discourse but also as a concern raised by MK:Smart and the MotionMap project themselves. Firstly, the term was used extensively by the project members themselves. Milton Keynes, as a new town, has its own particular historical relationship with this vocabulary of experimentation. As Valdez describes, talking about the Milton Keynes Council:

> So they are trying to develop this culture where they… you could say that this is an experimental city. Because it is a relatively small population, a relatively easy to work with –the industry here is easy to work with, the Council is on board for trying new things and we are trying to frame the city as a place where you can come and test things without spending a lot of money. And then you… if they work you take them to other places. (…) And this has been basically since the 70s. Because well, the city is a new town. It was founded very recently. And since then they have been trying to do new recycling programs here, new energy efficiency programs. They got the electric vehicles. They got MK:Smart. We got the autonomous

> driverless cars. And the Council is trying to get – is succeeding I think – in getting a reputation for being a place where you can come and try new things. (Interview with Alan Miguel Valdez, 6 May 2016)

Indeed, the Milton Keynes Futures 2050 Commission in 2016 described the need for commitment to and investment in a culture of experimentation and creativity:

> Milton Keynes is at a critical moment of cultural transition. It is moving from adolescence to adulthood, but risks embalming itself through fear of change, swapping a spirit of innovation for one of convention. (…) The city's future depends on its people and a culture of experimentation and creativity. Yet people feel Milton Keynes can be complacent and lacks spontaneity, and that a more experimental and subversive 'try and test' approach to culture should be taken. (Milton Keynes Futures 2050 Commission, 2016, p. 21)

This report on the future of Milton Keynes develops these ideas further by describing the town as a 'real-life city test bed environment' for driverless vehicles, smart cities and low-carbon transport technology research (p. 40). It even outlines plans for a new university, establishing Milton Keynes as the centre of the Cambridge-Milton Keynes-Oxford arc, that will promote 'Living Lab Research' that engages 'with the city as a living laboratory for developing and testing new thinking in the five thematic areas, drawing in national and international academic and business partners and working with local communities on the solutions to these problems' (p. 42).

The experimental attitude of Milton Keynes and MK:Smart also defined the project approach of MotionMap (e.g. Cook et al., 2019; Valdez et al., 2018). Throughout the various stages of its development, a number of prototypes were produced. The first of these were on paper, representing only a vague idea of what the final product might look like. Eventually an app was created, with improved functionality as it went through successive iterations. These different prototypes were tested in a number of workshops, where different people, such as university staff, employees of the Transport Catapult, PhD students, and members of transport user groups, tried out and experimented with the models. In the first instance, these prototyping workshops served as focus groups. With the app itself initially of limited or no functionality, the project first sought to find out how people would want to use an app such as MotionMap. In doing so, the workshops served not only to develop the app, but also to engage different community groups and promote participation in what will alter be described as a process of co-creation.

As the project progressed, the sessions moved from focusing on ideas of what kind of app people would find useful to testing the functionality of the subsequent versions of MotionMap. Thus, discussing the events with Alan Miguel Valdez and Stephen Potter after the workshop I attended, they explained that these sessions were not so much citizen engagement events but could be better described as beta-testing or prototyping workshops. With this shift from engagement to functionality the modes of evaluating the results of each session also changed. At first, the workshops were like focus groups, where participants were asked to provide feedback:

> We're not having a full interview. We usually just get a few pages of scrabbled notes and also we have somebody on each table. Usually we've got people working in groups for the workshops. So we just get one observer at each table, making anonymous notes of what was said at the table. And then we get notes – usually when people complete work it's like this [showing a feedback form], about what they tried to do with the prototype or what they would do. (Interview with Alan Miguel Valdez, 6 May 2016)

Later on, such as in the session that I attended, participants were coupled with one of the developers. Together, they went through a series of questions testing the various elements of the app and asking participants for suggestions to improve it. The responses to these questionnaires were then added to the developers' 'backlog' and analysed and processed in the following months.

Even later, particularly when the project was moved to Cambridge, it shifted away from group workshops altogether, towards individual testers experimenting with the app in their daily lives. As Daniela Krug, head of Building Intellect describes:

> So we got a lot of data when we did face-to-face testing, and that was really invaluable because we had very concrete insights, because we were also able to look over a person's shoulder and to see where [they get] stuck. So that was – we had a wealth of data from that and it allowed us to

> completely redesign the app. And after we redesigned it from the feedback that we received in Milton Keynes, broadly it was quite good. People were able to use the app. So now we've progressed beyond that stage, because it's quite a somewhat larger number of people. (Interview with Daniela Krug, 18 October 2017)

In this way, the role of workshop participants changed from co-creating MotionMap to testing it. Partly this could be related to the gradual hand over of the project from the researchers at the Open University to the software engineers at Building Intellect, and their slightly different views of the role of citizens in the smart city. It is, moreover, also inherent to the approach – as will be described below by Ernst Kretschmann from Building Intellect – of agile software development, which emphasises the potential for projects to change as they develop. This is based on emphasising 'working software over comprehensive documentation' (https://agilemanifesto.org). In other words, as with MotionMap, projects develop through many iterations of prototypes, and only in the process of this testing does it become clear – or is it hoped to become clear – what exactly the final outcome is supposed to be like.

In this case study, the concept of the prototype will be used to open up a way of thinking about the map with reference to the debate on object-oriented cartography. In particular, the analysis will build on Corsín Jiménez's discussion of prototypes, for whom the 'prototype indexes a cultural form (…) that is "more than many and less than one": always on the move and proliferating into affinal objects, yet never quite accomplishing its own closure' (Corsín Jiménez, 2013, p. 385). This movement between the more-than-many and the less-than-one is described through a rhythm of overlapping moments of speeding up and slowing down, respectively. As Corsín Jiménez (2014, p. 393) describes:

> A phrase one often hears in such projects is, 'We are getting ahead of ourselves', when the work of prototyping is experienced as releasing alternating currents of excitement and frustration; moments of liberation followed by disciplinary calls to hold back, to contain oneself.

This chapter will unpick this distinction between these moments of excitement, getting ahead, speeding up, more than many and proliferation on the one hand and frustration, less than one and slowing down on the other. Untangling this rhythm of speeding up and slowing down will enable an object-oriented analysis in which MotionMap as object is understood through a rhythm between its past and its future, its appearance and its essence, causality and interior, change and emergence.

More than many, speeding up: "How could you actually use big data?"

Prototypes are working models of what is hoped to eventually be a fully functional solution to an existing problem. So too for MotionMap: once up and running, it was supposed to offer an innovative solution. But to what problem exactly? This question can be answered in a number of ways. The project was seen as the solution to a range of problems, perceived differently by a range of stakeholders. Rather than narrowing down the purpose of MotionMap, testing a clearly formulated predefined hypothesis, its prototyping process served to multiply the problems and questions it sought to address.

At the heart of the conception of MotionMap was a vision of the fundamental benefit of new big data solutions. In particular, the project was born out of a concern of engagements with the Milton Keynes Data Hub. As Professor Miles from Cambridge described, MotionMap was the first project in the Transport "stripe" of MK:Smart:

> Right now, very few people access the Milton Keynes Data Hub. Because A, there's not much data in it and B, no one knows it's there. (…) The main purpose of MK:Smart is to set all that up, but in setting it up it sorts of needs to get kicked off. So, there needs to be a project in each one of these stripes. (Interview with John Miles, 11 April 2016)

For Miles, the initial premise of the project was not just the improvement of the transport system in Milton Keynes, but first and foremost the development and promotion of a Milton Keynes data hub. In other words, the notion of developing a project around the data hub preceded the ideas of exactly what MotionMap's purpose should be and how it should work.

Such an approach of taking big data as the starting point for smart city projects has been criticised (Mattern, 2013b) for marking a tendency towards 'solutionism,' 'data fetishism' and 'methodolatry' – defined as 'the aestheticization and idolization of method.’ Starting with the notion that solutions should be based on the use of data and methods of data analytics runs the risk of casting all potential problems in the city in the shape of these solutions. In this technocratic approach, all issues can be solved through the collection of data and implementation of algorithms. This limited view that does not justice to the social complexity of cities, nor to the potential of big data. Instead of fetishizing data and algorithms, Mattern argues, ‘we also have to think harder about what it all adds up to — or what we *want* it all to add up to’ (Mattern, 2013b n.p., emphasis in original).

In the case of MotionMap, there were various ideas about what it should all add up to. This question of what the map is supposed to solve or address is illustrated by Professor Potter, who recalled the start of the project:

> As we were looking at the early stages of MK:Smart – so, the idea was, you had a big data project going ahead, so you’ll have the data hub, and *how could you actually use big data*? (Interview with Stephen Potter, 8 December 2016)

In other words, MotionMap was place conceived as an exploration – an experiment – of the question ‘how could you actually use big data?’ As will be seen in what follows, different team members came up with different answers to this question of what big data could be used for. Throughout the project this question was intentionally left open. In this way, MotionMap can be seen as a prototype in the conventional technical sense – i.e. as the testing of a product, but also as an experiment regarding the question of what it means to be smart.

Firstly, as mentioned above, the aim of MotionMap was to provide an alternative tool for alleviating traffic congestion in the face of a rising population in Milton Keynes. Straightforward as this sounds, however, there were a number of ideas about the precise way in which the map was to achieve this. For Professor John Miles, who comes from a background of transport planning, the central concept was that of “busyness:”

> And so our premise comes down to busyness. If you make people aware of how busy things are, then they can make a decision whether they want to go to these busy places or not. And if they decide not to go to these busy places, then you will need to alleviate the congestion –either the congestion *en route* there, on the roads, or the congestion when you get

> there, which is simply too many people in the shopping centre, or too many people in the cinema, or whatever. (Interview with John Miles, 11 April 2016)

This role of MotionMap in visualising busyness relates to the common view of maps as analytic tools, making visible and intelligible complex patterns to enable their users to make decisions, as highlighted in Chapter 2. MotionMap integrates data streams from bus and traffic sensors, with cameras and computer vision systems in parking lots and shopping malls to give a real-time overview of the busyness of various places throughout Milton Keynes. It then calculates the best routes and modes of transportation to a destination, information which a user can use to decide how to travel, or even not to travel at all. As Professor Miles continued: "it's about trying to gather up all that information and make it easily available so you can make your choices."

Thus, for Professor Miles, the way big data could actually be used is by providing insight into the city and enabling choice. However, more than simply enabling people to make better-informed decisions, part of MotionMap's rationale was also to promote certain types of behaviour – namely public transport use – over others, such as driving. In addition to the app making it easier for people to use the public transport, it was also meant to include specific 'incentivisation' mechanisms. For example, it was suggested the map could be linked to a scheme where people would be rewarded with points for shopping discounts for choosing low-carbon transport options. Here the answer to how big data could be used is expanded from improving transport and congestion to stimulating positive (e.g. efficient, economical, sustainable, environment-friendly) behaviour.

Furthermore, while MotionMap was in the first instance meant to be used by Milton Keynes' residents, it was also aimed at the transport sector and the town's policy makers more generally. As Kitchin et al. describe, one of the key objectives of epistemic communities is 'to reshape the policy landscape and political agenda, but also to reconfigure how policy is made and implemented, and reorganize the associated institutional and organizational landscape' (2017, p. 6). So too in the case of MotionMap, the project was envisioned to pioneer a new way of doing, planning and designing, urban transport. This was one of the main concerns for Professor Potter, who contrasted the established models of organising public transport that have been prevalent in the UK and in Europe over the last decades with the new demands of the smart city. On the one hand, he described, these consisted of the transport departments' 'tax-spend model,' where private companies bid for competitive tenders to deliver certain outcomes. On the other hand, the lobby model entails the organisations of citizens in bicycle or bus user groups to pressure the authorities on specific issues.

In contrast, the potential of the smart city is to change the way in which transport is organised from these oppositional models to what Professor Potter described as a 'co-creation model.' Certainly, for the Open University researchers, the MotionMap was intended to contribute to a different 'skillset' and 'culture,' developing a model for organising transport more suited to the smart city:

> the sort of model that you have to have with smart cities, where you have a diverse network of actors, and you're actually negotiating and sorting out deals, and understanding where these diverse actors are coming from, and what's in it for them. (…) in Milton Keynes, where attracting inward investment is very important, they have actually developed that sort of skillset and that sort of culture.
>
> Transport departments find it quite hard to adapt to this different sort of culture, because they're so used to the traditional engineering and total control of their projects. So, they do have very good project management skills, but they're on projects where they have total control. That's not what you have when you're dealing with smart city developments. You nowhere have total control. (Interview with Stephen Potter, 8 December 2016)

In other words, for Potter smartness in transport consists not so much, or not only, of using technology to make processes more efficient, but also in navigating an ever-increasing set of actors and stakeholders. Here, the 'how' in the question of how big data can be used draws attention away from the use of big data for a specific outcome towards the actual manner in which big data can be used, as a central method in the organisation of public transport.

This shift towards a co-creation model is emphasised further by a concern with citizen engagement that preoccupied Valdez. Working closely with Professor Potter, Valdez was particularly interested in how big data could be used to achieve social and political change and empowerment. Indeed, as Valdez saw it, the academic researchers were primarily for representing the third of ‘three inter related pillars: technology, economy and society’ (Valdez Juarez & Potter, 2014). Citizen empowerment, in Valdez’s view, could take a range of different shapes. Firstly, by providing real-time information on the different modes of transport specific to Milton Keynes, people would feel that they have all the information needed to make ’more informed, flexible and spontaneous travel choices’ (Valdez et al., 2018, p. 144). This is a practical notion of empowerment, geared towards people who may feel frustrated navigating public transport in Milton Keynes without the adequate information to plan their journey. It can also be argued to be a limited notion. While citizens are provided with data with which they can make their own choices, these choices are ultimately expected to broadly coincide with decision makers’ ideas around sustainability and efficiency.

However, as described in the literature review, notions such as citizenship, engagement, participation and empowerment are envisioned in a variety of ways within the smart city. In contrast to the practical approach described above, a broader notion of empowerment focuses on how the conversation around the use of big data can be expanded so that citizens are empowered to help shape the narrative of what counts as a smart city in Milton Keynes. Through MotionMap, it was hoped that people could become active participants in the organisation of transport services in their city and, eventually, in the pioneering of entirely new forms of transport. This is what Valdez describes as the ‘Wikipedia approach,’ which, as a ‘shorthand for a model based on open co-creation of value (…) implies that, rather than providing a service, we will provide open transport data and a publicly available platform for citizens and businesses to develop their own applications on’ (Valdez Juarez & Potter, 2014 n.p.). Here, empowerment is understood as enabling citizens to take an active role in the design of the smart city, rather than being mere passive data subjects.

In this view, MotionMap aimed to raise an awareness among Milton Keynes residents of the potential value of big data and stimulate a more general uptake of the Milton Keynes Data Hub. For Valdez, promoting such an awareness was fundamental to moving away from the corporate vision of the smart city towards a more citizen-centred ideal:

> We already know the original smart city project, or the corporate version of the smart city project, is just almost unidirectional: sensors, so the authorities have all the information. After that you get to the stage where it is bi-directional: citizens using the smart city to talk to authorities, creating a channel of conversation. But when you say Wikipedia, because we want to take it to the next step, to make it a many-sided conversation, where maybe even what authorities are doing is not the most important thing.
>
> (…)
>
> People are going to create their own way to interact with the smart city. (…) we want people to take control from us. We want this project to escape our hands. And I think that the Wikipedia owners couldn't control that if they wanted. And we want to get to the same point. (Interview with Alan-Miguel Valdez, 6 May 2016)

For Valdez, the point of the question how you could use big data is not provide a definitive answer, but rather to promote debate and enable Milton Keynes citizens to think about the different uses of data in their city.

Stimulating people to take such an active role and to 'take control' and allowing the project to escape may lead to the application being taken into unpredicted, sometimes even undesirable, directions. Indeed, as Cook et al. (2019) describe, from the initial prototyping workshops emerged an altogether different idea of empowerment. Consulting with different user groups, drivers, pedestrians and public transport users did not particularly value the wayfinding functionality of MotionMap. They were not particularly interested in using the app to inform their transport choices: 'participants sought empowerment through MotionMap for very different purposes than travel information functionality' (p.139). Drivers, for instance, already had a good understanding of the city's busyness, which was at its height during rush hour. The map was not perceived to add much value in this regard.

Rather, its value for these groups was understood in terms of its ability to provide data with which to hold government and transport companies to account. Reflecting on the outcome of the citizen engagement workshops, Valdez described:

> We hadn't realised how much people want to use this so the citizens would be able to make the city accountable and the transport, the service providers, accountable. (…) We thought that the main application for the map was going to be for the citizen and for the transport provider to know what the citizens are doing – to realise, OK there's a lot of people here, there's a lot congestion here, we have to plan our roads differently. But then we – partly because of the workshops – we realised that citizens want to use the map to know what the city authorities are doing, and what the transport providers are doing about the problems. (…) And we hadn't realised that people would like to use it in that way. (Interview with Alan-Miguel Valdez, 6 May 2016)

As discussed in Chapter 1, the concept of the smart city is often framed around the importance of the citizen, using terms as engagement, participation and empowerment. There seems to be a tacit assumption that the interests of these citizens are compatible with those of local governments, corporations and researchers. As the case of MotionMap shows, this is not necessarily the case. Much of the promotional literature on the project describes it objectives in terms of congestion, sustainability and efficiency. However, for the Milton Keynes residents, the map had the potential to solve an additional problem: accountability. As Valdez adds: "and actually, I suspect that authorities hadn't realised and wouldn't have been so enthusiastic about the project if they had realised that people would want to use it to demand accountability."

While the researchers from the Open University and the University of Cambridge were interested in the potential of MotionMap to reconfigure transport practices, the engineers at technology firm Building Intellect were tasked with delivering a functional application. In this regard, their concerns were quite different. As Director Daniela Krug reflected after the conclusion of the MK:Smart program, the university researchers:

> looked at a bigger picture and they looked a bit further into the future. So MotionMap has the potential to do that in the future, but with the budget that we had it was already as a project extremely ambitious – to essentially build another Google Maps, that's as good as Google Maps, with a tiny fraction of the budget that Google have available. So yeah, I think that's

> more of a futuristic view of what MotionMap could become, not really what it is today. (Interview with Daniela Krug, 18 October 2017)

From this perspective, the aims as expressed by Miles, Potter and Valdez were overly ambitious, considering the amount of resource available. The relation of a small tech start-up as Building Intellect to the international corporations was a major consideration:

> There was a fear that there's too much competition in the mapping and transport app domain. And the question was how can MotionMap be different from these other applications? (Interview with Daniela Krug, 18 October 2017)

From a technological point of view, corporations as Google would be much more capable of delivering an application such as MotionMap. As Professor Miles commented, "I'm sure they'll do it in two minutes. If they decide it's the thing to do, they just do it. They'll overtake us instantly" (Interview with John Miles, 11 April 2016). However, both Krug and Miles agreed, companies such as Google were not interested in working closely with small towns such as Milton Keynes. Only smaller firms such as Building Intellect provided the flexibility to provide solutions tailored to the local context. Here, the question of how big data can actually be used brings into view the complex landscape of commercial interests, competition between corporations and between cities, and technological and financial resources.

Finally, for Building Intellect COO Kretschmann, the problems of MotionMap were immediately practical, and not necessarily specific to concerns of the smart city. Commenting somewhat provocatively, he described:

> I'm from a software development perspective. I don't have much of a background in transport, or smart cities, or things like that. And I still to this day refuse that these industries from software development perspective actually exist. Software development, whether they do it for finances, or health, for retail, always comes down to a certain set of practices that you do, technologies, texts that you choose, arrangements that you make with your team, deadlines that you manage. And the actual industry you're in doesn't actually change all that much. Some of them are more reactive than others, (…) but basically, I've got a software development background, and

> this attracted me from a software development perspective. (Interview with Ernst Kretschmann, 8 December 2016)

The ways in which MotionMap might be able to transform practices and organisation of transport in Milton Keynes were of secondary importance to Kretschmann. For him, the question about how big data can actually be used served mostly as a technical challenge. These challenges range from stakeholder management and navigating between clients' wishes and that what is technologically possible to cracking specific programming issues. Most importantly, these are particular not to the field of smart cities, but to that of agile software development.

Thus, while the initial aim of reducing traffic congestion seems straightforward, the members emphasise different ways in which MotionMap can contribute to this – by enabling better choices and accountability, by promoting public transport, by facilitating new ways of organising transport. Across these perspectives, the question of how you could actually use big data is addressed in a variety of ways. It draws attention to the different ideas about how big data could be used in the city and opens up discussion on how it should be used. MotionMap fulfils the various roles ascribed to prototypes by Lezaun et al., (2016): it mediates between these different ideas, allows different actors – governmental, academic, commercial – to come together, tries to produce solutions to different issues, pilots technologies and articulates issues. Starting from a shared interest in the promise of big data, 'what it all adds up to' (Mattern, 2013b) remained unclear throughout the project.

Rather than understanding prototypes as either problem validating or problem making, as suggested by Tironi (2020), MotionMap demonstrated that both can take place simultaneously. Some of the problems described by the participants can be understood as linked to a problem-validating logic. For instance, in his detachment of the context of smart city, approaching MotionMap as a purely technical problem, Building Intellect's Kretschmann is simply concerned with developing a working application that meet specified criteria, not with exploring unexpected realities or relationships. This is a logic of prototyping embedded in the vocabulary of software and product development. It understands the prototyping process instrumentally, as a means to deliver a way-finding application to the specification of the customer. In doing so, it is not concerned with tensions between the various stakeholders, the different possible meanings of smartness, or the social and political implications of the app.

Other problems, however, can be traced back to the prototype's problem-making capacity: different notions of citizen participation, engagement and empowerment, ways of carrying out public transport policy, questions of competition between technology companies and the tension between the local and the global. All of these are questions that to a certain degree problematise established technocratic visions of the smart city. They trouble the tacit assumption in the smart city discourse that the interests of governments, academia, corporations and citizens are aligned or compatible. TIroni (2020, p. 515) describes this process in terms of ontological politics, concerned with 'making worlds:'

> Here the urban reality ceases to be a problem and becomes a field of as yet unknown possibilities in an effort to expand the ways of understanding the problems at hand. This form of operating of prototypes forces entities and visions that had been ignored or undervalued to be recognized, promoting a commitment to the unexpected and recalcitrant and generating scenarios of intervention that go beyond the logic of the dominant solutionism. (Tironi, 2020, p. 517)

Instead of smoothing over tensions and contradictions, the problem-making prototype zooms in on the moments of 'friction,' allows for the articulation of issues and emphasises its own generative, inventive, world-making potential.

This forcing of entities and visions as described by Tironi can further be understood through Corsín Jiménez's emphasis on the prototype's work of producing scenarios of 'compossibility' (Corsín Jiménez, 2013, p. 385) – scenarios that are compatible and possible simultaneously. These scenarios contain different possible answers to what you can do with big data, different visions of what it means to be a smart city, different ideas to what it all adds up to. These differences are made compossible through the prototype's enabling of a moment of suspension. This is what Valdez describes as a 'Schrödinger smart city:'

> Actually a lot of the literature now complains that the label smart city is just an empty signifier. As long as you are doing something with technology you can call it a smart city and the promises are very vague.

And while this could be considered as a sceptical view of smart cities, he continues:

> And I think that's useful. You could call it strategically ambiguous. Because as soon as you make it concrete, a lot of people in your coalition are not going to like that specific meaning. (…) So I think being a bit unclear about the meaning of the city, the smart city, is useful for generating momentum – even if you have to become more and more concrete as you go along. (…) We have something of a Schrödinger smart city, when you don't know what's in the box until you open it. (Interview with Alan Miguel Valdez, 6 May 2016)

Thus, MotionMap thrived on the ambiguity of the smart city label. By suspending or postponing the answer of what problem it was there to solve, it enabled a coalition of different actors involved in the smart city. By temporarily making these differences compossible, it facilitates the proliferation of various, often conflicting 'things, ideas, publics, and politics' (Mattern, 2017).

From the start of the project, the meaning of the smart city was unclear, or rather – multiple meanings were in circulation. By keeping these multiple meanings in suspense, MotionMap allowed them to co-exist simultaneously. As 'more than many', it simultaneously carried multiple meanings for different actors, the promise to deliver on sometimes contradicting, but temporarily compossible, ideas and ideals, and solve disparate problems. 'As a figure of possibility and suspension' (Corsín Jiménez, 2013, p. 383), the concept of the prototype helps elicit MotionMap in terms of its own potentiality, a futurity that 'carries within, also, a momentum of impetus' (p. 393). Ever speeding up, this momentum of impetus suggests not only the many versions ascribed to it the prototype by the various actors – whether as vehicle for a more participatory city, or as tool to alleviate congestion. It also hints at something more – the possibility of more to come.

Less than one, slowing down, failure

Juxtaposed to these passages of promise and acceleration described above, the prototyping of MotionMap encountered various occasions of friction and failure. Failure, or the possibility of failure is fundamental to the practice of prototyping. As Corsín Jiménez (2013, p. 381) argues, one of the key features of prototyping is the ‘incorporation of failure as a legitimate and very often empirical realisation.’ These occasions are moments of frustration and of holding back. Corsín Jiménez describes this as the prototype being ‘less than one,’ as being ‘‘stuck’ in a permanent state of anteriority’ (2018, p. 123), always emphasising its own incompletion. The less-than-one is characterised by a slowing down, a space in which issues emerge and where different stakeholders can reflect on the relationships between them and articulate concerns around smartness, data, sustainability and participation.

Some of these were minor technical faults, others relate to the vision of the project as a whole. With regards to such technical faults, these became particularly clear during the two prototyping workshops I attended in Milton Keynes. Here, the key issue experienced by all testers was the difficulty of using the map itself. As Krug, Director of Building Intellect, herself described, talking about these workshops:

> the map was one of the worst things in the application. It was very difficult to scroll the map, to pan the map and also the amount of information found in the map was very insufficient. And that wasn't something that we could easily fix. We had to basically build the application from the ground up, so that was quite a big setback for us. (Interview with Daniela Krug, 18 October 2017)

The first of these two workshops took place at the Open University, with participants from the School of Engineering & Innovation. Here I had a chance to experiment with MotionMap myself. The second workshop took place at the Transport Catapult in Milton Keynes town centre. I was asked to observe the testing and film one of the sessions so that the developers could later look back on how people experienced the application. Below are a few episodes from this session. In these episodes, Krug runs through the app with an employee from the Transport Catapult. The participant is asked to plan a journey and comment on his experiences with the app, using his own phone. Through an online questionnaire, Krugman records this feedback on her laptop.

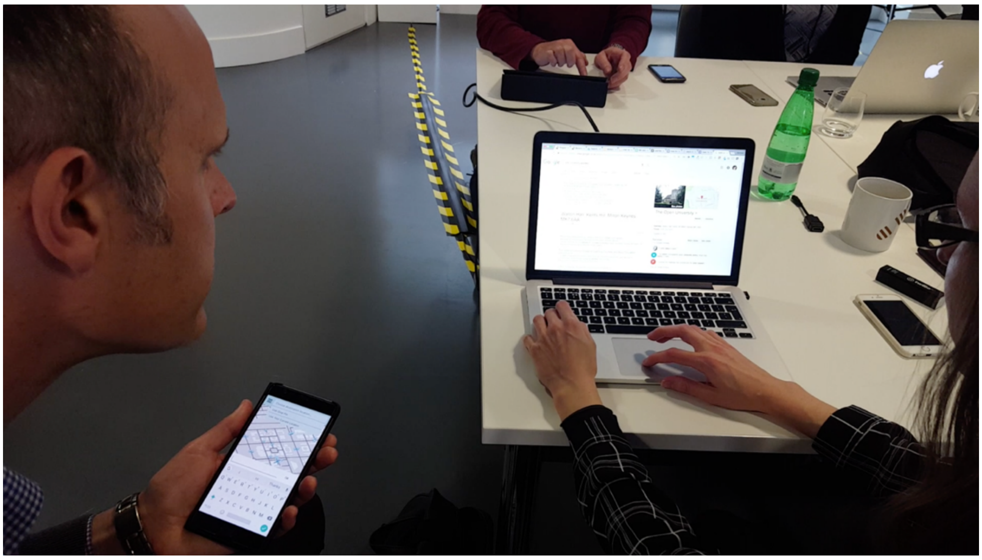

Figure 4.3 Interviewer looks up the destination postcode on her laptop (own photograph, taken 24 April 2017 in Milton Keynes)

To start the journey planning, Krug asks the participant to choose a destination location in the app. The participant starts by typing "Open University" in the search box. However, Krug notes:

> at present we're not supporting place names. We're only supporting addresses.

The participant looks at his phone and asks for the postcode of the university, which Krug looks up on her laptop (see Figure 4.3). She gives the postcode to the participant, who enters it into the app. After a short while, he manages to select the Open University as his destination. Being asked for feedback for the online survey, the participant answers, politely:

> I don't know if you're planning to – but if it did some kind of lookup from Google or some other database; further down the line, if you had like a Google search within that box. So if I put something a little bit more obscure, like Open University or something…

Clearly, the app's inability to look up places and landmarks by name makes the map very difficult to use. The user has to look up a place's address on the phone's web browser and then switch to the MotionMap app to insert it, which makes the whole process rather laborious. In response to the participant's suggestion to add a search function to the app itself, Krug replies:

> We can actually do that. It's really easy to do that. But the challenge is that Google charge a hell of a lot of money for this service.

The participant looks understanding but comments that "user expectancy is generally very high," suggesting that this limitation would be a drawback for users. Krug agrees. However, she argues, it is difficult to justify such a big cost while the number of users of the app is low.

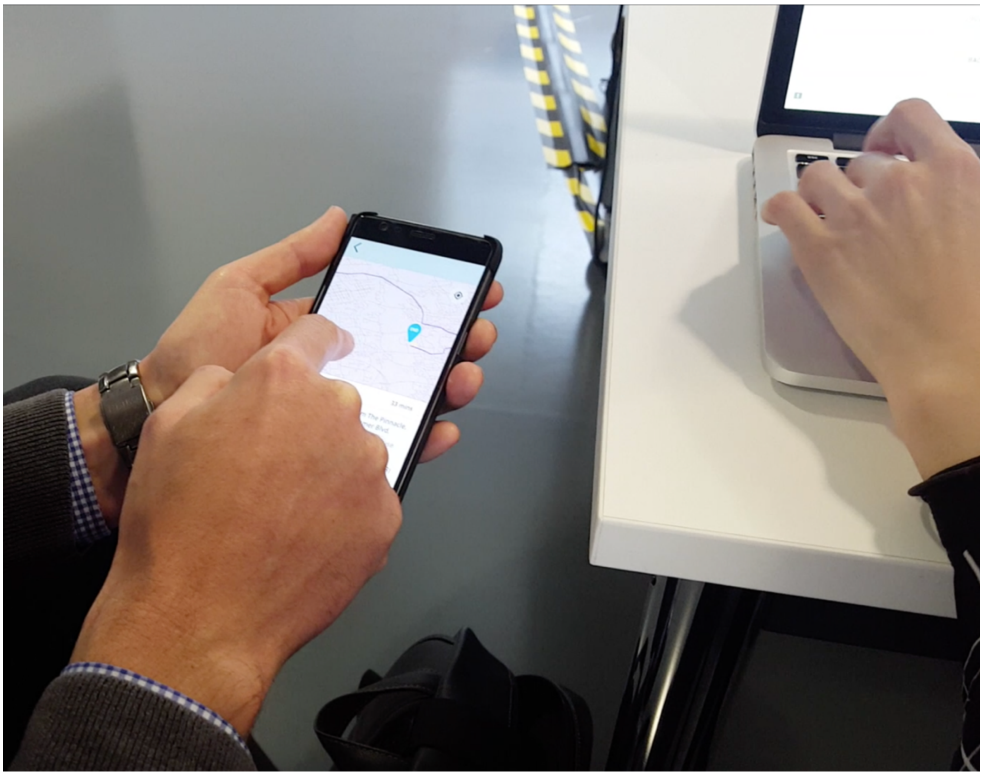

Figure 4.4 Participant tries to make sense of the map without any context (own photograph, taken 24 April 2017 in Milton Keynes)

Having selected a destination, the participant is able to set the app to bus mode and he selects the quickest journey from the Transport Catapult to the Open University. A map appears on which the journey is visualised as a line between a Start and an End point (see Figure 4.4). However, the map does not contain any further information such as street names or landmarks. The interviewer asks if the information displayed is what the participant expected. "No," he answers, "in that it's different to what I've seen on journey planners before." He explains:

> Because it's like a 3D, zoomed out view. I would probably instinctively zoom in and try see a little more. So yeah, I guess it's helpful in that I can see maps, but because I'm not that familiar with Milton Keynes, it would

probably be helpful to have one or two landmarks as a next stage of development. A few landmarks or a few, like, you know signs for the railway station and a few landmarks along the way.

The map shows the journey from the participant's current location to the Open University, but the lack of context makes it impossible for users to orient themselves. This capacity to clearly communicate relevant geographical information and to orient the user is one of the primary functions of any map. Without this context, it loses much of its usability, leaving the traveller confused and unable to find their way.

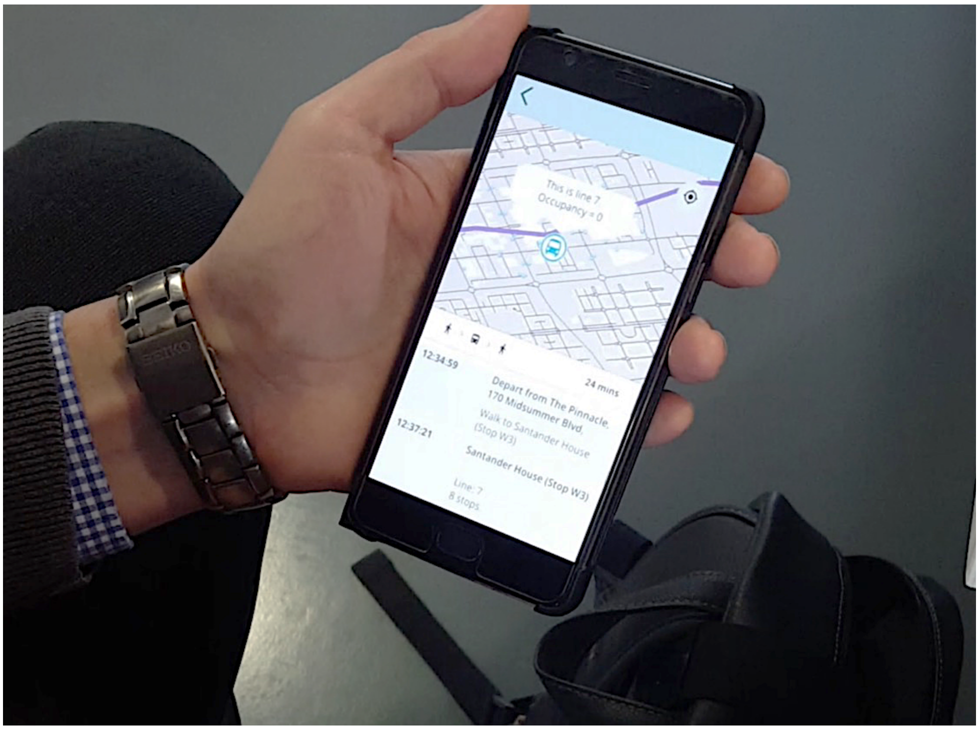

Figure 4.5 Real-time bus occupancy (own photograph, taken 24 April 2017 in Milton Keynes)

In addition to wayfinding, a further objective of MotionMap, as Professor Miles explained, was the ability to give a real-time account of the city's busyness. That means, for example, that when travelling by bus it would be possible to see how full a bus is before it arrives. Having selected a journey, the participant is asked if he can find the real-time passenger occupancy of the bus. He taps on the bus symbol, but nothing happens. Krug intervenes quickly: "so there's a known bug. You have to zoom in a bit more to be able to tap on it." The participant zooms in as far as possible and tries tapping on the bus symbols. Eventually, a window pops up, indicating the line (Line 7) and occupancy (0) of the selected bus (Figure 4.5). Subsequently, Krug asks the participant to try the same procedure with one of the other buses: “OK, try another bus, because sensors are not on all of them yet.” The participant tries a few more buses, without luck. This episode illustrates firstly the difficulty in using the app and the intricacies of zooming in to the right level before the passenger count function works. Moreover, it makes clear the way in which the map depends on physical sensors which have to be installed on the buses before the information can be processed and eventually displayed on the map.

This latter issue is further elucidated outside the workshops by Kretschmann, recounting a passage about the intricacies of tracking bus routes in real-time. Different options to achieve this tracking were explored. Some required the equipment of buses with sensors, so that it was clear which sensor belonged to which bus. However, this was problematic because these sensors had to be set manually to the right route every day by the bus driver. As Kretschmann explained, ‘as with everything that has human involvement it’s not very reliable’:

> We have data like that where City Bus in Cambridge, or a vehicle that claims it’s the City Bus in Cambridge, turns up in Bath, still claiming “I’m the City 3 line in Cambridge.” Because there were too many vehicles in Cambridge and not enough in Bath and they have the same provider so overnight they shipped the bus. And the new bus driver didn’t know anything about actually changing that. (Interview with Ernst Kretschmann, 8 December 2016)

In response, Building Intellect had to devise ways to track buses algorithmically. This had its own difficulties. It entailed looking at GPS data and trying to identify which route each bus was following:

> And to figure all that out just by looking at GPS data on a minute-by-minute basis for vehicles is hard and there is so much noise in there because sometimes vehicles just go to filling stations. Or they break down. Then you have the 10 o’clock service being quite full, and it’s overtaken by the 10.10. And you have to monitor this by just looking at minute-by-minute data. (Interview with Ernst Kretschmann, 8 December 2016)

Moreover, as Krug described, besides developing functional algorithms, a key challenge is the access to the relevant data in the first place. In Cambridge, for example, the data was provided by one particular company that was responsible for the sensors. It was then processed through three further data companies before it ended up in the hands of Building Intellect.

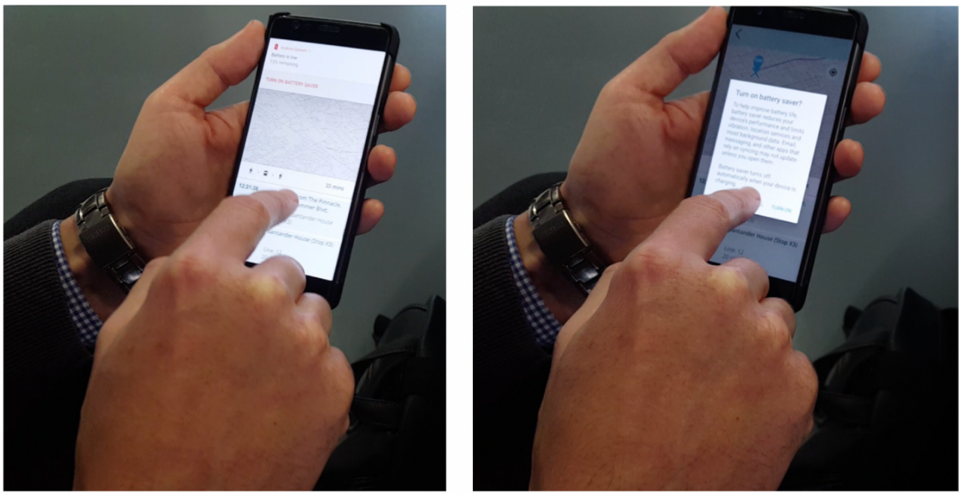

Figure 4.6 Low battery (own photograph, taken 24 April 2017 in Milton Keynes)

The final moment to be highlighted here does not refer to a problem with the functionality of the MotionMap application as such. Rather, it is an everyday experience that presumably everyone with a mobile phone has encountered at one point or another. In the middle of planning the journey, the participant is interrupted by his phone notifying him that his battery is down to 15%. He is able to quickly move past this and continue the trial by closing the notification (see Figure 4.6). This event passed without any mention and was over within a matter of seconds. However, what if it had happened during an actual journey? No matter how accurate the app, once a phone battery dies, the traveller may be left stranded in the middle of a journey. Further reflection might use this warning as a prompt for recalling other things that may go wrong when using a phone app in everyday life, such as a broken screen, or loss of signal. It illustrates how the testing of an app in the comfort of a room is very different than actually using it on the road, in a rush to get to a meeting on time. It is a reminder that for all the talk of apps as software, they still depend on hardware which in turn is affected by its physical environment.

Outside of these workshops, too, the project team encountered various obstacles to developing an app that met everyone's needs. Just as the promise of MotionMap to realise a multitude of visions, the concept of risk plays a central role in understanding the prototype's moments of slowing down. When first setting up the platform for MotionMap, the engineers chose a 3D engine called Unity, often used for video games. This platform was believed to help set MotionMap apart from other journey planners such as Google Maps through its 3D design. However, as Daniela Krug described:

> It was unfortunate to find that in a way it was a bit too early, or the funding that we had was far too little to basically overcome the obstacles that we would have had to overcome if we had continued with the 3D approach. … We'd have to essentially build the 3D map from the ground up. (Interview with Daniela Krug, 18 October 2017)

While Unity was initially promising, it turned out to be very difficult to build a working application on it. For example, the team discovered they were unable to use Unity in conjunction with some of Google's APIs for bus routing because of restriction in the latter's terms and conditions. Using Unity meant that MotionMap was limited to a web application only and could not easily be used on mobile phones. This was of course essential for a journey planner map, which is to be used on the road by travellers on their phones. Consequently, in the end the team was forced to abandon the Unity platform and rebuild the entire application on Google Maps instead.

What was behind this choice of the wrong platform? For Kretschmann, the software engineer at Building Intellect responsible for this choice, it was one of "a number of mistakes made that were not (…) de-risked initially." "Simply put," he explained the concept:

> you think about technical choices that you make, and you assemble these technical choices and you check: can I actually build the application on top of that?

De-risking is a fundamental aspect of agile software development, where technical choices are continuously tested, presented to the customer, and further revised. The problem with MotionMap's setup, however, for Kretschmann was that:

> the original contract we had with Milton Keynes was not modern agile contract or had modern agile software development in mind. And therefore, we are sometimes bound into a specification that was written

> by somebody two years ago, which is full of ideas that sounded like great ideas two years ago. (Interview with Ernst Kretschmann, 8 December 2016)

According to Kretschmann, the agreement of MotionMap was one in which the software engineers – Building Intellect – had to carry out what was previously defined by the customer – the researchers from the Open University and Cambridge. It followed a model that did not fit well with the principles of agile software development and that did not sufficiently allow changes throughout the process, or for sufficient dialogue between the programmers and the academics.

This lack of de-risking, identified by Kretschmann, points to the different approach to risk as one of the barriers in the collaboration between the different team members. Indeed, Krug describes risk, and specifically risk tolerance, as one of the defining differences between the different actors involved in MotionMap: "I suppose there's a difference in risk – risk tolerance". Each actor has a particular attitude towards risk and tolerance of failure:

> as a start-up that came out of a sort of university project, essentially, it's about bridging that chasm between the research domain with failure, where it's just a research project that may fail, to becoming a commercial entity, where suddenly you have to provide Service Level Agreements, and make sure the app is constantly running, day and night, and everything is fully functioning. So that's not an easy transition. (Interview with Daniela Krug, 18 October 2017)

As a commercial entity, Building Intellect has a relatively low risk tolerance, with failure of the project being synonymous with a loss of revenue and potentially even the failure of the company as a whole. Local authorities similarly have a lower risk tolerance as they have to be seen to spend taxpayers' money wisely – not least if they want to be re-elected. In the academic world, in contrast, there is much more of a tolerance, perhaps even an expectation, for taking risks. Rather than designated an experiment as failed, investigating the reasons for failure can be a productive academic enterprise: "if you do a project, it doesn't matter if it's successful or not. If it fails you just write about its failure and in the commercial world it's different" (Interview with Daniela Krug, 18 October 2017).

Speaking of failure from the researchers' perspectives, for Professor Stephen Potter the project was ultimately unable to realise some of the new ways of doing transport as hoped. In particular, changing to a co-creation model of organising transport in Milton Keynes was very difficult to achieve in practice:

> in the end, rather than having people on the busses reporting how crowded it is, it was actually relatively simple to put a camera above the entrance just to record how many people came on and how many people came off, and the instrumentation approach seemed to be able to produce large amounts of reliable data quicker than the crowdsourced approach. (Interview with Stephen Potter, 8 December 2016)

Indeed, reflecting on the success of the project, and of MK:Smart as a whole, Professor Potter described his worry that it had turned out too much in the favour of the technocratic perspective they had sought to avoid:

> I think MK:Smart has, in its ideology and its founding principles, and linked to the Open University's open principles, was very much seeking the democratisation view of the smart city, but I think has found that the technocentric top down concept of the smart city has often crept in, and it quite a difficult thing to resist, as you're actually trying to deliver something that offers functionality at the end of the day. (Interview with Stephen Potter, 8 December 2016)

Both citizens and the local government found it hard to move away from the lobbying model they were used to. The project did not manage to reach the Wikipedia point where people took over control of the smart city in Milton Keynes. MotionMap never quite escaped the hands of the researchers, as Valdez had hoped.

This failure to effect meaningful citizen engagement is a common problem within smart city projects, as suggested by Cardullo and Kitchin. In their review of smart city initiatives in Dublin, they produce a scaffold of citizen participation in the smart city. (see Figure 4.7). These range from inclusive, bottom-up and experimental modes of participation to those that are top-down and paternalistic but bound-to-succeed. They found that while citizen power is often seen as the ideal form of participation and engagement, 'in practice bottom-up, inclusive, empowering citizen involvement in key decision-making about cities is difficult to achieve' (2019b, p. 9).

Form and Level of Participation		Role	Citizen Involvement	Political discourse/ framing	Modality	Dublin Examples
Citizen Power	Citizen Control	Leader/ Member	Ideas, Vision, Leadership, Ownership, Create	Rights, Social/Political Citizenship, Deliberative Democracy, Commons	Inclusive, Bottom-up, Collective, Autonomy, Experimental	Code for Ireland, Tog
	Delegated Power	Decision-maker, Maker				Civic Hacking, Hackathons, Living Labs, Dublin Beta
	Partnership	Co-creator	Negotiate, Produce	Participation, Co-creation		
Tokenism	Placation	Proposer	Suggest		Top-down, Civic Paternalism, Stewardship, Bound-to-succeed	Fix-Your-Street, Smart Dublin Advisory Network
	Consultation	Participant, Tester	Feedback	Civic Engagement		CIVIQ, Smart Stadium
	Information	Recipient	Browse, Consume, Act			Dublinked, Dublin Dashboard, RTPI
Consumerism	Choice	Resident		Capitalism, Market, Neoliberalism		Smart building/ Smart district
		Consumer				Smart meters
		Product				Personal data generated by tech
Non-Participation	Therapy	Patient, Learner, User, Data-point	Steered, Nudged, Controlled	Stewardship, Technocracy, Paternalism		Smart Dublin, Dublin Bikes
	Manipulation					Traffic control

Figure 4.7 Cardullo and Kitchin's (2019b, p. 5) Scaffold of Citizen Participation

Analysing the outcomes of the project, Cook et al. (2019, p. 139) suggest various reasons for why such a technocentric approach prevailed and why the 'MotionMap had limited success as a means of empowering its users.' Firstly, they argued, the technical team strong technical skillset but 'its background and culture, although open to learning from co-creation and crowdsourcing experience, was not centred on such approaches' (p. 139). Krug describes her point of view on the aspirations of citizen engagement and empowerment:

> This was heavily inspired by the researchers. And I think it's fair to say that the research... they looked at a much bigger picture and they looked a bit further into the future. So MotionMap has the potential to do that in the future, but with the budget that we had it was already as a project extremely ambitious – to essentially build another Google Maps, that's as good as Google Map, with a tiny fraction of the budget that Google have available. So yeah, I think that's more of a futuristic view of what MotionMap could become, not really what it is today. (Interview with Daniela Krug, 18 October 2017)

Secondly, as hinted at by Professor Potter above, the low user buy-in in the initial phase of the project simply made a crowdsourcing approach rather impractical.

Finally, as already mentioned in the previous section, one of the insights that emerged from the workshops was that the users were more interested in using the app to hold the transport organisations and authorities to account than for finding their way around Milton Keynes.

For all the different visions of smartness made compossible by MotionMap's various answers to how big data can be used, the project encountered just as many issues, errors and obstacles. Reflecting on moments of breakdown and failure within smart city projects, Tironi and Valderrama (2018) develop the idea of 'idiotic data' to explore the inventive potential of such moments. Drawing on the figure of the idiot, whose 'murmur … is the unexpected and disturbing noise that reminds that there is always something else that breaks or escapes on how it is defined a situation' (p. 305), they propose that these failures or problems are:

> not just errors – they are indicative of the presence of something more that does not make sense, aspects that are not being taken into account in how [the situation is presented], transforming incomprehensible bits of information into generative and inventive events. (2018, p. 296)

By emphasising the generative potential of these moments of breakdown, the concept of the prototype opens up a 'privileged [space] for deploying forms of open exploration of frictions and the unknown' (Tironi, 2020, p. 505). In accordance with Corsín Jiménez's analysis, these moments slow down the project, in order to explore these moments of friction and question, problematise and reflection on ideas, assumptions, relationships and assemblages.

MotionMap as object

Through the concept of the prototype, this case study has described MotionMap's from two directions: its ability to provoke different ideas about the smart city and the problems emerging in trying to realise these ideas. These two directions illustrate the two focus points of an object-oriented cartography as developed in Chapter 2. They revolve around MotionMap's capacity to act autonomy and enter in relationships with others on the one hand, and its autonomy as an object with its withdrawn, vacuum-sealed interior on the other. Crucially, these two dimensions are related to one another. The prototype's more-than-many and its less-than-one, are different sides of the same coin. They both refer to the map's 'capacity for withdrawal that also is its capacity for differing with itself, its dynamism' (Clough, 2014, p. 45).

It is this capacity for withdrawal and for differing with itself that forms the basis for Morton's (2012a) object-oriented defence of poetry, highlighted in Chapter 2, and which offers a way of thinking about MotionMap in relation to causality. In this defence, Morton describes the present of an object in terms of a rift between its past and its future, between the way it appears – as the culmination of its history of past encounters – and what it could be. This present, the time in which 'things remain what they are' can be characterised by 'the feeling of being caught or suspended in a multiplicity of rhythms:'

> These rhythms are fundamentally composed of the irreducible difference between an object and its sensual qualities, as those qualities interact with the sensual qualities of other objects. Thus the most basic rhythm is *the difference of an object from itself* (…). This difference-from-itself is what constitutes persisting. When objects coexist without creation or destruction, this difference-from-themselves multiplies, like the expanding waves of a techno tune. (Morton, 2013, p. 154 emphasis in original)

The object persists because of the difference between its appearance, its sensual qualities, through which it relates to other objects, and its essence, which always remains withdrawn in the future. Thus, the prototype as a 'as a figure of possibility and suspension' (Corsín Jiménez, 2013, p. 383) accentuates MotionMap's being caught in a rhythm of speeding up and slowing down – of capacity for differing with itself and its capacity for withdrawal.

As the prototype helps to hone in on MotionMap's more-than-many, it draws attention to the way it proliferates – multiplies – the answers to the question of what you could actually do with big data. With each of these answers, it produces a sense of hope: hope of a solution to the various problems faced by cities today. By enabling these different answers, and making them compossible, MotionMap gestures towards the future. This promise of what could be alludes to the being of the map: 'the future is the essence of a thing' (Morton, 2012a, p. 220 emphasis in original). It is what propels the project forward, what produces a sense of 'a momentum of impetus' (Corsín Jiménez, 2013, p. 393). However, the final answer to this question and, consequently, to the question of the purpose and nature of MotionMap remains unclear – suspended, withdrawn. As long as the map remains at the stage of the prototype this hope can be maintained. The different answers are made compossible, until the "Schrödinger smart city" – as coined by Valdez – is opened and it is 'forced to speak nothing but the truth:' 'eventually essence collapses into appearance, which is how an object ends' (Morton, 2012a, pp. 221–222).

Perhaps this explains the appeal of the prototyping and experimenting in the smart city: prototypes embody a sense of indeterminacy and inexhaustibility. They emphasise and make evident the connection between the object's withdrawal and a future to come:

> The development of smart cities follows a logic of demoing, constant prototyping, testing and updating; instead of a finished product, infinitely replicable but always preliminary versions are installed in cities around the globe. At the same time, the idea of the smart city is inextricably linked to notions of catastrophe, where the logic of the demo or test-bed becomes a means for responding to impending environmental, security, and financial destruction by constantly deferring this future from ever arriving. (Halpern & Günel, 2017, p. 2)

In the face of the many crises facing cities today, the urban demos and testbeds offer a sense of hope of a solution – of smart, sustainable, liveable, happy cities. Crucially, such hope is an 'aesthetic category,' which refers to 'a particular organisation of sense that mobilises, in the Rancierian understanding, affect toward action' (ibid, 2017, p. 14). Since objects relate to one another via their appearances, Morton argues, these relations, the way they change, operate, affect – in short, causality – should be understood as aesthetic: 'causality is aesthetic' (Morton, 2013, p. 120).

This offers a new interpretation of Thrift's view of maps as aesthetic tools, as discussed in Chapter 2. It moves away from the association of the aesthetic with the visual only and expands it to include other forms of change and affect made possible by considering the map as object. In this way, an object-oriented cartography defines the two functions of maps as suggested by Thrift differently.

While they may be important as analytic tools, their ability to analyse, visualise and represent are only one part of their aesthetic capacity, which means the way in which they relate to and influence other objects. Thus understood, MotionMap's proliferation and its making compossible of different versions of the smart city can be described as an aesthetic process – an aesthetics that is not just visual but also non-representational. In this way, OOO is sympathetic to the non-representational approaches to cartography, but also develops its own perspective on the relationship between the representational and the non-representational.

While MotionMap's more-than-many offers a way of thinking change, its less-than-one can be conceptualised in relation to emergence – the second theme of thinking maps as objects as developed in Chapter 2. If the former relates to the map's 'capacity for differing with itself,' the latter relies on its 'capacity for withdrawal' (Clough, 2014, p. 45). As argued above, as the prototype juxtaposes the moments of speeding up with those of slowing down, it opens an approach for conceiving the generative potential of errors and breakdowns. From an object-oriented perspective, these moments of friction and failure, are occasions where MotionMap 'loudly announces itself' (Harman, 2010, p. 19), indicating that there is 'something more' (Tironi & Valderrama, 2018, p. 296) to it than the various purposes for which it is intended or the various situations in which it is deployed.

For Harman, the productive potential of these moments is based on the object's switch between being present-at-hand and ready-to-hand. Building on (though not necessarily in complete agreement with) Heidegger's tool-analysis, Harman (2002, 2010) argues that all entities and the way to relate to one another can be understood through their two distinct modes of being 'present-at-hand' (*vorhanden*) and 'ready-to-hand' (*zuhanden*). This 'continual exchange' (2002, p. 4) can also be described as 'the double life of equipment – tool in action, tool in disrepair' (ibid, p. 45). In action, a tool (which Harman expands to mean every entity) relates to another by being ready-to-hand – it 'operates in an inconspicuous usefulness, doing its work without our noticing it.' It allows certain qualities or functions to come to the fore, while the tool's being remains withdrawn.

In disrepair, however, it becomes clear that there is more to the tool or object than this particular function as encountered in action:

> The fact that hammers and trees sometimes generate obtrusive surprises proves that they are not reducible to their current sleek functioning amidst the unified system of the world. They must have some excess or residue not currently expressed in the relational system of the world. In other words, the fact that tool-beings withdraw does not just mean that they withdraw from human perception into unnoticed human praxis. Instead, it means that the ready-to-hand must withdraw from the system of the world altogether – otherwise it could never malfunction. (Harman, 2010, pp. 20–21)

Thus, these moments of friction in which MotionMap refuses to cooperate and be put to use to the purposes intended by the project team prove that there is 'some excess or residue.' Through its obtrusiveness, the tool switches from being ready-to-hand to being present-at-hand. It alludes to the object's withdrawn interior that escapes the relational system in which it is deployed. Being present-at-hand, MotionMap becomes the object of explicit awareness and contemplation.

Thus, in this state of disrepair, the interviewer and participant in the workshops may reflect on the different qualities that make a map a map. For example, the app's limited search function and the reliance on Google's technology hint at the map's place in a competitive global marketplace. The cumbersome process of making buses display their line numbers and occupancy rates alludes to MotionMap's dependence on sensors and algorithms. The interruption of the wayfinding process by a low-battery warning illustrates that the map is not just a piece of software, but also consists of hardware which interfaces with the user as much as with its physical environment. The inability of the user to orient themselves due to the lack of street names and landmarks is a reminder of the perseverance of the map's primary role in communicating geographical information. Meanwhile, the project's difficulties in enabling a co-creative, participatory model of doing and organising transport in Milton Keynes points towards MotionMap being more than a tool of communication.

Within the smart city, the concept of the prototype is used in a variety of ways, for a number of purposes. In the project of MotionMap, it underpinned the logic of agile software development for the technologists from Building Intellect. It constituted the basis of citizen engagement for the researchers of the Open

University. At the same time, it formed the backbone of the theoretical analysis in his case study and facilitated a link to the object-oriented perspective. In this latter guise, through its signposting to both risk and promise, it helped draw attention to both MotionMap as object and to the way in which it operates and effects – how it makes worlds. It entails a critique of both under- and overmining approaches to cartography, demonstrating both processes of emergence and of change, failure and promise – respectively.

In order to capture this way of 'making things that explain how things make their world', Bogost (2012, p. 93) uses the term 'carpentry.' It is a way of doing philosophy that shifts from writing about things to making and engaging with them. This shift, Bogost argues, enables a break from the inherently correlationist approach to philosophy embodied by writing as the carpenter 'must contend with the material resistance of his or her chosen form, making the object itself become the philosophy.' Understanding the prototyping process of MotionMap in terms of carpentry draws attention away from the focus on developing a functional application – however this may be defined. Instead, for Bryant (Bryant, 2014, p. 19), 'what attentiveness to the time of production and engagement with matter reveals is that the production of any artifact is much closer to a *negotiation* than the simple imposition of a form upon passive matter' (emphasis in original). Through this idea of negotiation, Bryant tries to escape anthropocentric notions of designing and places people, the various stakeholders in the project, on the same ontological plane as the materials used in creating MotionMap.

By framing prototyping as a form of carpentry, the process of developing MotionMap becomes itself a process of doing philosophy, a way of explaining how maps, as things, make their worlds. This world-making goes beyond the functions of the map of visualising and communicating geographical information, and beyond its roles as demonstrator project, facilitator of new ways of doing transport, and enabler of citizen engagement and empowerment. As a form of carpentry, prototyping refuses to let the map be reduced to a collection of code, or to any of the functions to which it may be put to use. It emphasises the individuality of the map as object and shows how it consists of a range of 'surprising and counterintuitive units that deeply resist corroborating one another' (Bogost, 2012, p. 94): ideas and interests of stakeholders, infrastructures of data and sensors, phones, people, busyness, vehicles, bikes.

Conclusion

The case study of MotionMap in this chapter has aimed to juxtapose the polished narratives of smart urbanism with an example of the smart city in practice. It contrasted the hopes and ideas of the different stakeholders with the obstacles and recalcitrance of the reality with which they worked. This produces a somewhat messy picture which illustrates the diversity of objectives in the smart city movement and the obstacles involved in realising its promises. In doing so, the case study troubles the notion of a consensus on the question of what you actually could – and should – do with big data. Even within a relatively small project such as that of MotionMap, the use of data and technology to create a smart city turned out to be far from self-evident.

The chapter started with introducing the MotionMap project and describing how it originated in the context of the MK:Smart programme in Milton Keynes. It described the different actors involved in the thinking behind and execution of the project, highlighting the concept of the smart city epistemic community. Following this, it introduced the concept of the prototype, which has been central to the analysis. The importance of the prototype, it has been argued, stems from firstly, its role in the literature on smart cities and digital culture more generally. Secondly, the project of MotionMap itself made extensive use of the concept in its development of the app. Finally, as a figure of analysis in the social scientific literature it was instrumental in connecting the empirical findings to the study's theoretical concerns. In particular, its dual movement between signposting possible futures and the risk of failure helped elicit the map's capacity to affect and its endurance as an individual object.

Thus, the concept of the prototype helped explore what an object-oriented approach to analysing the map might look like. By withdrawing into the future, the map enabled the proliferation of a range of ideas of what can be done with big data. These ideas entailed various definitions of the smart city which ultimately may be incompatible, but which are temporarily made compossible. In this process, the map allows for the creation of a smart city epistemic community that, despite its diversity of interests, is able to align itself in its revolving around the map. What is more, approaching the map in way may facilitate an expansion of this notion of the epistemic community, allowing critical scholarly researchers to join. By considering prototyping as a form of carpentry, it opens up the object to practices of philosophical experimentation into the way things make worlds, with the possibility of a new aesthetics of hope. This is an aesthetics that raises the question: 'not how *must* we survive the present, but how would we *like* to live in the future?' (Halpern & Günel, 2017, p. 20).

5. Whereabouts London

Big data is commonly perceived as one of the cornerstones of the smart city. With technological developments such as sensors, the Internet of Things and social media, large bodies of new forms of data have become available to inform the understanding and management of the city. However, just as important as this production of new types of data is the ability to make better, smarter, use of the data that is already there. Although local, regional and national administrations have long kept all sorts of records, these have often remained rather separate and difficult to access by others. As discussed in Chapter 1, the smart city seeks to overcome these "data silos" and make data more open, accountable and participatory. While previously data was often collected for specific aims, the aggregation of data from different sources is hoped to generate unexpected insights into how cities work. Giving different stakeholders the opportunity to explore and analyse this data may lead to the discovery of solutions to problems that have not necessarily been formulated yet.

Within this context, this chapter presents a case study of Whereabouts London, a mapping project developed by the Future Cities Catapult in London. Using a clustering algorithm, it presents a data-driven way of categorising London's population. Rather than presupposing certain categories by which different areas of London can be classified, it aims to uncover characteristics and patterns emerging from the combination of data sources. The result is a map that divides London in eight groups – eight Whereabouts – spread across the city. This map can be used to explore differences and similarities between places in London based on an almost infinitely long list of attributes. In turn, this can be used to inform decision-making on allocation of resources, but also as a way to demonstrate the value of big and open data in the city.

Firstly, the chapter will introduce the London Whereabouts project, and the Future Cities Catapult where it was developed. Among others, this section will look at the terminology of "future cities" and describe its relation to that of the smart city. It will then develop Amoore and Piotukh's (2015, 2016) concept of the little analytic to enable the formulation of an object-oriented analysis of Whereabouts London. Little analytics are devices that help make big data perceptible. Specifically, the concept developed to investigate not just *what* specific analytics make visible, but more importantly *how* they do so. It involves a technique of tracing the processes in which these devices make sense of data. This emphasis on the how will enable a discussion revolving around the object-oriented theory of unit operations, which has been outlined in Chapter 2. Thus, the case study will examine the three-step process of Whereabouts London's unit operations: ingestion, clustering and visualising.

London Whereabouts

The Future Cities Catapult described itself as a 'global centre of excellence for urban innovation' (Clark & Moonen, 2014, p. 3). It was one of – at the time – ten catapults in the UK which each address a particular area of technology, ranging from the Digital and Energy Systems Catapults to those for Cell and Gene Therapy and for Medicines Discovery. Together, these form 'a network of world-leading centres designed to transform the UK's capability for innovation in specific areas and help drive future economic growth' (*About Catapult*, n.d.). Funded by Innovate UK, the catapults are aimed to bring together business and research to develop new products in their respective areas. As the Future Cities Catapult described on its website:

> We help other organisations accelerate their urban ideas to market, to help make cities healthier, safer, more efficient places, whilst also growing the UK economy. We bring together businesses, universities and city leaders that understand the problems that cities face, now and in the future. Then, we provide additional support with our multidisciplinary team and world-class facilities to help them create the most effective solutions. (*Frequently Asked Questions*, n.d.-a)

In 2019, The Future Cities Catapult merged with the Transport Catapult to form the new Connected Places Catapult.

The term 'future cities' is part of a terminology that 'can convey either environmental, social, economic or governance aims, or a hybrid of some or all of these elements.' It includes many of the cities covered in Chapter 1, such as digital, intelligent, wired, sustainable, resilient and liveable cities, of which the 'smart city' has 'become the most popular formulation' (Moir et al., 2014, p. 4). Thus, the Future Cities Catapult saw its role in connecting stakeholders, as well as in providing research on the latest state of play on issues such as smart city strategies (*Smart City Strategies: A Global Review*, 2017) and smart city demonstrators (Griffiths, 2019).

Whereabouts London was one of the early projects of the Future Cities Catapult. It is a map of London that categorises the different areas of the city in eight different categories – eight Whereabouts. Its innovative character lies in the approach used for deriving these categories, which will be described in detail below. The map draws together a wide range of publicly available data sources, including the Census, the Land Registry and social media. Using a clustering algorithm, it analyses this data and groups the different areas that make up London, the Output Areas, based on the characteristics of all these data sets. Similarity is thus understood in terms of areas' relationship to one another in terms of a large number of attributes, from types of housing and access to public space to demographics and crime rates. The aim of the clustering algorithm is to find a classification such that those areas in the same group are most similar to one another.

This project can be placed in a wider context of geodemographics, a research area, often associated with business and marketing, that tries to develop classification that 'organize areas into categories sharing similarities across multiple socioeconomic attributes' (Singleton & Spielman, 2014, p. 558). Geodemographic classifications often are based on high-dimensional data, 'typically including anywhere from a dozen to several hundred empirically derived characteristics' (ibid). Within this, the use of clustering algorithms, including k-means clustering, is well-established in the context of the use of GIS for neighbourhood demographics (e.g. Harris et al., 2005, p. 162).

The relationship between geodemographic research and sociological and urban social theory is uneasy. On the one hand Singleton and Spielman argue that 'geodemographic classifications are "theory-free," as they do not hypothesize a priori about the role of large-scale social mechanisms or individual-level theoretical constructs' (2014, p. 563). On the other, Burrows and Gane have argued that while geodemographic classifications have been widely used in business and the public sector throughout the second half of the 20th century, it has increasingly become an area of interest for the social sciences in recent years, due to a growing concern with 'informational capitalism, within which the functioning of software is becoming ever more fundamental' (2006, p. 801). As a result, there has been a growing interest in and attention to their underlying techniques and to the sociological implications these classifications have.

With its specific approach to categorisation, Whereabouts London hopes to 'help cities and citizens see their environment in a new light' and to 'investigate what London could look like if we drew London's boundaries afresh, grouping neighbourhoods based on how we live, not where we live' (DataPress, 2015). This contrast between 'how we live' and 'where we live' represents two different approaches to classification. Grouping neighbourhoods based on 'where we live' entails starting with a specific area, such as a borough, and describing this using the available information. Grouping based on 'how we live,' in contrast, entails starting with the data so that the resulting groups are similar in terms of these attributes regardless of geographical boundaries. Consequently, the eight Whereabouts displayed on the map which are scattered across the city (see Figure 5.1).

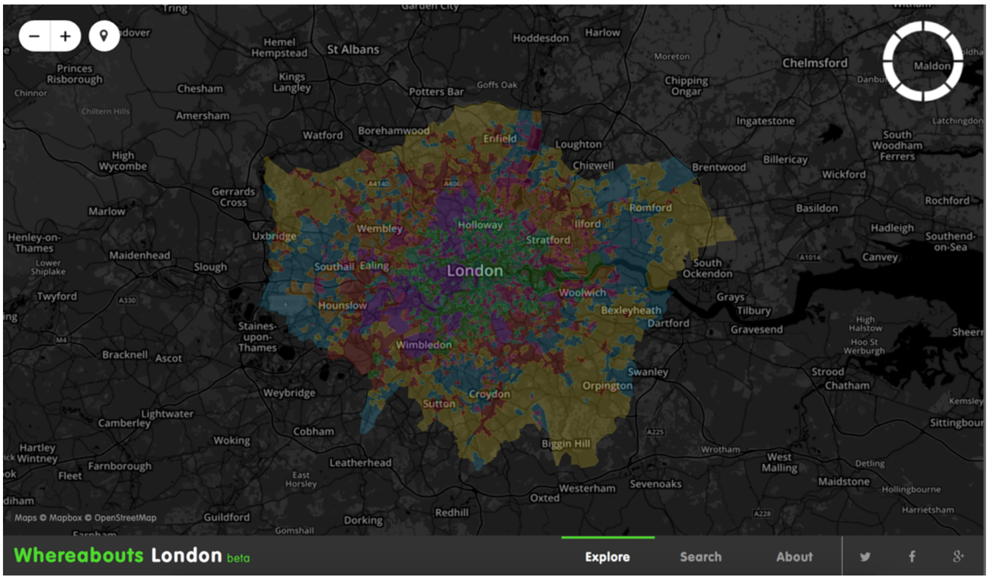

Figure 5.1 The Whereabouts London map (screenshot from http://whereaboutslondon.org/#/map)

The idea is that through this way of calculating similarity between places algorithmically, the map shows a classification that is not based on pre-defined geographical, political, or administrative criteria, but which is believed to originate from the data itself. In doing so, the map enables a way of thinking across governmental boundaries and facilitate cooperation between people in places that may be geographically remote, but are similar according to the data:

Reimagining neighbourhoods in this way could help us all. Local authorities could work out how to share their services with each other; transport providers could tailor their services to travellers better than ever; behavioural change campaigns could be targeted in new ways to make them work more effectively. The possibilities are just as rich as the data. (*Whereabouts London*, n.d.)

It is this process of classifying, the way in which defines similarity, how it assembles, processes and visualises the data, that will be the explored in this chapter.

Whereabouts London is an interactive map, where the user can move through the different neighbourhoods to see which Whereabouts they belong to. Any particular area of interest can be found either by using the map itself, or by using the Search function to find a particular postcode, street or place of interest (see Figure 5.2). Clicking on an area opens up a description box that explains the characteristics of that particular Whereabouts (Figure 5.3). Each of these boxes starts with a brief sentence to summarise the Whereabouts. For example, for Whereabouts 1 'residents are a professional and well educated population mainly residing in outer London.' Meanwhile, those in Whereabouts 2 'are representative of the London average, but score higher for racial diversity than any other Whereabouts', while 'Whereabouts 7 residents are, on average, the most well off of all the Whereabouts with the highest proportion of company directors.'

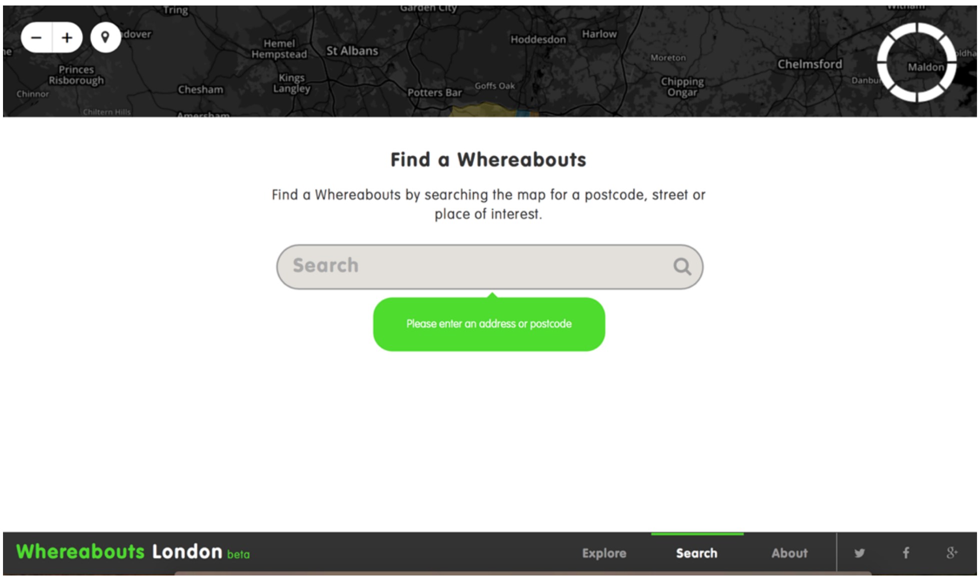

Figure 5.2 The Whereabouts Search function (http://whereaboutslondon.org/#/map)

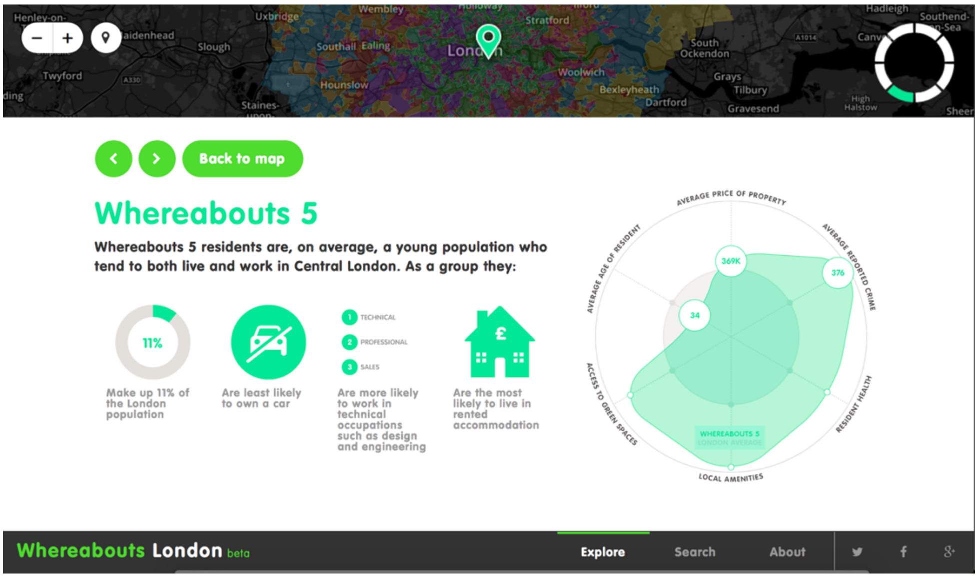

Figure 5.3 Opening up Whereabouts 5 (http://whereaboutslondon.org/#/map)

Following this top line, each category includes four graphics that show some of the specifics about the neighbourhoods that it encompasses (Figure 5.4). For each it is described what proportion of London's population that Whereabout includes, ranging from 8% in Whereabouts 7 to 17% in Whereabouts 3 and 6. The other three graphics vary per group, relating to information about household make-up, working life and occupation (Whereabouts 4) to car and house ownership (Whereabouts 5) to crime (Whereabouts 8). Finally, there is a standard diagram (Figure 5.5) that shows how the Whereabouts perform against the six axes of: average price of property, average reported crime, resident health, local amenities, access to green spaces and average age of resident. This diagram offers a most comprehensive, standardised description of each Whereabouts, so that they can be compared with one another.

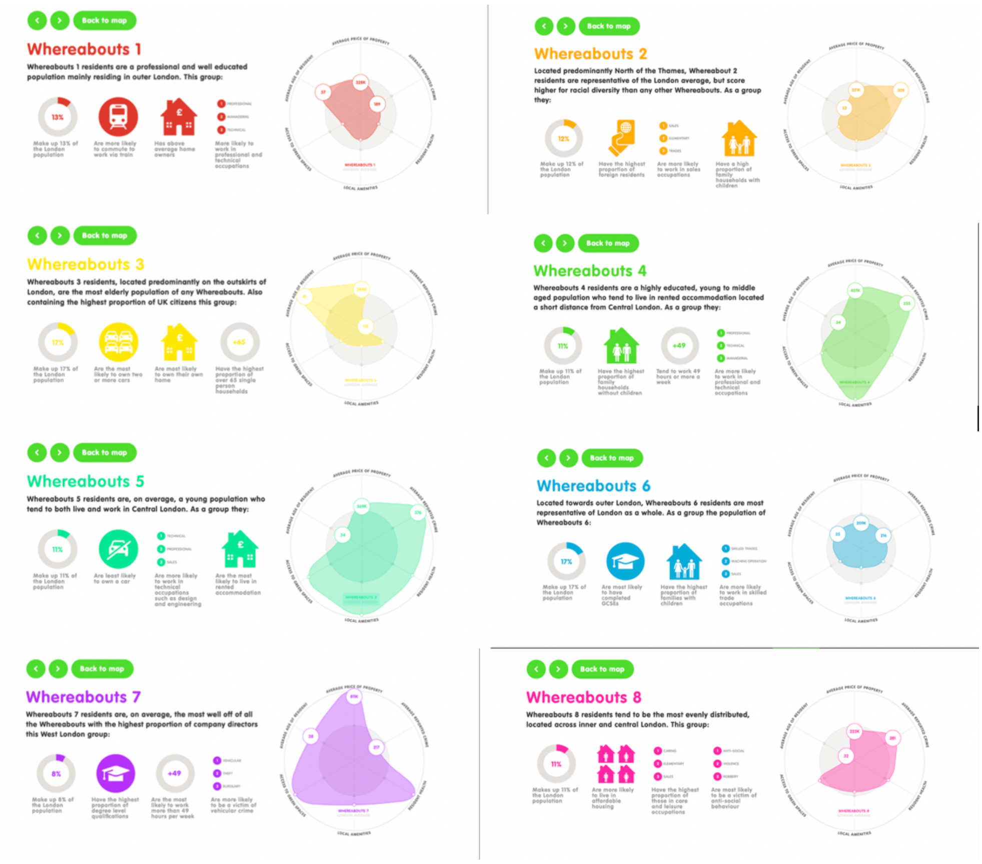

Figure 5.4 The eight Whereabouts explained (screenshot of (http://whereaboutslondon.org/#/map)

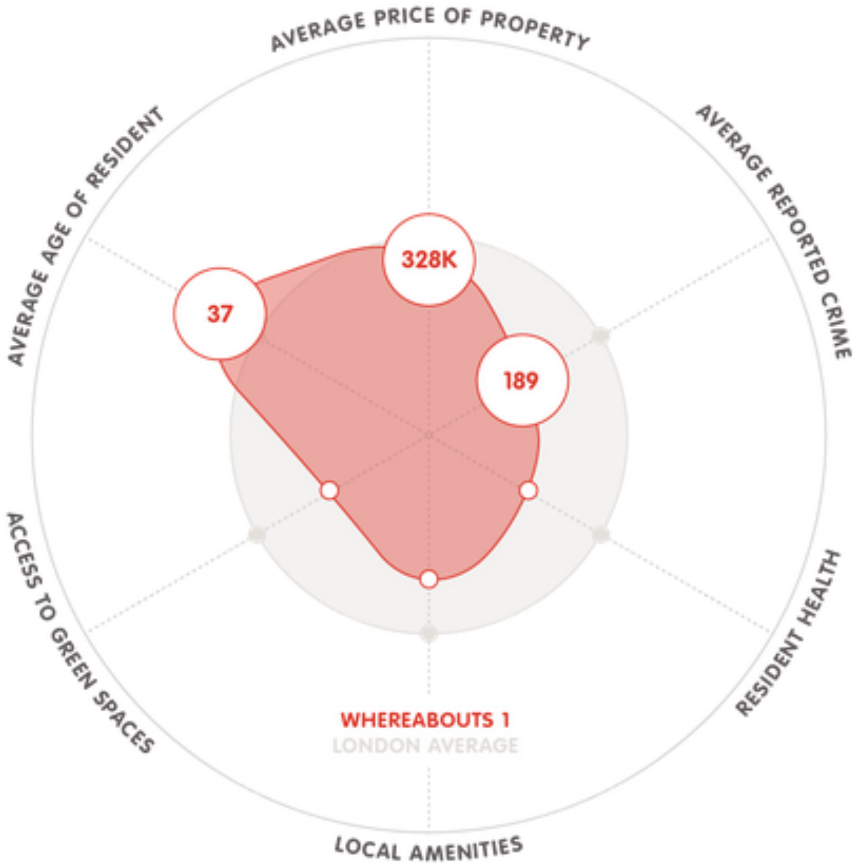

Figure 5.5 Diagram that shows how the Whereabouts compare to a range of standardised criteria (http://whereaboutslondon.org/#/map)

Similar to the MotionMap project, the Whereabouts London was embedded in the discourse of experimentation, testbeds and urban laboratories. It described itself as an 'an ongoing experiment by the Future Cities Catapult to explore how open data can be used to improve future cities' (http://whereaboutslondon.org/#/). In this context, the project was linked to London's smart city strategy and in particular one of this strategy's central tenets (Romualdo-Suzuki, 2016): the London Datastore 2 (LDS2), which formed provided a lot of the data for Whereabouts London. The LDS2 was set up to provide an expanding range of datasets through cooperation with institutions such as the Open Data Institute and the Future Cities Catapult. Launched in October 2014 by the Greater London Authority (GLA), the LDS2 was described by Andrew Collinge, then Assistant Director Intelligence and Analysis of the GLA, as the 'next step to a city data future' (Collinge, 2014). It was set up to collect data from many different sources and make this available 'for businesses, professional organisations, academics, local authorities, developers and the general public to download and use as they see fit' (Scroxton, 2014).

However, as Alan Waldock, who worked on the Whereabouts London project as Data Visualisation Designer at the Future Cities Catapult, explained: whereas LDS2 collected large amounts of data, it was not clear what this data could be used for.

> So the idea for Whereabouts came from let's take all that data, let's take as much data as we can and try and just come up with something interesting around it – and try to come up with a use that pulls in data that might not have such obvious uses and turn it into something that could potentially be useful. (Interview with Alan Waldock, 15 April 2016)

Thus, Whereabouts London was intended as an experimental, exploratory project to demonstrate some potential ways of using big data.

In doing so, it hoped to showcase the value of big data, encouraging others experiment with data and with the Whereabouts London software. In the same way as MotionMap was meant to draw attention to the Milton Keynes Data Hub, Whereabouts London was hoped to promote the London Datastore. As Peter Madden, then Chief Executive of the Future Cities Catapult, argued:

> The London Datastore 2 is a huge asset, and Whereabouts London is just the start of the city experimenting with its data to generate insights, create better products and services for the city and to make life more enjoyable for Londoners. (*Redrawing London's Boundaries with Data*, 2014)

Similarly, then deputy Mayor for business and enterprise Malthouse argued:

> Whereabouts London shows how open data can help us view our city in a new light and is an exciting and original way to help Londoners exploit its potential. Coming so soon after the launch of City Hall's Datastore 2, this project gives us new way of rethinking how we live and work and it will be fascinating to see how this might affect the way boroughs can collaborate. (*Redrawing London's Boundaries with Data*, 2014)

Thus, while the project started with an interest in exploring the potential of various data sets, it is also important to understand it in this context of the promotion of the London Datastore.

Moreover, the project's experimental can also be understood in relation to the exploring ways of working together as a new team – the 'lab team' – at the Future Cities Catapult. As Waldock described:

> I think we were trying to figure out how to work together as much as anything else. A lot of the stuff we do is a lot more user focused – actually trying to solve problems for citizens and councils and that sorts of things, whereas this was a lot more just a kind of exploratory thing, like what if we apply this type of clustering technique to open data. (Interview with Alan Waldock, 15 April 2016)

In this description, the use of a clustering technique was an experiment with the ways in which the various team members, which included data analysts and designers, could collaborate and relate to one another – making use of everyone's skills. The experimental character of Whereabouts London can thus be understood in a number of ways – exploring the use of big data, engaging publics, promoting the city's infrastructure, and enabling different disciplines to work together. Implicit in all of these meanings is the link between the experimental and the concept of the smart city epistemic community described in Chapter 1. Via the Datastore, Whereabouts London reaches out to decision makers, businesses, data engineers, designers, and residents.

This section has served to provide an overview of what Whereabouts London is, how it works and the context in which it was developed. The rest of this chapter will focus on the precise ways in which the map assembles, analyses and visualises the data. Facilitated by the concept of the little analytic, an object-oriented perspective on these steps will unpick how the map operates and how, through this process, it configures itself as unit. In doing so, this case study explores the themes of emergence and change as a key theme for an object-oriented approach to cartography.

Little analytic

In order to facilitate the analysis of the steps involved grouping neighbourhoods based on 'how we live,' this case study will draw on Amoore and Piotukh's (2015) concept of 'little analytics.' Chapter 1 outlined the importance of data analytics in the smart city, highlighting the argument that within the debates on big data, they received relatively little attention. In this context, Amoore and Piotukh (2015, p. 344) argue, 'if the metaphor of big data is to continue to dominate the governing of digital life, then it cannot be understood without the little analytics that make data perceptible.' Little analytics are the calculative devices that help break down the large amounts of unstructured data into comprehensible patterns and objects of interest. As the vastness and generally unstructured nature of big data make it impossible for human reasoning to determine what is of relevance, little analytics become of interest as '*instruments of perception*; they carve out images; reduce heterogeneous objects to a homogeneous space; and stitch together qualitatively different things such that attributes can be rendered quantifiable' (Amoore & Piotukh, 2015, p. 344 emphasis in original).

The concept of the little analytic in the case study of Whereabouts performs a similar role London as that of the prototype for MotionMap in Chapter 4. It enables a bridge between the empirical findings of the case study and the theoretical objective of thinking maps as objects. Crucially, the little analytic will be used to draw attention not just to *what* Whereabouts makes visible, its output, but more importantly to *how* it does so: its operation. Discussing Bergson's writings on perception, Amoore and Piotukh describe how:

> The question for Bergson's philosophical method, then, is not 'how perception arises', but 'how is it limited', to know 'how and why this image is chosen to form part of my perception, while an infinite number of other images remain excluded from it' (1912, p. 34). The task at hand, as Bergson understands it, is to 'give up your magician's wand' and 'follow the process to the end', to understand how a perception that 'should be the image of the whole' becomes limited and 'reduced to the image of that which interests you' (1912, pp. 35–36). (Amoore & Piotukh, 2015, p. 344)

This case study will delve into the technical process of Whereabouts London in order to understand exactly how it achieves its objective of drawing London's boundaries 'afresh' and reimagining its neighbourhoods. By following this process to the end, analysing the trajectory from data to map, it will describe Whereabouts London's process of "limiting" perception in terms of three distinct steps: ingestion, clustering and visualizing.

Reverse engineering

This approach of following the process to the end, of examining the Whereabouts London's unit operations, will take place through a method of reverse engineering, developed in the context of researching algorithms (Kitchin, 2016, pp. 23-24). Using the various types of information available, the case study pieces together the steps the data went through before it could be visualised. As Kitchin describes:

> each program inherently each has two openings that enable lines of enquiry: input and output. By examining what data is fed into an algorithm and what output is produced it is possible to start to reverse engineer how the recipe of the algorithm is composed (how it weights and preferences some criteria) and what it does. (p. 19)

The method of reverse engineering Whereabouts London draws on a number of sources, each of which is emphasised to a different degree in each of the sections. Firstly, of most importance in understanding the different steps involved in creating London Whereabouts is the repository ('repo') which was made available on Bitbucket, and later transferred to GitHub[1] (see Figure 5.6) – an online platform used by software developers to share their programming codes, collaborate and manage projects.

[1] Unfortunately, not all the information included on BitBucket was transferred onto the GitHub. Therefore, some of the information included below in the form of quotes and screenshots is no longer available online. I contacted the Future Cities Catapult to see if they could be made available again, but they too were not able to retrieve these sections.

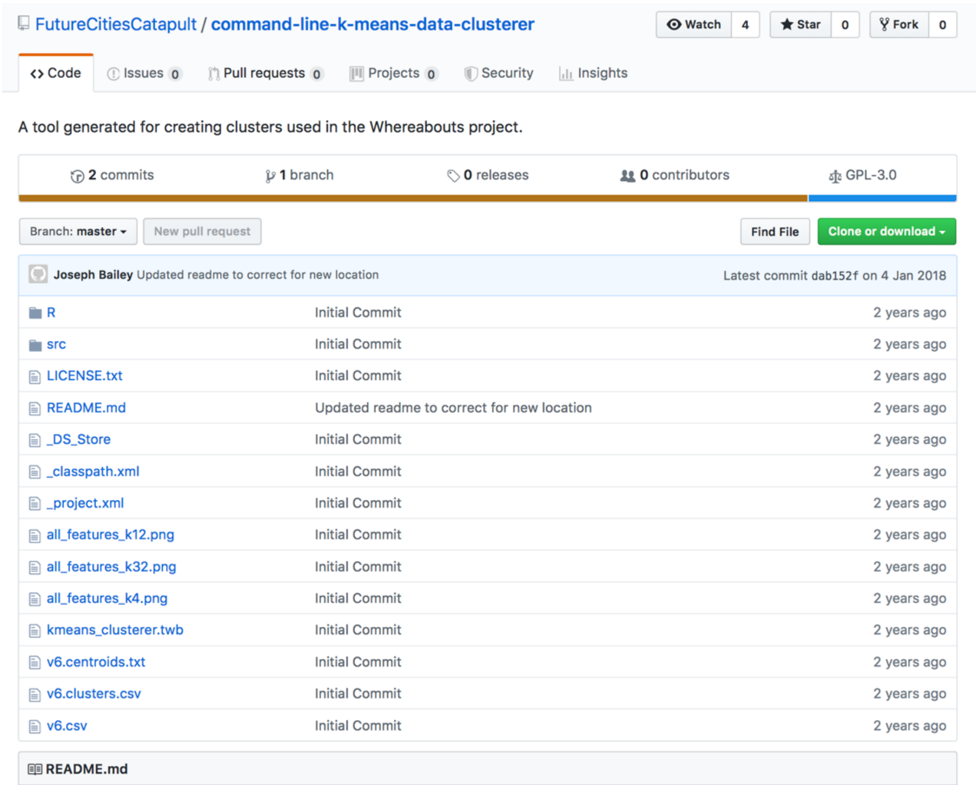

Figure 5.6 The Whereabouts London GitHub repository (*Whereabouts London GitHub*, n.d.)

This repository 'contains the code, assets and methodology used to construct the Whereabouts London website' (*Whereabouts London GitHub*, n.d.) (*Whereabouts London GitHub*, n.d.). It comprises a range of files and documents, including the Java command line to operate the clustering algorithm, various output files created at different points in the process, a tutorial, and information about attribution and licensing. This material was made available to the public specifically in order that others could understand the Whereabouts' methods and replicate the project in other cities. It took a variety of formats, including text documents, Excel spreadsheet, images, XML and JAVA code, and R script. Making sense of these was a bit like solving a puzzle: it involved sifting through each file individually, identifying the relationships between them and placing them in their logical order. The starting point for this was the ReadMe file, which described, in limited detail, the order of the steps and the function of some of the key documents. In addition, I was provided with some guidance by James Tripp, academic technologist at the Centre for Interdisciplinary Methodologies, University of Warwick.

From these materials, a three-step process emerged, which will structure the case study. These steps were: joining, where the data is assembled; clustering, where it is partitioned; and visualising, where the map itself is produced. In addition to looking at the input and output files, Kitchin (2016, pp. 23-24) suggests seeking external advice such as following online forums and interviewing experts to inform the process of reverse engineering . Section 2, on clustering, uses such advice in the form of textbooks and journal articles on data analysis and classification to understand the mechanics of k-means clustering algorithms. While the algorithm itself was not included in the repository, k-means clustering is one of the most well-established clustering techniques, meaning that plenty of material was available to describe this in varying levels of detail and difficulty.

Finally, in addition to the sources described above, the case study draws on an interview with Waldock, who has already been introduced in the previous section. As Kitchin (2014, p. 20) explains, such interviews provide 'a means of uncovering the story behind the production of an algorithm and to interrogate its purpose and assumptions.' Here, the interview helped understand the key considerations and rationale behind the visualisation of the data in the third section. It enabled a link from a context of big data as explored in the sections on joining and clustering to one of small stories.

By unpicking these steps, the little analytic's focus on how rather than what enables a discussion of Whereabouts London in terms of the object-oriented concept of "unit operations." Introduced in Chapter 2 as one approach thinking maps as objects, unit operations offer a way of conceptualising the relationship between objects' dual dimensions of vacuum-sealed autonomy and capacity to act. By untangling Whereabouts London's unit operations in terms of ingesting, clustering and visualising, the case study will develop insights both into what the map does, as object, and into the world which it encounters and makes understandable - the smart city.

Ingesting

The first step is grouping London's neighbourhoods in terms of where we live is preparing and formatting the data for analysis. In their discussion of little analytics, Amoore and Piotukh describe this preparatory process in terms of 'ingestion':

> From the Latin "in-generere", to carry into, to ingest suggests a process of drawing in quantities of matter into an engine or body, such that the contents can be filtered, some of them absorbed and others expelled or discarded. (Amoore & Piotukh, 2016, p. 5)

In the context of the 'datafication' of society, where analytics play an increasingly important role in making sense of the large amounts of data available, ingestion is distinguished from collection. While data collection as associated with previous forms of analysis such as statistics relates to types of data that are similar – e.g. survey responses, little analytics deal with many different types of data from different sources at any one time.

> the rise of big data witnesses a transformation in *what* can be collected or sampled as data, and *how* it can be rendered analysable. In the vocabulary of the computer scientists and data analysts, data are no longer strictly *collected*, but rather are *ingested*, such that everything becomes available to analysis, the sample being represented as infinite, or *n=all.* (Amoore & Piotukh, 2015, p. 345 emphasis in original)

Consequently, different types of information are made compatible and commensurable: 'qualitative differences between data forms become obscured by the pursuit of the object of interest' (2015, p. 348).

For Whereabouts London, while the project's Bitbucket repository did describe a collection step in this initial phase, this collecting did not so much entail the gathering of data in the sense of going out into the field to gather, for instance survey response. Rather, it entailed the identification of existing data sets, from the Datastore and other place, suitable for the subsequent analysis. Thus, the stage is outlined as a process of collecting ('identifying and collecting data-sets which have commonality, which can be consistently unified'), filtering ('determination of errors or outliers in the data which might negatively affect the visualisation or model. At this stage, data may be removed or identified as inadequate for inclusion'), before being joined ('the process of merging consistent data on a common index') (*Whereabouts London Bitbucket*, n.d.). In this stage, different data inputs such as the census data and those extracted from Flickr were combined and made commensurable in the aggregation of the Whereabouts London map. Here, it is not (yet) known which of these types of data will be significant in the categorization of locations. Ingestion involves the drawing together, joining and making commensurate of heterogenous data sets so that the neighbourhoods can be described in as much detail – as many attributes – as possible.

The data sets gathered for Whereabouts London were drawn from a number of places. As is described in the README section on the GitHub repository:

> We've used the Datastore's new spatial search functionality to help us extract data for neighbourhoods across the city, and merged that with open data from other sources, including the Food Standards Agency, the Office for National Statistics, Land Registry, OpenStreetMap, Flickr and Transport for London. (*Whereabouts London GitHub*, n.d.)

From the files uploaded to the repository by the Future Cities Catapult, only the results of this process of collecting, filtering and joining are visible. This means that from looking through the data files, it is difficult to identify the exact sources of each set of data or to understand the criteria used to include or exclude certain sets. However, as will be seen in this section, a key prerequisite of each data set is that it has a 'common index' – namely, that it is defined in terms of geographical location. Specifically, all data needs to be classed by their Lower Layer Super Output Areas (LSOAs) as defined by the Office of National Statistics (ONS).

Output Areas were devised by the ONS for the purpose of the census. Used from 2001, they were 'designed in such a way to provide users with a stable geography base that would allow reporting of statistics across time on a consistent geographical base' (*Frequently Asked Questions*, n.d.-b). Each Output Area contains a minimum of 100 people and 40 households, but on average this comes down to 297 people and 123 households. Drawn up around similarity in terms of tenure and accommodation type, each Output Area is meant to contain people that are more or less alike:

> As they are a small, non-disclosive, socially homogeneous geography, purpose built for the publication of statistics, they are consistent, comparable and stable to an extent not provided by any other level of UK geography. (*Frequently Asked Questions*, n.d.-b)

These small Output Areas are aggregated into LSOAs, each of which contains five OAs. These LSOAs are given codes, starting for instance in London from E01000001 to E01033746. In turn, five of these LSOAs make up the Middle Layer Super Output Areas (MSOAs), so that they encompass between 5,000 and 15,000 people, and between 2,000 and 6,000 households. Each of these MSOAs are named by the borough into which they fit, and a code – for example 'City of London 001A', 'Barking and Dagenham 016A', or 'Barnet 009A.'

Having these LSOAs as a common link across all data sets is crucial in the ordering and organising of these different sets in a single table, in preparation of the clustering process described in the next section. This ordering is achieved through the method of joining. Joining is defined by the Environmental Systems Research Institute's (ESRI) GIS dictionary as:

> Appending the fields of one table to those of another through an attribute or field common to both tables. A join is usually used to attach more attributes to the attribute table of a geographic layer. ("Joining," n.d.)

In other words, joining is the process of linking different datasets, collected in the form of individual tables, into one general table so that this can be used for the subsequent algorithmic calculations.

Figure 5.7 is a schematic representation of the way the Whereabouts data is joined. On the left is the place, the Lower Layer Super Output Areas. As will be seen in more detail below, this is the first column on the left-hand side of the table. Each time a new data set is added, this constitutes a join, and can be found in the final table as another column. Each of these data sets are defined as attributes.

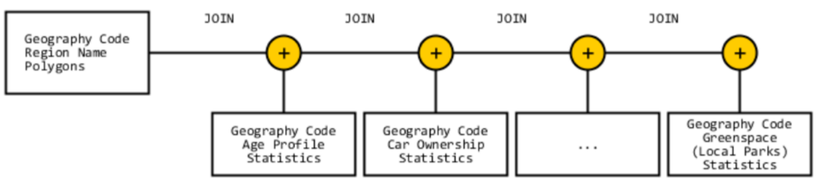

Figure 5.7 The process of joining in Whereabouts London (*Whereabouts London Bitbucket*, n.d.)

Within the Tableau data visualisation software, this type of joining constitutes a Left Join (see Figure 5.8). Each data set needs to be formatted into a table. The joining process then matches the data of each new table to that of the main table, thus adding another column. Where the new table does not contain any corresponding values for a certain row, this will enter a null value. The Whereabouts file contains a number of null values, for example for the FlickrPhotoCount (Column GD), meaning that for those rows (i.e. LSOAs), there was no data available.

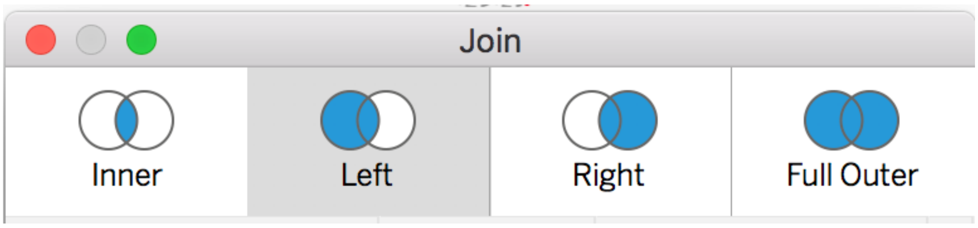

Figure 5.8 Joining options in Tableau (screenshot)

Elsewhere, the Whereabouts London project website also refers to this process as 'blending' (*Whereabouts London*, n.d.). Although the terms of joining and blending are sometimes used interchangeably, they are in fact two slightly different techniques: joining is used primarily for tables from the same source, in the same format, while blending is used for tables from different sources, in for example different formats or at different levels of granularity.

The raw data used for joining the data is not included on the GitHub. From the clustering algorithm, which will be discussed in the next section, it can be deduced that this table was saved in an Excel file named *statistics.csv*, which is unfortunately not available on the repository. However, the *clusters.csv* file, which is one of the outputs of the clustering algorithm still 'contains the original input data with joined cluster ids' (*Whereabouts London GitHub*, n.d.) Therefore, examining this table helps provide an understanding of which types of data were used and which attributes were included in the Whereabouts London map. While this table is not immediately visible for the end user engaging with the final map, it is worth exploring it in some detail as it forms the basis for the clustering algorithm which will be discussed in the next section.

Figure 5.9 shows the first seven columns of the *v6.clusters.csv* file, which identify each location in terms its Output Area and location on the map. Columns A and B define each location in terms of Lower and Middle Layer Super Output Areas.

Column C describes the year from which all the data sets were taken. Columns F and G refer to the area's latitude and longitude. These first columns do not contain data that describe anything about the quality of the areas, but they are needed to identify each location so that the further data sets can be joined to this.

	A	B	C	D	E	F	G
1	Geography	Geography Code	Date	X	Y	Lat	Lon
2	City of London 001A'	E01000001	2011	532179	181798	51.519634	-0.096304
3	'City of London 001B'	E01000002	2011	532448	181804	51.519625	-0.092427
4	'City of London 001C'	E01000003	2011	532194	182070	51.522074	-0.095986
5	'City of London 001E'	E01000005	2011	533755	181103	51.513017	-0.073867

Figure 5.9 The first rows and columns of the v6.clusters.csv file

The full table contains 4836 rows – or tuples, referring to the 4835 (excluding the table's header row) Lower Layer Super Output Areas of London. There are 244 columns, seven of which are depicted in Figure 5.9, while the last column identifies the cluster that location belongs to, as calculated by the clustering algorithm. This leaves 236 columns with joined data (attributes) to be used for the clustering.

It is not clear from the *v6.clusters.csv* file where exactly these different types of data come from. As will be shown from looking at the attributes in detail, it does not seem that each constitutes a different data set, but that many share the same source. The first attribute, for example, of age, is composed of 16 columns (H to W). It is divided into increments from Age 0 to 4 to Age 90 and over (see figure 5.10). The values each of these columns all relate to one another as they show the proportion each age group constitutes – rather than, for example, a simple count of people. This ensures that the different areas can be more accurately compared as the total number of people varies between LSOAs, as discussed above.

A1 fx Geography

	A	B	H	I	J	K	L	M	N	O
1	Geography	Geography C	Age: Age 0 to 4; measures: Value	Age: Age 10 to 14; measures: Value	Age: Age 15; measures: Value	Age: Age 16 to 17; measures: Value	Age: Age 18 to 19; measures: Value	Age: Age 20 to 24; measures: Value	Age: Age 25 to 29; measures: Value	Age: Age 30 to 44; measures: Value
2	'City of London 001	E01000001	0.03413	0.017747	0.004096	0.004778	0.004096	0.043003	0.095563	0.258703
3	'City of London 001	E01000002	0.041783	0.020891	0.004875	0.00766	0.006964	0.027855	0.064067	0.273677
4	'City of London 001	E01000003	0.039376	0.017831	0.003715	0.024517	0.02526	0.057207	0.106984	0.268945
5	'City of London 001	E01000005	0.04264	0.049746	0.013198	0.018274	0.017259	0.098477	0.123858	0.215228

Figure 5.10 The first columns of the category of Age in clusters.csv

This applies to a number of further attributes, including number of cars or vans per household (spanning columns X to AB, ranging from no cars to four or more) (see Figure 5.11) and type of central heating (spanning columns AC to AI, including electric central heating, gas central heating, no central heating, oil central heating, other central heating and solid fuel). Further attributes calculated in the same way are distance travelled to work, dwelling type, level of health, number of hours worked per week, household composition, passports held, tenure type, level of qualification, method of travel to work, main language and occupation.

A	B	C	D	E	F	G	X	Y	Z	AA	AB
Geography	Geography C	Date	X	Y	Lat	Lon	Cars: 1 car or van in household; measures: Value	Cars: 2 cars or vans in household; measures: Value	Cars: 3 cars or vans in household; measures: Value	Cars: 4 or more cars or vans in household; measures: Value	Cars: No cars or vans in household; measures: Value
City of London 001A'	E01000001	2011	532179	181798	51.519634	-0.096304	0.325342	0.060502	0.017123	0.004566	0.592466
'City of London 001B'	E01000002	2011	532448	181804	51.519625	-0.092427	0.353012	0.045783	0.015663	0.006024	0.579518
'City of London 001C'	E01000003	2011	532194	182070	51.522074	-0.095986	0.181151	0.013464	0.002448	0.001224	0.801714
'City of London 001E'	E01000005	2011	533755	181103	51.513017	-0.073867	0.214133	0.019272	0.004283	0	0.762313
'Barking and Dagenham 016A'	E01000006	2011	544908	184321	51.539185	0.08807	0.458564	0.160221	0.025783	0.012891	0.342541
'Barking and Dagenham 015A'	E01000007	2011	544138	184462	51.540649	0.077033	0.302288	0.062092	0.004902	0.001634	0.629085

Figure 5.11 The category of Cars in clusters.csv

The latter attribute, however, that of occupation, is included twice in different formats within the *v6.clusters.csv* table. Firstly, ranging from Columns FU to GC, it is categorised into nine types of occupation: managers, directors and senior officials, professional occupations, associate professional and technical occupations, administrative and secretarial occupations, skilled trades occupations, caring, leisure and other service occupations, caring, leisure and other service occupations, sales and customer service occupations, process, plant and machine operatives and elementary occupations. In the second instance, these nine groups are further divided into five different age ranges, so that each class of occupation makes up 1 (see Figure 5.12), making up a total of 45 columns (CM to EE).

	A	B	C	D	E	F	G	CM	CN	CO	CP	CQ	CR
1	Geography	Geography Code	Date	X	Y	Lat	Lon	Occupation: 1. Managers, directors and senior officials; Age: Age 16 to 24; measures: Value	Occupation: 1. Managers, directors and senior officials; Age: Age 25 to 34; measures: Value	Occupation: 1. Managers, directors and senior officials; Age: Age 35 to 49; measures: Value	Occupation: 1. Managers, directors and senior officials; Age: Age 50 to 64; measures: Value	Occupation: 1. Managers, directors and senior officials; Age: Age 65 and over; measures: Value	Occupation: 2. Professional occupations ; Age: Age 16 to 24; measures: Value
2	City of London 001A'	E01000001	2011	532179	181798	51.519634	-0.096304	0.023669	0.248521	0.349112	0.343195	0.035503	0.026846
3	'City of London 001B'	E01000002	2011	532448	181804	51.519625	-0.092427	0.011494	0.143678	0.41954	0.350575	0.074713	0.007143
4	'City of London 001C'	E01000003	2011	532194	182070	51.522074	-0.095986	0.044444	0.2	0.511111	0.222222	0.022222	0.034965
5	'City of London 001E'	E01000005	2011	533755	181103	51.513017	-0.073867	0.081633	0.346939	0.387755	0.183673	0	0.109756

Figure 5.12 The category of Occupation clusters.csv

An alternative typology is used by another included data set, that of the National Statistics Socio-economic Classification. This classification uses eight types of occupation: higher managerial and professional occupations, lower managerial and professional occupations, intermediate occupations (clerical, sales, service), small employers and own account workers, lower supervisory and technical occupations, semi-routine occupations, routine occupations, and never worked or long-term unemployed. For Whereabouts London, each of these is further divided into six groups: part-time employed, full-time employed, part-time self-employed, full-time self-employed, unemployed and economically inactive (See Figure 5.13). In total, this gives 48 columns for socio-economic classification, spanning columns GN to IG.

	A	B	GN	GO	GP	GQ	GR	GS
1	Geography	Geography Code	NS-SeC: 1. Higher managerial, administrative and professional occupations; Economic Activity: Economically active: In employment: Employee: Part-time (including full-time students); measures: Value	NS-SeC: 1. Higher managerial, administrative and professional occupations; Economic Activity: Economically active: In employment: Employee: Full-time (including full-time students); measures: Value	NS-SeC: 1. Higher managerial, administrative and professional occupations; Economic Activity: Economically active: In employment: Self-employed: Part-time (including full-time students); measures: Value	NS-SeC: 1. Higher managerial, administrative and professional occupations; Economic Activity: Economically active: In employment: Self-employed: Full-time (including full-time students); measures: Value	NS-SeC: 1. Higher managerial, administrative and professional occupations; Economic Activity: Economically active: Unemployed (including full-time students); measures: Value	NS-SeC: 1. Higher managerial, administrative and professional occupations; Economic Activity: Economically inactive; measures: Value
2	City of London 001A'	E01000001	0.014074	0.233333	0.017037	0.063704	0.007407	0.087407
3	'City of London 001B'	E01000002	0.020882	0.229698	0.020882	0.067285	0.00464	0.08198
4	'City of London 001C'	E01000003	0.014493	0.133655	0.012077	0.041063	0.002415	0.02818
5	'City of London 001E'	E01000005	0.002436	0.081608	0.001218	0.010962	0.00609	0.009744

Figure 5.13 National Statistics Socio-economic Classification in clusters.csv

Furthermore, there are a couple of further attributes which are made up of simple counts, namely Flickr photo count, food agency establishment count, food agency per square km, cycle hire locations count, pubs per square km, local parks and local parks per square km. The final attribute to mention is that of Mean of Medians Weighted by Sale Counts (2009 to 2013), which is assumed to refer to house prices in each area.

There are no criteria for the number of columns: data sets can always be added or removed. The more data sets are included, the more granularly the place is captured – 'the possibilities are just as rich as the data' (*Whereabouts London*, n.d.). Although the exact process of creating these data joins has not been documented by the project team, the materials available on the GitHub repository still allow us to unpick some of the complexities involved with preparing large amounts of data so that they can be analysed by algorithms. In particular, it shows how despite all of the emphasis on the multitude and unstructured nature of data, a significant amount of work is often needed to render all data in the appropriate formats.

For Amoore and Piotukh, what is crucial to the process of ingestion is the way it amalgamates and makes compatible different types of information. This section has explored how the process of ingestion works for Whereabouts London. Specifically, it has described how the map brings together a wide variety of different types of data which are coupled through a common denominator of place. This process of making heterogenous objects commensurable, Amoore and Piotukh argue, constitutes an ontological question: little analytics 'tend to reduce differences in kind to differences in degree' (Amoore & Piotukh, 2015, p. 360). Indeed, as can be seen above, all data sets are put into a single table, with each attribute showing as a new column. There is no qualitative difference between the different columns. Age (columns H to W) is placed next to Cars (columns X to AB), followed by Central Heating (columns AC to AI) and Crime (columns AJ to AT). There is no particular logic to the order of these columns and, for the purposed of the clustering algorithm, they could be switched around into any order without consequence.

Clustering

Following this process of ingestion, Amoore and Piotukh describe a next step for little analytics of 'partitioning.' This is where the analytic is put to work to identify and make perceptible the objects, patterns and signatures of interest hidden in the large masses of data. Partitioning is understood as 'one specific from of sense-making – one means by which subjects and objects of interest are partitioned from a remainder and singled out for attention' (2015, p. 349). A key feature of partitioning is that it is often refers to the ability to 'analyse multiple data forms without defining all queries and structure ahead of time' (Amoore & Piotukh, 2016, p. 6). This feature is important for understanding the power of little analytics. As the analysis is not guided by specific queries or hypotheses, it often appears that the analytics find patterns of significance that are waiting to be discover. In other words, 'with enough data, the numbers speak for themselves' (Anderson, 2008 n.p.).

As Amoore and Piotukh continue (2016, p. 6), this approach marks 'a shift in focus from causation to correlation.' Indeed, Anderson (2008) – now a classic figure in this school of thought – arguing that as the traditional model of science becomes obsolete with the advent of the 'Petabyte Age,' claims that:

> There is now a better way. Petabytes allow us to say: "Correlation is enough." We can stop looking for models. We can analyze the data without hypotheses about what it might show. We can throw the numbers into the

> biggest computing clusters the world has ever seen and let statistical algorithms find patterns where science cannot.

This view has since been widely critiqued. For example, for boyd and Crawford (2012, p. 666) such statements reveal 'an arrogant undercurrent in many Big Data debates where other forms of analysis are too easily sidelined.' Nevertheless, it is still a common argument in discussions involving big data, as can be seen at various points throughout the analysis of clustering below.

For Whereabouts London, partitioning of the data takes place through a specific algorithm – namely, the k-means clustering algorithm. As Alan Waldock explained:

> there's this thing called k-means clustering, which basically the data, or the algorithm would look for similarities in data and cluster it based on those – based on similarities that it saw and commonalities. We didn't necessarily know what those commonalities were. It would sort of spit out these polygons which were actually like: we classified these areas as being similar to these areas. (interview with Alan Waldock, 15 April 2016)

With k-means clustering, what is of interest is not defined in advance, but is expected to emerge from the data itself and from the way the various data points relate to one another. In other words, the little analytic not only identifies what is of interest, but also the rules on the basis of which such an identification can be made. However, while clustering may operate without predefined criteria, this does not mean the data speaks for itself. Rather, as will be discussed in detail, the Whereabouts are the result of specific calculative techniques that define k-means clustering. This section will explore how k-means clustering algorithm works in order to start developing an understanding of how the Whereabouts partitions the objects or patterns of interest from the data assembled in the previous step of joining.

Clustering is a process of classification in which data points or objects are grouped together so that similarity between those within the same cluster is as high as possible, while similarity with points in other clusters is minimised. Aggarwal defines the 'basic problem of clustering' as: 'given a set of data points, partition them into a set of groups which are as similar as possible' (2014, p. 2). In other words, the clustering algorithm of the Whereabouts London groups all of the LSOAs so that those within the same cluster, the same Whereabouts, are more similar to one another and more dissimilar to those locations in different clusters. Clustering is a distinct type of classification in that, as an unsupervised method, it does not use any predefined labels for categorisation, 'meaning that the investigator does not have pre-specified models or hypotheses but wants to understand the general characteristics or structure of the high-dimensional data' (Jain, 2010, p. 651). In contrast to 'confirmatory' techniques, which start with a set of assumptions that needs to be tested, clustering can be used to 'generate' (p. 653) or 'suggest' (p. 663) hypotheses. As Jain describes, 'the goal of data clustering, also known as cluster analysis, is to discover the *natural* grouping(s) of a set of patterns, points, or objects' (2010, p. 652 original emphasis).

The k-means algorithm, a specific clustering algorithm which was used in Whereabouts London, is commonly described as 'the most popular clustering algorithm and a representative of partitional and prototype-based clustering methods' (Moreira et al., 2019, p. 110). For instance, Aggarwal (2014, p. 6) claims that 'the k-Means method is considered one of the simplest and most classical methods for data clustering and is also perhaps one of the most widely used methods in practical implementations because of its simplicity.'

The procedure of the K-means algorithm is described by Polczynski and Polczynski (2014, p. 70) as a series of steps:

1. 'Guess the centre of each class by choosing a random value for each feature attribute.
2. For each feature, calculate the distance from the feature to the centre of each class.
3. For each feature, find the nearest class centre, and assign the feature to that class.
4. For each class, calculate the class centroid.
5. Go to Step 2 until no features change cluster assignment in Step 3'

K-means clustering is thus an iterative process in which a series of steps is repeated until the algorithm eventually settles on a stable classification. Due to this iterative nature, the algorithm is understood as a prototype-based algorithm (see Wu, 2012, p. 4). As such, its aim is to test and refine the prototypes that are the centres of each clusters until a functional result is achieved.

Thus, the first step in this process is to randomly select – guess – the cluster centres, or centroid. This is where the number of clusters, k, is set. For Whereabouts London, this number was set at eight, for reasons discussed in the next section on visualising. Eight random values were selected by the algorithm within each of the attributes – i.e. columns. In other words, these are eight centroids of 236 dimensions with random values across all attributes. Secondly, the algorithm calculates the distance of each feature to each of the centroids. In other words, for each of the rows, every LSOA, it is calculated how far it is from the randomly chosen centroids. Calculating the distance between data points can be done based on numerous different 'proximity measures', such as the Manhattan distance, Euclidean distance and Cosine similarity (see Reddy & Vinzamuri, 2014, p. 89). For the Whereabouts data set, Euclidean distance was used, one of the most common proximity measures for k-means clustering – as can be seen in the project's JAVA Command Line (see Figure 5.14).

```

    /**
     * Method to compute the k-means clustering using default settings and Euclidean distance.
     *
     * @param args
     */
```

Figure 5.14 The DataClusterer command line (***Whereabouts London GitHub***, **n.d.)**

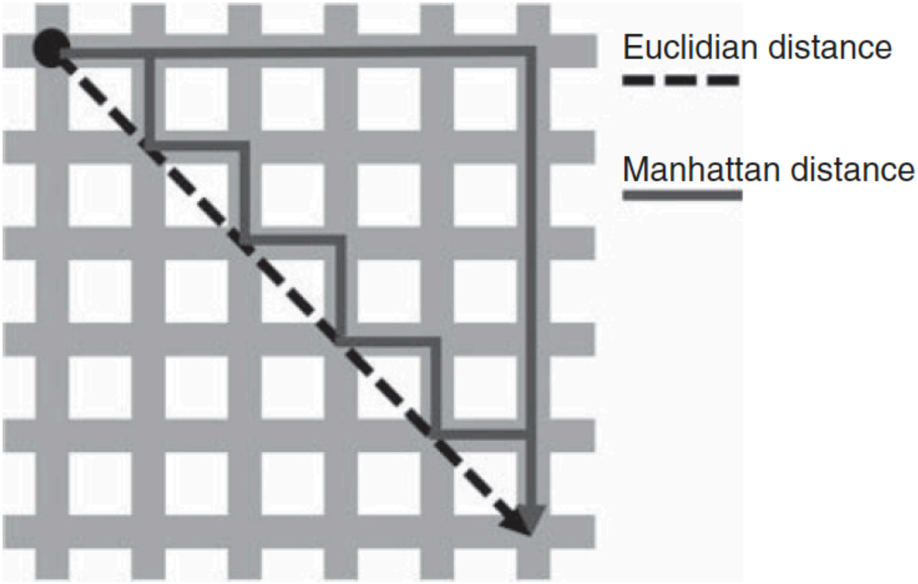

Figure 5.15 Euclidean and Manhattan distances (Moreira et al., 2019, p. 103)

Euclidean distance can be conceptualised as a straight line drawn between two points in space. For example, Figure 5.15 demonstrates the concept of Euclidean distance, as compared to Manhattan distance in two-dimensional space. In this example, the data has only two attributes, which can be plotted on an x- and a y-axis in a graph. Consequently, the distance between the two points can be calculated relatively straightforwardly using the Pythagoras theorem. The Whereabouts London data set contains many more attributes, so that calculating the distance of each area to each of the centroids involves a distance calculation that spans across each of the 236 rows, from number of cars per household, to types of heating, to occupation and number of parks and so on. These attributes cannot be graphically represented in a 236-dimensional graph on a two-dimensional page. Nevertheless, the principle of calculating the distance between data points remains the same as for those data points with only two attributes.

Having calculated the distance from each location to the various centroids, each area, each LSOA, is assigned to the cluster of its nearest cluster centre. This results in a first classification into clusters, an initial set of Whereabouts, based on a number of k randomly chosen cluster centres. While each of the areas has been assigned to the cluster centroid closest to it, this does not mean that these centroids are actually in the centre of their respective clusters. The next step therefore is to calculate the centre of each cluster, which will likely mean that the centroid moves. From here, the algorithm will go back to step 2, calculating the distance of each LSOA to the various centroids and, step 3, assigning it to the nearest one. It will then recalculate the centre of each of the clusters. These steps are repeated an unspecified number of times until the clusters stabilise – i.e. following recalculation of the cluster centre the centroid does not move anymore. In practice, a common rule is that 'the iterative procedure must be continued until 1% of the points change their cluster memberships' (Reddy & Vinzamuri, 2014, p. 89).

For the Whereabouts London data, the algorithm needed a total of 34 iterations was needed, as is described in the *v6.centroids.txt* file on the project's GitHub depository (see Figure 5.16). This file, which is one of the output of files of the Java DataClusterer, describes the centroid values per attribute for each of the eight Whereabouts. In addition to the number of iterations, it also displays the 'within cluster sum of squared errors,' which describes the variation between the clusters in terms of each row's distance to its allocated centre. The process is completed once the algorithm has found a 'partition such that the squared error between the empirical mean of a cluster and the points in the cluster is minimized' (Jain, 2010, p. 653).

```
kMeans
======

Number of iterations: 34
Within cluster sum of squared errors: 66810.11046154422
```

Figure 5.16 Number of iterations in v6.centroids.txt (*Whereabouts London GitHub*, n.d.)

This section on clustering has examined the function of 'partitioning' as one of the key operations of little analytics. The k-means clustering algorithm divides the data ingested in the previous step into eight different categories. The criteria for each of these categories is not specified in advanced but emerges from the calculation. That does not mean that the classification the algorithm produces is inevitable. As can be seen from the process explained above, it depends on a number of variables. For instance, the first step of k-means clustering is essentially a guess, meaning that setting the initial random values for each attribute differently may well produce different results. Indeed, running the same algorithm with the same data again may well produce a different classification each time. In addition, there is nothing natural or inevitable to the number of clusters, which has to be specified before running the algorithm – which will be discussed in more detail in the next section.

Visualising

The third and last aspect of little analytics highlighted by Amoore and Piotukh is that of memory (Amoore & Piotukh, 2015, p. 355), which describes the temporal implications of the ways in which analytics allow for the extrapolation of the present to enable decision making for the future. While there may well be some relevance of the concept of memory to the case of Whereabouts London and the way in which the map supports new types of decision making, this term has primarily been posited in the context of real-time or near-real-time analytics. In contrast, the analysis of Whereabouts London raises the issue of another process, essential to mapping, namely visualisation. Therefore, after ingestion, partitioning and memory, this case study suggests visualising as a further process 'through which little analytics reshape the landscape of what can be perceived, known and acted upon' (Amoore & Piotukh, 2015, p. 344).

This section will explore some of the considerations associated with visualising the data previously processed, through ingestion and clustering, into a map. In so doing, the case study will move away from the data and algorithm discussed in the previous section, and further draw on an interview conducted with Alan Waldock from the Future Cities Catapult. For Waldock, who worked on the project as a designer, the key objective of visualising or mapping the data was framed in terms of storytelling and the engagement of the reader or map user. As Waldock explains, the

> 'strengths [of maps] are born out of that they are just incredibly engaging things, as just a piece of content, or visualisation (…) I think people are just drawn towards them' (interview with Alan Waldock, 15 April 2016).

Crucially, one of the reasons people are drawn towards maps is that the ability to read maps has become ingrained so that they do not require the same technical skills or knowledge other types of data visualisations might:

> it has become more or less so engrained, in our abilities, that I think you probably struggle to find many people nowadays who consciously think about that process of putting themselves into a map, and then reading it – whereas you don't necessarily say the same thing for a visualisation. Like a data visualisation can be quite specialised, you know. And it can be quite a complex thing – you know if you're not familiar with data and statistical analysis and those sorts of things, actually reading abstract visualisations is a lot more kind of a mental process. And it can take a lot more work to decode whereas maps, because so much of that work has been sort of precomputed in people's heads just through their childhood and through their lives. (interview with Alan Waldock, 15 April 2016)

While other types of advanced data visualisation might have been better at describing the intricacies of each of the Whereabouts, they lacked the capacity to engage the end users, who might not have the ability to easily read these. The map still used other types of data visualisations, but they were hidden in the labels that pop up when clicking on each of the Whereabouts. These labels explain some of the characteristics of the data for each of the eight Whereabouts (see Figures 5.3 and 5.4 earlier in this chapter).

In this step, the results of the clustering process are visualised in order to communicate its findings to the map users. As Waldock described, one of the main difficulties of visualising a complex dataset like the one for Whereabouts London lies in finding the right balance between the detail or nuance of the data on the one hand and the story on the other:

> Sometimes as a designer you're looking for a small story that's just going to you know hook people in. And often, or not often, but it can be the case where like looking for that story you might tend to gloss over certain things or you know you sort of emphasise certain things and de-emphasise others, whereas we're trying to tell a really accurate story through data and the analysis of data and the representation of data – it can be quite tempting to try to gloss over bits that maybe don't fit that narrative, whereas actually in the context of what we're trying to do here you can't, you know you don't really want to iron over those problems. It's like you kind of have to show them because they are – those inconsistencies and those difficulties are a big part of the story as well.

> So it's quite a tension between trying to tell a simple engaging story that people can look at and sort of understand without having to delve really deeply and a deep understanding of the data science, but at the same time not do disservice to the data science as well – actually show the complexity. I think that's two tensions that we sort of grapple with quite a lot. (interview with Alan Waldock, 15 April 2016)

Waldock's emphasis on the small stories within big data underscores the "little" in little analytics, contrasting the big and complex, which is part of the data science domain, with the simple and engaging, which is of interest to the designer. In this way, the designers add a new perspective to the process so far led by the data scientists, bringing into view the eventual map user or reader.

As the focus shifts towards the end user, this concern of balancing the detail of big data and the persuasiveness of the map was most fundamentally expressed through the question of finding the appropriate number of clusters. The right number of clusters is usually not known before running a clustering algorithm. Selecting this number is essentially a balancing act. As Moreira et al. (2019, p. 99) describe, 'the larger the number of clusters, the more similar the objects inside the cluster are likely to be. The limit is to define the number of clusters to be equal to the number of objects, so each cluster has just one object.' In other words, there is not always necessarily a perfect or natural number (k) of clusters, as much depends on the rationale and purpose of any particular project. While a larger number of k result in smaller groups and therefore reduces the differences between the objects in each group, this also makes it increasingly difficult to draw comparisons across groups and derive meaning from the analysis. On the other hand, a lower number of k may result in more pronounced differences between the different clusters, but at the same time increases the variety within each cluster, running the risk doing a 'disservice' to the complexity of the data.

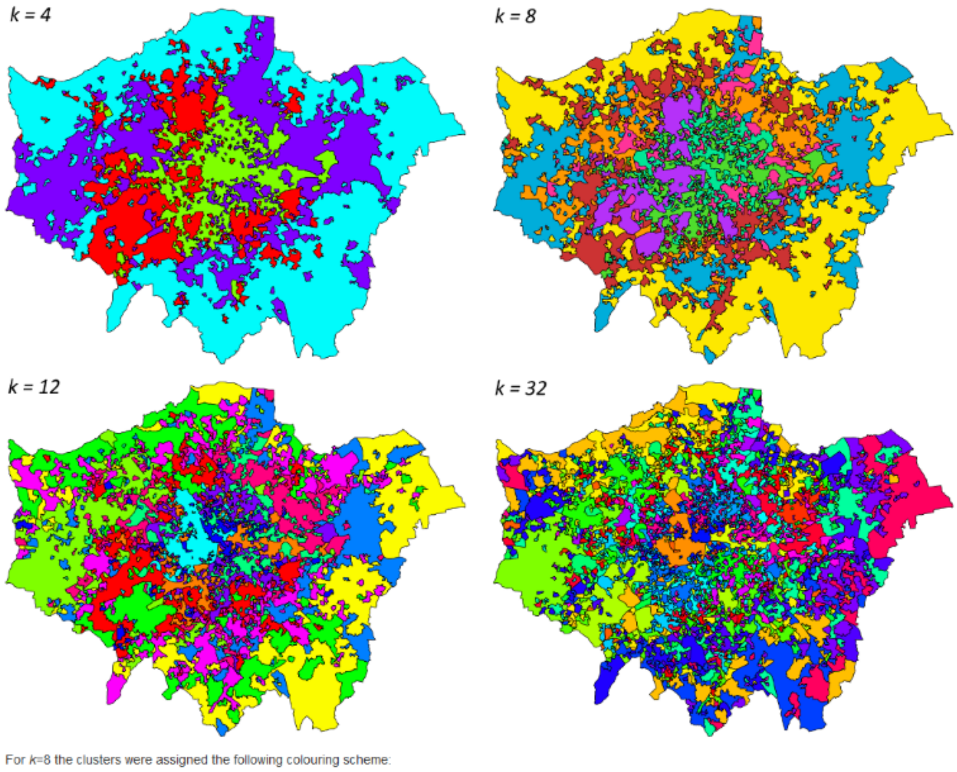

Figure 5.17 Four visualisations of the various iterations of the map with different numbers of clusters (*Whereabouts London Bitbucket*, n.d.)

For Whereabouts London, finding the right number of clusters involved a process of trial and error. Waldock explained:

> It was really just a choice that we made so it felt like we didn't want it to be too low, because then that's doing quite a disservice to the data but too high and it becomes really difficult for someone to read and get their head around. (Interview with Alan Waldock, 15 April 2016)

As Figure 5.17 shows, the team tried out four different numbers of k for the clustering algorithm, ranging from 4 to 32. The map in the top left corner, with k=4, is certainly the most easy to read. It consists of large areas of the same colour, with light blue on the outside and green in the centre of London. In contrast, the map in the bottom right, with k=32 is much more complex. Not only are the different clusters much more scattered across the city, it is also hard to actually distinguish 32 different colours within the map. Thus, in the balancing of complexity and clarity, k=4 tends towards the latter, being easy to read but with a lack of nuance, while k=32 tends towards the former -high in nuance but virtually incomprehensible.

There are various ways of assessing the optimal number of k in a k-means clustering algorithm scientifically (e.g. see Pham et al., 2005). However, in the case of Whereabouts London, the ideal number of k was not intrinsic to the data set as put together in step 1; it did not necessarily reflect the data's inevitable '*natural* grouping(s)' (Jain, 2010, p. 652 emphasis in original), as spoken by the numbers themselves. Rather, it was the result of a deliberation within the project team where contributions of data science where weighed up against those of design and communication. Indeed, as described on the Whereabouts London Bitbucket:

> Objectively 32 clusters provide a better overall means distribution of LSOAs. However, as the representation of 32 clusters was problematic in terms of simple visualisation and comparison, k-means was applied with a cluster count of 8 (k=8). (*Whereabouts London Bitbucket*, n.d.)

Prompted on this notion of 'objectively', Waldock reflects:

> My understanding of it … when the algorithm is left unguided there is, in terms of how these similarities and commonalities are drawn out, it would choose to fit them into 32, or 33, I forget now, clusters. But obviously I think there was a lot, when we did look at that, there was a lot of subtlety in how they were differentiated so it would be really hard to tell a story about cluster 1 versus cluster 2 because it was quite subtle variation. So just intentionally limited [the number of clusters] to make those differences much more pronounced so we could give more of a feeling of the differences between the areas. (Interview with Alan Waldock, 15 April 2016)

This chapter has described the process of creating the London Whereabouts as three sequential steps of joining, clustering and visualising. As this description shows, however, in practice this sequence is not as clear cut, as the different steps feed into one another. In particular, while the map shows the result of the analysis carried out by the clustering algorithm, at the same time this algorithm was led by concerns emerging through the process of visualising.

However, with the joining of qualitatively different types of data under ingestion, and the clustering algorithm's unsupervised approach to calculating similarities, it is difficult to see which stories these Whereabouts tell exactly. While neighbourhoods within a cluster are similar to one another in terms of a Euclidean distance measure to a randomly selected centroid, it is not clear what these centroids represent. Within the 236-dimensional space, there is no distinction in the meaning or importance of different types of data. As Amoore and Piotukh (2015, pp. 353–354) describe, in the context of the use of little analytics in retail, 'co-occurrence in itself is not always a matter of interest, for example, milk co-occurring with bread in basket data would have high levels of support and confidence, but would not constitute an object of interest.' Similarly, for Whereabouts London, there is no guarantee that the final output of Whereabouts London is actually of interest. In fact, one commentator noted, 'the result shows what many Londoners already instinctively know, but in a way which is visually striking' ("Data Are Transforming How Cities Operate," 2014 n.p.).

Thus, while the Whereabouts indicate there is certain similarity to the neighbourhoods within the same clusters, what this similarity consists of is not immediately clear. As a result, Waldock argues, from a design perspective, there is a risk that "you go for too much of a story on it:"

> because I think we intentionally shied away from naming any of the Whereabouts –which is why it's called Whereabouts 1 through 8. A catchy name, but we didn't want to get into sort of draw any actual names, descriptive names, for the clusters, because again, we're doing a disservice to the data, sort of stereotyping these areas and kind of reading things into it that weren't necessarily true. So we intentionally kept it quite neutral. (Interview with Alan Waldock, 15 April 2016)

Not everyone agreed with this decision not to give the Whereabouts descriptive names. For instance, Time Out remarked that the different categories should have had proper names instead of numbers to distinguish them more easily. It even gives four suggestions: 'Abhorrently Wealthy', 'Where Londoners Go To Die', 'Your Peers, But With Better Careers' (see "Map: The 8 Types of Londoner," 2014 n.p.). Elsewhere, Clarke (2014 n.p.) described the map as having 'more than a passing resemblance to Dante's nine circles of Hell.' Although the categories do not form neat rings and are all to a greater or lesser extent scattered over the city, a structure of inner and outer zones clearly emerges.

To some proponents of the promise of big data this question of meaning is irrelevant. For example, Anderson (2008) claims: 'who knows why people do what they do? The point is they do it, and we can track and measure it with unprecedented fidelity.' In this same vein, it could be argued – who knows why these neighbourhoods are similar to one another? The point is that they are and that we can track and measure it with unprecedented fidelity. However, it raises a question about the point of the little stories told by little analytics. As they single out patterns and correlations within the big data, the reason for their significance is not always given and open to interpretation and speculations. While for Waldock characterisations such as the ones described above were simplifications, he also described these responses as a success:

> So when people start to read it, it starts to throw up these little kind of questions in their minds and it gets them thinking about these places and, you know, people start making up their own stories about maybe why it's taken the shape that it has. So I see that as a success, I think as a conversation starter, as something to sort of make people question why London might be the shape that it is. (Interview with Alan Waldock, 15 April 2016)

Considered in this way, the small stories told by Whereabouts London are not so much, or not only, about the similarities found between neighbourhoods in different parts of the city, but rather about its own ability to produce new ways of seeing things and to make people question.

Whereabouts London as object

This chapter has described the trajectory by which Whereabouts London makes sense of big data and groups neighbourhoods based on how rather than where people live. In this final section, this trajectory will be discussed using the OOO notion of unit operations, which has been outlined in Chapter 2. Whereabouts London's unit operations consist of a process of ingesting, clustering and visualising. In the first step, ingestion, the data is collected, filtered and joined to assemble single table that describes each LSOA through a long list of attributes. In the second step, clustering, this table is partitioned into eight Whereabouts, each of which revolves around a randomly created centroid. The k-means clustering algorithm divides the different output areas into eight groups such that similarities, based on the attributes assembled in step 1, are maximised. Finally, these clusters are visualised as a map, showing areas determined to be similar spread out over the city.

To be sure, the classification produced by the k-means clustering algorithm is not the only one possible, as described above. Indeed, the Whereabouts project encourages users to use their methodology to create their own maps:

> But our Whereabouts are only one way of interpreting the data. The same information could be used by anyone to create their own maps, tailored to their own needs and interests. Fancy a go? (*Whereabouts London*, n.d.)

There are many other ways of partitioning the data, be it with the same clustering algorithm or otherwise. Given the table structure of the data produced in the ingestion stage, new data sets can be added relatively easily, as long as they have the same common index of LSOAs. Running the algorithm again would likely produce different results. Finally, the visualisation stage involved a number of design choices which had less to do with the nature of the data itself and more with the communication of this data to the map user. In other words, the same map can generate many different images, while still being understood as Whereabouts London. This mutability of the map image is emphasised in the context of digital mapping. With the rise of digital cartography, Lammes claims, 'the status of the image has changed' (2017, p. 1026). As digital interfaces allow for increasing interactivity between the map and its user, the image – which may change at any moment – becomes just one of many elements in networks of screens, processors, software and infrastructure.

However, from an object-oriented perspective, these questions of the relationships between maps, their images and their operations can be understood in terms of the nature of objects more generally. For Harman, an object cannot be reduced to its appearance, as this is only one of its dimensions. Similarly, central to Bryant's discussion of objects as machines is his argument that 'machines are *split* between their operations and the output or products of their operations' (2014, p. 40 emphasis in original). The map image the user encounters when visiting the website is a 'local manifestation' of Whereabouts London's operations. These operations are not exhaustive of the machine's powers, which refers to 'a *capacity* possessed by a machine regardless of whether or not that power is exercised' (2014, p. 42 emphasis in original). Thus, OOO advances a split understanding of the map as consisting of its operations – ingestion, clustering, visualising, which are in turn an actualisation of its powers – and the final output that is the visualisation.

This ingestion, clustering and visualising of data can be described in a wider context of databases and tables making and 'doing of multiples' (Mackenzie, 2012; Mackenzie & McNally, 2013). The interest in the doing of multiples is intended to account for their historical becoming and ontological status within modern society (Mackenzie, 2012, pp. 337–338). Emphasising the 'centrality of databases in information societies, network cultures, and so on' (p. 337), the idea of doing multiples presents a concern with the ways in which 'data multiples' are passed through and mediated through databases: 'while multiples in the world remain innumerable, databases have increasingly emerged as a way of collecting, numerating, and enunciating multiples in particular ways' (p. 338). Whereabouts London's unit operations of ingestion, clustering and visualising thus describe a doing of the city's data multiples by the map.

Each time a Whereabouts map is produced, it tells a particular story, a small story against the backdrop of big data. The visualisation of Whereabouts London's classification plays a key role here. As Mackenzie and McNally argue in the context of the function of heatmaps in proteomics research, 'the visual device itself is an attempt to stabilize not proteins themselves (to which it has no direct access), but the multiple experiments undertaken to find out how many proteins are in blood plasma' (Mackenzie & McNally, 2013, p. 75). Applying this to Whereabouts London, the map image is an attempt to stabilise not the city and its demographics itself (to which it has no direct access), but rather the various processes of 'collecting, numerating and enunciating multiples' (Mackenzie, 2012, p. 338) as performed by its preceding steps of ingesting and clustering. It is in this step that the data multiple of London, described through its many attributes in the table assembled in step 1, becomes stabilised into a coherent idea, a story, re-presenting London as a city.

In other words, units are always also multiples; or, as OOO argues, unity and multiplicity, exterior and interior, are two dimensions of objects. Whereabouts London encounters the data from the London Datastore in their multiplicity, performs its operations on these multiples and presents them in a single map. This map, presented as a unity, can in turn constitute another multiplicity for other objects. The trajectory from ingestion to visualisation can thus be understood as oscillating between the doing of multiples on one hand and configuration of units on the other.

Bogost (2006, pp. 10–12) formulation of the concept of unit operations is inspired by Badiou's concept of 'the count as one.' This concept is fundamental in Badiou's ontology for understanding how multiplicities come to be presented as unities. Within his ontology of set theory, sets consist of their members, which in turn can combine in various ways to form further subsets. Sets both constitute and consist of other sets. The count as one describes a 'process or a frame for *a* multiplicity, the count as one *produces a particular* set; it takes a multiplicity and treats it as a completed whole' (Bogost, 2006, p. 11). Units are similar to sets: each unit consists of, takes part in and combines with further units. In other words, examining Whereabouts London's unit operations describes both how it encounters and perceives the world around it, and how it configures itself – i.e. how it emerges – as a discrete unit within this world.

By counting the data multiple as one, it comes to be counted as one for itself. Mackenzie's idea of the 'doing of multiples' can thus be understood both as the ways in which multiples are done – dealt with and produced – and the ways in which multiples do themselves. Paraphrasing Bogost (2012, p. 22), the smart city is a unit as much as the data and datastores, the sensors, cameras, little analytics, prototypes, dashboards, infrastructures, citizens, public-private partnerships, and so on. The smart city erects a boundary in which everything it contains withdraws within it, while those units that compose it do so similarly, simultaneously, and at the same fundamental level of existence. In this way, unit operations address the dual themes of change and emergence, set out in Chapter 2. Units emerge through their operations – that is, their process of relating to others, of change.

Amoore and Piotukh are particularly interested in the implications of the work of little analytics 'as they transform the governing of economic, social and political life' (2015, p. 360). In other words, how can the examination of the ways in which they ingest and partition data, of the ways in which they enable perception and attention, enable wider questions about the environments in which these analytics operate? Bogost frames this question in terms of the opposition between unit and system operations, arguing that 'pattern recognition too can act either as a unit or a system operation:'

> The individual act of information processing that identifies patterns in a field of random data, for example, a software subsystem for determining airline passenger risk, is indeed a unit operation. (…) As a discrete computational unit, such a data analysis system would indeed produce outputs for every input. But what kinds of conclusions can the system's operators draw from its output? These political, social, economic, and ethical issues are not so simply mapped to machine processes. (Bogost, 2006, p. 29)

Thus, while unit operations describe how Whereabouts London ingests, partitions and visualises its data, the political, social, economic and ethical implications of these processes extend beyond the unit, into the system of which the unit is a part.

In this way, Whereabouts London helps produce the smart city as 'a new kind of system: the spontaneous and complex result of multitudes rather than singular and absolute holisms' (2006, p. 4). Smartness understood in this way is not a deterministic force but emerges in interplay with the unit operations of the objects that take part in the smart city – without being reduced to the simple sum of these operations. Similarly, Bryant (2014, pp. 52–53) describes the agency of works of art:

> The milieu actualizes the work in a particular way, leading it to be interpreted in a certain way. But the work also organizes the historical and cultural milieu in a particular way leading us to attend to certain cultural phenomena as significant while ignoring others.

In its milieu of the smart, Whereabouts London's unit operations can be said to 'enforce a broader (…) system operation' (Bogost, 2006, p. 30). As a little analytic, it is able to dissect and represent the city in resonance with wider social, political and cultural system operations in the context of the power of big data and the nature of the urban.

Amoore and Piotukh highlight several wider implications of the work of little analytics which can be understood as such system operation, that apply to the Whereabouts London as well. Firstly, the process of ingestion, in which different data sets are gathered and joined, represents a concern with 'a specific and novel epistemology of population' (Amoore & Piotukh, 2015, p. 360 emphasis in original). This refers to the often-emphasised ability of big data to capture a population as a whole, n=all, rather than working with selected samples. Whereabouts London indexes the whole of the city, down to the granularity of Lower Layer Super Output Areas as defined by the UK Census. As London's demographics are fitted into a table where each LSOA is described by a long list of attributes, difference becomes a matter of each area's relation, measured by the k-means clustering algorithm through Euclidean distance, to a mean. In this process, the steps of ingesting and clustering 'reduce heterogeneous forms of life and data to homogenous spaces of calculation' (Amoore & Piotukh, 2015, p. 361).

Moreover, as the clustering algorithm divides the output areas into eight Whereabouts, it resonates with a logic of little analytics working 'not merely with a statistical notion of what is interesting, but also via an inductive process of knowledge discovery, in which the process generates the rules' (Amoore & Piotukh, 2015, p. 360). This relates to the popular but controversial idea of the data deluge leading to the 'end of theory,' where 'correlation supersedes causation, and science can advance even without coherent models, unified theories, or really any mechanistic explanation at all' (Anderson, 2008 n.p.). The Whereabouts classification is based on the correlations found within the data by the clustering algorithm, rather than any presupposed model or hypothesis. For the users engaging with the end product of the map, the eight Whereabouts are seemingly "natural" or pre-existing groupings into which the city can be classified. They seem not so much derived through a particular mode of clustering as one of many possible configurations, but appear to have been waiting within the data to be uncovered by the clustering algorithm, as 'the 8 types of Londoner' ("Map: The 8 Types of Londoner," 2014).

Finally, the step of visualising resonates with another system operation relates to Thrift's appreciation of maps as aesthetic tools, as discussed in Chapter 2. Amoore and Piotukh are primarily interested in algorithms, rather than maps specifically, and therefore do not address the theme of visuality. However, the visual dimension of the Whereabouts London map is crucial to its capacity for telling small stories. Despite its novelty, the smart city is also continuous with a longer tradition of visual culture. As Rose (2019, p. 98) argues, 'visuals and visuality are at the core of smart city activity' (see also Wigley & Rose, 2020). Within this visual culture, the map is a powerful medium for telling the small stories of big data and the smart city.

From an object-oriented perspective, the importance of little analytics cannot be reduced to their being instrumental, in the service of a human subject. Rather, they form part of a 'post-human media ecology' (Bryant, 2014, p. 15) of data, analytics, users, open data policies and so on. Within this ecology, 'seeing is performed by a multitude of human and computational agents whose 'vision' passes across and along platforms, eluding any singular coordinating position, and heterogeneously conjoining things and practices' (MacKenzie & Munster, 2019, p. 9). By untangling the map's unit operations, it becomes distinguishable as a specific unit within this ecology, this multitude of agents. In doing so, the analysis of Whereabouts London's unit operations is simultaneously an alien phenomenology of the map as unit (or object, or machine) and an 'onto-cartography' (Bryant, 2014) of the way it relates to other objects within the system that is the smart city.

Conclusion

This chapter has analysed the case of the Whereabouts London map developed by the Future Cities Catapult. The Whereabouts London project has highlighted how smart cities make use of both new and old sources of data. It emphasised not only the ability to generate and capture data through advanced technologies, but also questions around how this data is used, analysed, shared and communicated. Using the concept of little analytics, the case study reverse engineered Whereabouts London's process from data ingestion, to clustering, to visualisation to show how the map, was able to draw attention to and tell stories presumed to be hidden within the data.

Firstly, the step of ingestion involved collecting and selecting a range of data sets which together describe the city in numerous facets. These data sets were joined in a single table so that each individual location, each Lower Layer Super Output Area, was linked to an equal number of attributes. Next, the k-means clustering algorithm categorised the table assembled in step 1 into eight distinct clusters, eight Whereabouts. The clustering algorithm helped make sense of the large amount of data across its many attributes in a way that exceeds human cognition. Finally, these eight Whereabouts were presented through the visualisation that is the interactive map. This map enables the end user to see and explore the city in a new way.

With this focus on following the process, the concept of the little analytic was instrumental in facilitating an analysis of Whereabouts London's unit operations. In doing so, it forms a bridge between the literature on big data, analytics and the smart cities on one hand and an object-oriented approach to studying maps on the other. The map's unit operations – its ways of perceiving, engaging with and transforming the world – describe how by dealing with the multiplicity of the objects around it, Whereabouts London emerges as a unit itself. By considering the visual and the operational as constitutive of two different dimensions of maps, an object-oriented cartography is interested in the relationship between the two: how does a map's way of engaging with and perceiving other objects generate particular visualisations? How do particular visual images affect the map's ability to operate on and transform the world around it?

Conclusion

Before delving into the proposals for understanding maps as objects, Chapter 1 provided a review of the literature on smart cities, informed by a series of interviews with people working on smart cities and urban informatics in New York. It covered a selection of topics, starting with an overview of the smart city concept and the different types of research that have been conducted in the area. It also explored the importance of the focus on cities, an element of significant political and rhetorical importance, which has often taken for granted in the focus on smartness. The second half of the chapter reviewed some of the major technologies that are deployed within the smart city, such as big data, open data and data generated through the use of sensors. These were put in a wider context of neogeography, spatial media and VGI. In turn, this wider context was used to discuss the changing nature of maps within the smart city, and various conceptual frameworks that have been developed to conceptualise this.

From there, the chapter went on to describe the corporate players that have been instrumental in creating the global smart city industry, and the way these engage in partnerships with governments and universities. The notion of the urban laboratory provided a particular arena for such partnerships, and – through ideas of experiments and prototypes – raises a host of interesting questions from a research perspective. While there are many more topics that could be discussed as part of literature review on this vast area, the themes included were selected to demonstrate how the smart city remains a contested, ambiguous concept. The chapter highlighted some of the tensions that exist between the various actors and explored themes that were relevant for informing the analysis later in the case study chapters.

Following this literature review, Chapter 2 was a journey into different ways of studying maps in order to explore what it means to consider maps as objects. It started by highlighting the importance of maps in the context of the smart city, discussing how new technologies have enabled new ways of both creating and using maps. The chapter then gave a brief overview of the recent history of cartography, outlining the basic principles of critical cartography in the 1980s and subsequent approaches revolving around notions such as the performative, affect and the non-representational. The central argument of this discussion was that the history of cartographic thought as described has often developed in tandem or resonance with wider developments in social and philosophical theory. Building on this argument, the chapter explored how developments around the rise of object-oriented ontology (OOO), could be used to further probe new ways of thinking about and studying maps.

To this end, it introduced the key authors and fundamental arguments of OOO. Examining Harman's concepts of under-, over- and duomining, it developed a conceptualisation of maps in contrast to those in communicative, critical and non-representational cartographies. Taking the object-hood of maps seriously, according to OOO, entails approaching maps such that they are not simply the product of the political, social and ideological contexts, situations and encounters in which they are produced, used and circulated. Instead, the map consists of an interior, which always remains withdrawn, but simultaneously explains its capacity for change – to affect and to be affected. Thus, an object-oriented cartography draws attention to both the withdrawn nature of the map as object and the way this enables particular ways of relating to other objects.

The last chapter before the two case studies was Chapter 3 on methodology. The aim of this chapter was to build a bridge between the conceptual framework set out in Chapter 2 and the empirical material of the cases, in order to facilitate an answer to the research question set out in the Introduction – *Can object-oriented ontology be used to inform cartographic theory and research?* In doing so, it discussed the concept of casing, to emphasise that there are many different ways of doing case study research. Casing explains the process of defining a case and of determining what it is a case of is. One particular way of being a case is by being an example. The example is a single case that relates through what it exemplifies not by being generalisable, but rather through the concepts of analogy and intelligibility. Rather than being representative of something that is out there, that is pre-given, the detail of the example is able to multiply and extend beyond itself. The extent to which the two case studies, as examples of understanding maps as objects are able produce new ways of thinking about the smart city will be the subject of discussion in the next section of this Conclusion.

Having laid out the thesis' theoretical and methodological foundations, Chapter 4 presented the first case study: the MotionMap in Milton Keynes. The case followed the process of creating the map. What became apparent in this process, was the map's challenge to mediate between a range of different visions. The project's approach was explicitly based on the method of prototyping. The case study analysis also used this notion of the prototype and the way this has been further elaborated within social theory to link the case to the conceptual framework of OOO. It followed the case in two different, but complementary, directions. On the one hand the prototype was envisioned as more than many, signalling a process of multiplication and speeding up. Here, the MotionMap's role was its ability to generate a variety of answers to the question of how big data could actually be used. On the other hand, the development process was marked with a number of failures and obstacles to implementing these answers. From an OOO perspective, this tension was described as one between readiness to and presence at hand, between the future and the past, and between a map's capacity to affect others and its announcing as itself.

Chapter 5 presented the second case study, of Whereabouts London developed by the Future Cities Catapult. This case study reverse engineered the map, using the materials available on the project's repository. This method was facilitated through the approach of the map as a little analytic, a concept that juxtaposes the big in big data with the role of analytics in identifying meaningful patterns and relationships. In doing so, the chapter traced the map's three steps of ingestion, clustering and visualising by which the map identified and presented similarities between groups across the city. These steps were then put in an object-oriented perspective through the theory of unit operations. Following Bogost's understanding of unit operations as configurative, this concept helped reflect on the distinction between what a map's actual operations and appearance and its powers and being. Detangling what Whereabouts London does was a way of problematising the relationship between the object's surroundings – the way it perceives other objects – and its unity as a coherent, autonomous entity. Finally, through the concept of unit operations, OOO brought into question the relationship of the map as unit and the system of the smart city in and on which it operates.

This Conclusion brings together these case studies to address the research question raised in the introduction, of whether OOO can inform cartographic theory and research. In particular, using the themes of change and emergence, it will outline how OOO may challenge other theories about maps. In doing so, it will reflect on the use of the case study methodology, as outlined in Chapter 3. It will discuss the differences and commonalities between the two cases in the way they exemplify different lines of enquiry of object-oriented approaches to cartography. Finally, it will reflect on the application of OOO to cartography and how this might be developed further in future research.

Can object-oriented ontology be used to inform cartographic theory and research?

This thesis has aimed to contribute to a number of research areas. Firstly, it has been an examination of the methodological and theoretical relevance of the philosophical principles of OOO to empirical research. Applying these philosophical debates of OOO to cartographic thinking, it hoped to develop a greater understanding of these debates and how they can guide research designs. Secondly, in doing so, the thesis has explored whether and how an object-oriented perspective can open up different ways of conceptualising and researching maps. Finally, it hopes to add to empirical studies of smart cities, contrasting the big ideas of smartness with real-world case studies. This section will unpick these different areas.

In both case studies, the object-oriented approach to studying the two maps revolved around the twin themes of emergence and change. These themes emerged from a critique of under, over and duomining strategies: those philosophical strategies that do not deal with objects on their own terms but explain them in terms of something else – smaller, bigger, or both at once. For Harman, as discussed in Chapter 2, undermining objects leads to the inability to account for emergence: viewing objects purely as a collection of smaller elements does not explain how they exist as distinct entities with properties not found within these elements. Likewise, overmining objects results in the inability to explain change: viewing objects as an outcome of their relationships does not explain how they may play a role in changing such relationships over time. In contrast, OOO argues for the need for objects to be taken seriously on their own terms. On the one hand, it looks for ways to explore the essentially withdrawn interior of objects, the inexhaustible interiority which can never be perceived fully. On the other, it investigates how objects engage with and perceive other objects, the process in which they encounter certain qualities of other objects, but never their entirety.

Through this focus on the relationships between change and emergence, the two case studies were able to organise a variety of texts and arguments from within the OOO literature. For example, the analysis in the MotionMap chapter drew on Morton's argument on the present of an object as a rift or tension between its past/appearance and its future/essence. It also made use of Harman's distinction of object's being alternately present-at-hand and ready-to-hand, and the way in which moments of objects becoming present-at-hand allude to their withdrawn interior. Finally, it referred to Bogost's concept of carpentry, a way of making things that explain how objects make and experience their worlds. Likewise, in the Whereabouts London chapter, the analysis revolved around the notion of unit operations as developed in different ways by Bogost and Bryant, highlighting the relationships between the ways objects relate and operate and how they are configured as units. Moreover, by being able to enlist these various arguments from within the OOO literature, the themes of change and emergence also enabled engagement with concepts from the wider social science literature on such as prototyping, little analytics and doing multiples.

While there may be multiple routes into dissecting and organising and understanding the arguments of OOO, the themes of change and emergence capture the field's most fundamental premises: the object's withdrawal and existence independent of any knowing subject, and its ability to relate, affect and cause change. Distilling the OOO literature down to these fundamental themes offers a potential entry point for engaging these complex debates in a variety of research settings. This is not intended to diminish the differences between the various authors' nuanced standpoints, but rather to offer a springboard from which these can be investigated.

Secondly, turning to the perspective of cartographic theory and research, by focusing on these themes of emergence and change, an object-oriented framework suggests an approach to conceptualising maps that questions both the ways in which maps act and their emergence as specific units. As a critique of undermining, it investigates how the map emerges as more than a collection of smaller elements – be they visual (symbols, lines, colours) or infrastructural (satellites, screens, sensors). As a critique of overmining, it examines the power of maps – e.g. their ability to translate, mediate, visualise, make compossible, do multiples – beyond their function as tools of communication or regimes of power. Understood in this way, an object-oriented cartography allows for an investigation of both of these dimensions of maps, as well as the relationships between these: how is a map's emergence as distinct object related to its capacity for change? How is its ability to affect related to its emergence as an autonomous object?

The relationship between the two sides or dimensions of objects played out differently across the two cases. Yet, for both it showed itself through a concern with the interplay between the one or the unit on the one hand and the many or the multiple on the other. In this interplay, the one or the unit refers to the nature of objects as distinct entities, while the many and the multiple refer to their inexhaustibility in terms of what they are and what they do. This commonality was not anticipated before doing the two case study discussions, but rather an observation afterwards, and will serve as the starting point for reflecting on the similarities and differences between the two cases in this conclusion.

On the one hand, the case of the MotionMap hinged on the movement between the map as being alternately more-than-one and less-than-many, enabled by the concept of the prototype. The object-oriented approach built on this by bringing to the fore the present of the map as a rift or tension between its history and its future: its presentation as the result of past decisions and the promise and possibility of what it could deliver in the future. This tension manifested itself in the analysis through an alternating rhythm of slowing down and speeding up, of the map as being present-at-hand and ready-to-hand.

During moments of speeding up, different ideas about the MotionMap's role and meaning proliferated. The strategic ambivalence afforded by the map's temporality of suspension allowed the simultaneous answering by different stakeholders of the questions of what you can actually do with big data. The map's capacity to change and affect, to speed up and propel the project forward, was understood in terms of its ability, as a map, to mobilise and allude to a future in which it would transition to a fully functional application, even when the meaning of the term functional was not well defined or agreed upon. Here, framing the map as object in relation to change allows us to think about how it makes visible and compossible a multitude of – sometimes contradictory – visions of the smart city and the use of big data: the smart city as computational problem, the promise of data to hold authorities to account, new models of collaborating between stakeholders in the organisation of transport service.

In response to these moments of speeding up and proliferating, on many occasions the map refused to be put to use as hoped by the project, slowing the project down through failures and obstacles. This announcing itself – in Harman's vocabulary – describes the emergence of the map as specific object amidst many others. In doing so, therefore, this emergence of the MotionMap as an autonomous object simultaneously draws attention to these many other things that are found in the smart city: GPS satellites, cameras and motion sensors, cars, bikes, buses, pedestrians, cell phones, batteries, transport user groups, start-ups, academic research projects, datastores, parking lots, roundabouts and so on.

This latter point resonates with Gerlach's (2017, p. 96) argument on the importance of a 'non-representational take on performance and cartography' because of its ability to shine a light on the role of the non-human:

> Mapping as performance cannot be figured without a consideration of the implication and potential agency of non-human actors. Ancient or contemporary, mapping as a performance has of course always relied upon the nonhuman; material and instrumental; paper, protractors, satellites and GPS devices to name but a few of such things. Whilst it seems immediately unremarkable to focus on the non-human, what matters is how the non-human intervenes in cartography and thereby how mapping performs. Strangely enough, we are already probably all too aware of how the non-human intervenes, given the role of the map itself; a non-human artefact or performance that has material and immaterial consequences!

Thus, for Gerlach, the map's performativity depends on these other – non-human – objects, the emphasis on which is shared by OOO. However, from an object-oriented perspective, the performative focus on the unfolding of mapping encounters and map spaces can be criticised as examples of overmining: it does not account for the nature of the map outside of these situations. While mapping as performance cannot be figured out without these other non-human actors, as the case of the MotionMap demonstrated, sometimes it can be the moments of nonperformance, of failure, of slowing down, that are most illuminating in understanding these non-human actors and their relationships.

In an opposite direction to that of the MotionMap, the Whereabouts London case study described how the map established itself as a unit through its encounter with and operation on the multiplicities of other objects. Through reference to the concept of the little analytic, these moments of encounter and operations were also understood in terms of perception. Approaching Whereabouts London from an object-oriented perspective revolved around the distinction between how an object – a unit, a machine – appears and what it looks like, and how it operates – i.e. its way of perceiving, relating to, and affecting other objects. The concept of unit operations aimed to explain how a unit configures itself by way of its operations. In other words, Whereabouts London emerged as a distinct unit through its operations – its capacity for change – which was described in terms of its three distinct steps of ingestion, clustering and visualising. The precise nature of these steps further resonated with and served to reinforce a number of 'system operations' of the smart city: a big data epistemology of n=all; a method of inductive reasoning in which what is of relevance is discovered from within the data itself; and a visual culture which values the rhetorical power of data visualisations.

While the two cases have revolved around the same premise of a distinction in the being of objects and the way they appear and relate to other objects, they each did so from opposite directions. For MotionMap, the analysis of its capacity for change arose from the way in which it announced itself as a singular object. In contrast, Whereabouts London emerged as a unit as a result of its unit operations, the way it relates and enables relations. This does not mean that either of the dimensions – the object's autonomy or its capacity for change – is more important or comes first for either of the maps, but rather that an object-oriented cartography can approach maps in a variety of ways.

The two case studies thus exemplify two different approaches of thinking maps as objects. This methodology of exemplification has been particularly helpful in the context of an explorative study, where there are no established methods and no clear sense of what to expect from the results. As examples, the two cases developed different ways of thinking maps as objects, not so much to serve as a model to be replicated in further case studies, but rather to offer starting points and suggestions for how OOO could be applied to cartography. By unpicking the movements between unity and multiplicity, autonomy and relation, emergence and change, the case studies do not provide a manual, but open up the imagination to new ways of understanding the map. While not giving a step-by-step guide, by focusing on these themes the thesis has hoped to do justice to the detail of the two cases and to provide a framework for making sense of it – a sense of 'what to do with it all' (see Massumi, 2002, p. 19).

Thus, an object-oriented approach to cartography is interested in the different roles and functions maps may play in the representation and production of space. None of these functions or operations can be reduced to overmining understandings that see maps as social, cultural or ideological expressions, as the result of particular situations or encounters, or as instruments of communication. Nor can the maps be dissolved into a series of component parts. By emphasising the emergence of objects as distinct entities, the case studies helped develop an analysis and awareness of the wide variety of things within the smart city. In the face of numerous forces of change, objects are also able to resist and remain the same. While the smart city is a space of movement and relationships, it is also littered with objects that work with and against each other, that may be moved or stay in place, that may succeed or fail. An object-oriented perspective emphasises the disjunction in the relationships between objects, reminding us that 'no matter how fluidly a system may operate, its members nevertheless remain utterly isolated, mutual aliens' (Bogost, 2012, p. 40).

By insisting on the independent nature of maps as distinct entities in their own right, an object-oriented approach develops an understanding of emergence and change in the places these maps represent and produce – in this case the smart city. Thus, the smart city is made up of a wide variety of objects that do a wide variety of things. As objects, maps facilitate the proliferation and making compossible of many different visions of how big data can be used. They enable collaboration between the various corporate, governmental and academic stakeholders. They speed up and spread into different directions, producing a variety of futures. They slow down and cause obstacles and failures. Meanwhile, as these maps do their things, as little analytics ingest, cluster and visualise, they configure themselves as independent objects, part of the smart city but always maintaining their own identity.

At the same time, the smart city itself is more than the accumulation of these different objects, as – from an object-oriented perspective – it is also an object in its own right. It provides an environment, a milieu as Bryant would describe it, in which particular types of objects are particularly prominent, many of which have been featured in the literature review of Chapter 1: prototypes and analytics, but also others such as dashboards, platforms, apps and infrastructures. It is in the interaction between the milieu, environment or system with their objects, machines or units that certain powers are manifested and not others, that maps can be put to certain ends and not others. The result is a smart city in which the logics of urban laboratories, experiments and prototypes thrive, and little analytics become so important as both analytic and aesthetic tools.

These logics can of course only offer a partial account of the smart city, as under the principles of OOO it will always – as an object itself – remain inexhaustible. The two case studies thus help explore change and emergence *within* the smart city, but not necessarily *of* it – i.e. the smart city's own ability to act as an autonomous object – which would be another story in itself. Nevertheless, a glimpse of this story takes shape via the object-oriented cartography as described here. The smart city is more than just a product of neoliberal and technocratic ideologies, directed by an elite of international technology firms and research institutes. It is also more than the assemblage of big data and smart technologies within urban space.

The concept of the smart city has been quite a successful one. It has travelled across the world, taken up – be it as a utopian promise or a dystopian nightmare, or anywhere in between – by numerous technology firms, governmental and nongovernmental organisations, interdisciplinary academic researchers and grassroots community organisers. Amidst this proliferation, the meaning of the term smart city has remained multiple and ambiguous. In the past, writing about smart urbanism has been described as falling into one of two broad strands: triumphalist or sceptical (see Tironi & Sánchez Criado, 2015). However, over more recent years this has changed as there have been large numbers of empirical case studies across a wide range of academic disciplines. Likewise, the case studies presented here fit neither of these two strands. Describing how smart city projects work in practice complicates the triumphalist accounts in which technology can smoothly fit in or be imposed on existing spaces, offering solutions to everything from waste management and traffic congestion to climate change and social-economic inequalities. It also unsettles those critical accounts that envision dystopian, pervasive, invasive, fully automated, technocratically governed cities.

As discussed in the introduction, thinking about maps in the contexts of smart urbanism, big data, data analytics, digital data visualisations and digital culture more generally, poses the question of the extent to which new ways of producing and using maps require new ways of conceptualising. To be sure, OOO has not been developed with specific reference to the digital. Yet arguably, the insistence on the affective capacity of the map as object becomes even more pertinent with the abundance of digital maps and data visualisations. The ability to incorporate increasingly large data sets and draw together ever more disparate elements; the progressively near real-time capacity to respond to empirical fluctuations; the proliferation of devices and the diverse forms of interaction they afford; all of these pose questions to our understanding of the relationships between the map and its environment, its media and appearance, its users and producers.

Object-oriented cartography: next steps?

This conclusion ends with a number of thoughts and reflections on further research directions of or with an object-oriented cartography. These include themes that have sometimes come up briefly in the course of the thesis but have not yet been developed fully. In putting forward their proposals for an ontogenetic view of maps, Kitchin and Dodge describe how a reviewer criticised these as intended to 'demonstrate clever word play or to partake in aimless philosophizing' (2007, p. 335). In response, they argued that the change in conceptual framework for understanding maps has significant practical implications. So too for the shift towards an object-oriented cartography: formulating maps as objects has profound implications for studying maps and understanding their role in relation to their places, users, producers and other objects.

From a cartographic theory perspective, as developed in this Conclusion, one of the key contributions of an object-oriented approach OOO is the way in which it is able to challenge previous paradigms such as critical, non-representational and performative cartography. In particular, for the two case studies, this challenge revolved around the themes of change and emergence, resulting from OOO's critique of over, under and duomining. Elaborating on these themes, an object-oriented focus could help cartography find new ways of analysing how maps change, affect and encounter other objects – how maps do different things besides representing and making visible. At the same time, it provokes ways of thinking about the nature of maps, what they consist of and how they can be defined. Importantly, it entails reflection on the relationship between these two dimensions: how the specific nature of maps affords certain capacities to affect and how these capacities may in turn affect the nature of maps.

Crucially, as set out in the Introduction, the purpose of this thesis has not been to advocate for an exclusively object-oriented cartography, for a new paradigm to replace other approaches, but to explore its potential for informing both cartographic research and practice. Thus, by exploring these areas of challenge in cartographic theory, the aim should not be to formulate a nuanced framework based purely on OOO, but rather to enable what Rossetto (2019, p. 139) has described as 'theoretical hybridisations.' Surely, to take advantage of the insights of OOO does not necessarily require a wholesale subscription to its metaphysical and ontological arguments. Rather, specific elements may be selected to enrich map studies, reflecting on the extent to which the philosophical differences actually generate and necessitate different ways of looking at maps, how they may produce different kinds of questions and emphasise different issues.

Such hybridisations don't need to focus exclusively on specifically cartographic theory but can be extended to look at many different types of objects. As explored in Chapter 2, the increasing diversity of formats maps take and roles they play – in particular in digital contexts such as the smart city – has been mirrored by a growing diversity in theories that consider maps as spatial media, GIS, and assemblages. While this thesis has explored the relationship between OOO and cartographic theory, further research should expand on this by considering these additional debates. Indeed, both MotionMap and Whereabouts London could be explored further by considering these not only as cases of maps, but also as geospatial technologies, spatial media, and apps. In this context, there may be many other types of objects that have been studied in the social science literature of digital culture that can be brought into the conversation, such as the prototype and little analytics, but also interfaces, platforms, infrastructures, algorithms, dashboards, devices and so on.

In addition, further research into object-oriented cartography will be of relevance not only to studying and making maps, but also to OOO itself. It provides an opportunity to scrutinise and explore OOO's philosophical principles and methodological relevance. As described in Chapter 2, OOO has been formulated as a critique against a whole range of philosophical and social theoretical positions – not least those that have informed the foundations of previous schools of cartographic theory. Indeed, if anything characterises authors such as Harman, Bogost and Morton it is probably their polemical stance against established modes of thought. OOO's commitments to ontology, being, the autonomy of objects and anti-correlationism have been put forward in contrast to orientations that privilege epistemology, social construction, communication, representation, becoming or relations. Cartography is a fertile ground for exploring these critiques and polemics, as it enables an examination of these points of difference.

Pursuing an object-oriented cartography in this way requires further and more detailed examination of OOO's arguments and nuances, as well as points of difference with associated schools of thought. This involves delving further into the OOO texts and scrutinising some of the concepts which have not been developed in this thesis. For instance, it could be explored how Harman's (2012a) framework of vicarious causation and the different types of relations between objects – containment, contiguity, sincerity, connection, and no relation at all – could be applied to studying maps. Additionally, it would be worth thinking about how debates, some of which have been mentioned in passing but have been outside the scope of this thesis, between different OOO thinkers as well as those in related philosophical orientations such as speculative realism and new materialism, could be illuminated through the study of maps.

While the emphasis so far has mainly been on how the insights of OOO can inform the study of maps, further research could also focus on how it may contribute to making them. Crampton and Krygier (2005) have described how critical cartography as a school of thought should be understood in a historic context of an ongoing struggle of on the one hand cartographers, making maps and trying to establish map making as an academic discipline, and on the other hand geographers and philosophers arguing for the impossibility of thinking maps without conceptual, theoretical and philosophical grounding. While Harley (1989, p. 1) famously argued that we should not trust map makers to tell us what maps are supposed to be, an object-oriented perspective could instead seek to bridge the gap between the making of and philosophising about maps.

For example, as mentioned briefly in Chapter 4 on MotionMap, central to Bogost's alien phenomenology project is the concept of carpentry, with its focus on 'constructing artefacts that do philosophy' (2012, p. 85). The idea of an alien phenomenology of maps has been explored in Rossetto's work on object-oriented cartography, with the aim to 'grasp maps "in person"' (2019, p. 35). However, making maps '*with philosophy in mind'* (2012, p. 100 emphasis in original) can be put to use towards developing not only phenomenologies of maps but also of the places they represent. For Bogost, doing philosophy can consist of doing and making things just as much as thinking and writing. Following this idea, cartography – that is, the making of maps – can itself constitute a form of philosophy. It suggests a carpentry with maps: the making of maps 'that explain how [maps] make their world' (paraphrasing Bogost, 2012, p. 93)

Another approach to thinking about the relationship between doing and thinking is suggested by Bennett. For critical cartography, intervention might involve countermapping, representing the previously unrepresented. Performative cartographies may include artistic experimentations with maps. In contrast, for Bennett, the point about paying attention to the force of things is the hope that it 'will enhance receptivity to the impersonal life that surrounds and infuses us, will generate a more subtle awareness of the complicated web of dissonant connections between bodies, and will enable wiser interventions into that ecology' (Bennett, 2010, p. 4). Studying maps as objects thus understood serves not to isolate and extract them from their environment, but to more adequately understand their relationships to other objects and appreciate the complexity of these environments. An object-oriented cartography could open up the question of how maps can add to this vibrancy and complexity and how they can support interventions that 'help us feel more of the liveliness' (Bennett, 2012, p. 232) of our shared environments.

Finally, the question – *can object-oriented ontology be used to inform cartographic theory and research*? – emphasises the more general promise of socio-theoretical thinking for invigorating cartographic theory. As argued in Chapter 2, cartography has always developed in resonance and conversation with developments in fields such as philosophy, the social sciences and the humanities, taking ideas from critical theory, non-representational theory, literature and so on. For all the differences between the different theoretical orientations, one common thread throughout seems to be a commitment to creativity in thought and practice as well as a willingness to break with the past. Arguing to take advantage of object-oriented insights therefore is not simply to argue for OOO, but rather to argue more widely for dialogues between cartography and other disciplines. It means encouraging an open mindset, receptive for both past insights and further developments, so that our thinking of maps may continue to be challenged and refined.

References

6, P., & Bellamy, C. A. (2012). *Principles of methodology: Research design in social science*. SAGE Publications.

Abbott, A. (2004). *Methods of discovery: Heuristics for the social sciences*. W. W. Norton & Company.

About. (n.d.). MK:Smart. Retrieved November 8, 2020, from http://www.mksmart.org/about/

About catapult. (n.d.). Catapult. Retrieved November 14, 2020, from https://catapult.org.uk/about-us/about-catapult/

About MODA. (2020). NYC Analytics. Retrieved November 15, 2020, from https://www1.nyc.gov/site/analytics/about/about-office-data-analytics.page

Acuto, M. (2011). Finding the global city: An analytical journey through the 'Invisible College.' *Urban Studies*, *48*(14), 2953–2973. https://doi.org/10.1177/0042098010392081

Aesthetics. (1992). In T. McArthur (Ed.), *The Oxford companion to the English Language*. Oxford University Press.

Agamben, G. (2009). *The signature of all things: On method*. Zone Books ; Distributed by the MIT Press.

Agamben, G. (2002). *What is a paradigm? (Transcribed by Max van Manen)* [Lecture]. http://www.maxvanmanen.com/files/2014/03/Agamben-What-is-a-paradigm1.pdf

Agamben, G. (2009). *The signature of all things: On method* (L. D'Isanto & K. Attell, Trans.). Zone Books.

Aggarwal, C. C. (2014). An introduction to cluster analysis. In C. C. Aggarwal & C. K. Reddy (Eds.), *Data clustering: Algorithms and applications* (pp. 1–28). CRC Press.

Albino, V., Berardi, U., & Dangelico, R. M. (2015). Smart Cities: Definitions, Dimensions, Performance, and Initiatives. *Journal of Urban Technology*, *22*(1), 3–21. https://doi.org/10.1080/10630732.2014.942092

Alexopoulos, C., Pereira, G. V., Charalabidis, Y., & Madrid, L. (2019). A Taxonomy of Smart Cities Initiatives. *Proceedings of the 12th International Conference on Theory and Practice of Electronic Governance - ICEGOV2019*, 281–290. https://doi.org/10.1145/3326365.3326402

Amoore, L., & Piotukh, V. (2015). Life beyond big data: Governing with little analytics. *Economy and Society*, *44*(3), 341–366. https://doi.org/10.1080/03085147.2015.1043793

Amoore, L., & Piotukh, V. (2016). Introduction. In L. Amoore & V. Piotukh (Eds.), *Algorithmic life: Calculative devices in the age of big data* (pp. 1–18). Routledge.

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

Anjomshoaa, A., Duarte, F., Rennings, D., Matarazzo, T. J., deSouza, P., & Ratti, C. (2018). City Scanner: Building and scheduling a mobile sensing platform for smart city services. *IEEE Internet of Things Journal*, *5*(6), 4567–4579. https://doi.org/10.1109/JIOT.2018.2839058

Anthopoulos, L. (2017). Smart utopia VS smart reality: Learning by experience from 10 smart city cases. *Cities*, *63*, 128–148. https://doi.org/10.1016/j.cities.2016.10.005

Arup in cities (pp. 1–107). (2015). Arup. https://www.arup.com/perspectives/publications/research/section/arup-in-cities

Ash, J., Kitchin, R., & Leszczynski, A. (2018). Digital turn, digital geographies? *Progress in Human Geography*, *42*(1), 25–43.

Batty, M. (2016). Big data and the city. *Built Environment*, *42*(3), 321–337.

Batty, M., Hudson-Smith, A., Milton, R., & Crooks, A. (2010). Map mashups, Web 2.0 and the GIS revolution. *Annals of GIS, 16*(1), 1–13. https://doi.org/10.1080/19475681003700831

Beer, D. (2018). Envisioning the power of data analytics. *Information, Communication & Society*, *21*(3), 465–479.

Bélissent, J., & Giron, F. (2013). *Service providers accelerate smart city projects* (No. 82981; pp. 1–27). Forrester Research. https://www.informatiquenews.fr/wp-content/uploads/2013/12/Forrester-smart-cities.pdf

Belyea, B. (1992). Images of power: Derrida/Foucault/Harley. *Cartographica: The International Journal for Geographic Information and Geovisualization*, *29*(2), 1–9. https://doi.org/10.3138/81V4-7552-8P01-83Q1

Bennett, J. (2001). *The enchantment of modern life: Attachments, crossings, and ethics*. Princeton University Press.

Bennett, J. (2010). *Vibrant matter: A political ecology of things*. Duke University Press.

Bennett, J. (2012). Systems and Things: A Response to Graham Harman and Timothy Morton. *New Literary History*, *43*(2), 225–233.

Bergson, H. (1912). *Matter and memory*. Dover Philosophical Classics.

Bettencourt, L., & West, G. (2010). A unified theory of urban living. *Nature*, *467*(7318), 912–913. https://doi.org/10.1038/467912a

Board, C. (2017). The communication models in cartography. In *The Routledge Handbook of Mapping and Cartography* (pp. 29–43). Routledge.

Bogost, I. (2006). *Unit operations: An approach to videogame criticism*. MIT Press.

Bogost, I. (2012). *Alien phenomenology, or what it's like to be a thing*. University of Minnesota Press.

boyd, danah, & Crawford, K. (2012). Critical questions for big data: Provocations for a cultural, technological, and scholarly phenomenon. *Information, Communication & Society*, *15*(5), 662–679. https://doi.org/10.1080/1369118X.2012.678878

Brenner, N., & Schmid, C. (2014). The 'urban age' in question. *International Journal of Urban and Regional Research*, *38*(3), 731–755. https://doi.org/10.1111/1468-2427.12115

Brenner, N., & Schmid, C. (2015). Towards a new epistemology of the urban? *City*, *19*(2–3), 151–182. https://doi.org/10.1080/13604813.2015.1014712

Bryant, L. R. (2011). *The democracy of objects* (1. ed). Open Humanities Press.

Bryant, L. R. (2014). *Onto-cartography: An ontology of machines and media*. Edinburgh University Press.

Bryant, L. R., Srnicek, N., & Harman, G. (Eds.). (2011). *The speculative turn: Continental materialism and realism*. re.press.

Bryman, A. (2012). *Social Research Methods* (4th ed.). Oxford University Press.

Bulkeley, H., & Castán Broto, V. (2013). Government by experiment? Global cities and the governing of climate change. *Transactions of the Institute of British Geographers*, *38*(3), 361–375. https://doi.org/10.1111/j.1475-5661.2012.00535.x

Burrows, R., & Gane, N. (2006). Geodemographics, software and class. *Sociology*, *40*(5), 793–812. https://doi.org/10.1177/0038038506067507

Byrne, D., & Pickard, A. J. (2016). Neogeography and the democratization of GIS: A metasynthesis of qualitative research. *Information, Communication & Society*, *19*(11), 1505–1522. https://doi.org/10.1080/1369118X.2015.1125936

Caird, S. (2017). City approaches to smart city evaluation and reporting: Case studies in the United Kingdom. *Urban Research & Practice*, 1–21.

Campkin, B., Mogilevich, M., & Ross, R. (2016). Picturing place: The agency of images in urban change. In B. Campkin & G. Duijzings (Eds.), *Engaged urbanism: Cities and methodologies* (pp. 147–154). I.B. Tauris.

Caragliu, A., Del Bo, C., & Nijkamp, P. (2011). Smart cities in Europe. *Journal of Urban Technology*, *18*(2), 65–82. https://doi.org/10.1080/10630732.2011.601117

Cardullo, P., & Kitchin, R. (2019a). Smart urbanism and smart citizenship: The neoliberal logic of ‘citizen-focused’ smart cities in Europe. *EPC: Politics and Space*, *37*(5), 813–830.

Cardullo, P., & Kitchin, R. (2019b). Being a ‘citizen’ in the smart city: Up and down the scaffold of smart citizen participation in Dublin, Ireland. *GeoJournal*, *84*(1), 1–13. https://doi.org/10.1007/s10708-018-9845-8

Catalyst Fund. (2014, February 26). [The National Archives]. Higher Education Funding Council for England.

https://webarchive.nationalarchives.gov.uk/20140712074356/https://www.hefce.ac.uk/whatwedo/invest/funds/catalyst/

Centre for Urban Science and Progress in London. (2015, December 1). *King's College London News Archive*. https://www.kcl.ac.uk/archive/news/nms/kings-and-warwick-partner-with-nyu-to-establish-centre-for-urban-science-and-progress-in-london

City Data Analytics Programme. (2020). London Datastore. https://data.london.gov.uk/city-data-analytics-programme/

City government and IBM close partnership to make Rio de Janeiro a smarter city. (2010). [IBM News Room]. IBM. https://newsroom.ibm.com/2010-12-27-City-Government-and-IBM-Close-Partnership-to-Make-Rio-de-Janeiro-a-Smarter-City,1

Clark, G., & Moonen, T. (2014). *Urban innovation and investment: The role of international financial institutions and development banks* (pp. 1–49). Future Cities Catapult. https://futurecities.catapult.org.uk/resource/urban-innovation-and-investment-full-report/

Clarke, K. (2014, October 24). Mapping the new London. *MapsMania*. http://googlemapsmania.blogspot.com/2014/10/mapping-new-london.html

Claudel, M., Birolo, A., & Ratti, C. (2015). Government's role in growing a smart city. In D. Araya (Ed.), *Smart cities as democratic ecologies* (pp. 23–34). Palgrave Macmillan.

Clough, P. T. (2014). The philosophical carpentry of the app: Criticism and practice. In P. D. Miller & S. Matviyenko (Eds.), *The imaginary app* (pp. 35–50). The MIT Press.

Cocchia, A. (2014). Smart and digital city: A systematic literature review. In R. P. Dameri & C. Rosenthal-Sabroux (Eds.), *Smart City* (pp. 13–43). Springer International Publishing. https://doi.org/10.1007/978-3-319-06160-3_2

Coleman, D., & Georgiadou, Y. (2009). Volunteered Geographic Information: The nature and motivation of produsers. *International Journal of Spatial Data*

Infrastructures Research, *4*, 332–358. https://doi.org/10.2902/1725-0463.2009.04.art16

Coletta, C., Heaphy, L., Perng, S.-Y., & Waller, L. (2017). Data-driven cities? Digital urbanism and its proxies: Introduction. *Tecnoscienza*, *8*(2), 5–18.

Collinge, A. (2014, October 22). LDS II: The next step to a city Data future. *London Datastore News*. https://data.london.gov.uk/blog/lds-ii-the-next-step-to-a-city-data-future-2/

Cook, M., Horne, R., Potter, S., & Valdez, A.-M. (2019). Exploring the epistemic politics of urban niche experiments. In J. Stissing Jensen, P. Späth, & M. Cashmore (Eds.), *The politics of urban sustainability transitions: Knowledge, power and governance* (pp. 125–147). Routledge.

Corsín Jiménez, A. (2013). Introduction: The prototype: more than many and less than one. *Journal of Cultural Economy*, *7*(4), 381–398. https://doi.org/10.1080/17530350.2013.858059

Corsín Jiménez, A. (2018). Prototyping. In C. Lury, R. Fensham, A. Heller-Nicholas, S. Lammes, A. Last, M. Michael, & E. Uprichard (Eds.), *Routledge handbook of interdisciplinary research methods* (pp. 122–125). Routledge.

Crampton, J. W. (2001). Maps as social constructions: Power, communication and visualization. *Progress in Human Geography*, *25*(2), 235–252.

Crampton, J. W. (2009). Cartography: Maps 2.0. *Progress in Human Geography*, *33*(1), 91–100. https://doi.org/10.1177/0309132508094074

Crampton, J. W. (2010). *Mapping: A critical introduction to cartography and GIS*. Wiley-Blackwell.

Crampton, J. W. (2017). Digital mapping. In R. Kitchin, T. P. Lauriault, & M. W. Wilson (Eds.), *Understanding spatial media* (pp. 35–43). SAGE Publications.

Crampton, J. W., Graham, M., Poorthuis, A., Shelton, T., Stephens, M., Wilson, M. W., & Zook, M. (2013). Beyond the geotag: Situating ‘big data’ and leveraging the potential of the geoweb. *Cartography and Geographic Information Science*, *40*(2), 130–139. https://doi.org/10.1080/15230406.2013.777137

Crampton, J. W., & Krygier, J. (2005). An introduction to critical cartography. *ACME: An International Journal for Critical Geographies*, *4*(1), 11–33.

Crampton, J. W., & Wilson, M. W. (2015). Harley and Friday Harbor: A conversation with John Pickles. *Cartographica: The International Journal for Geographic Information and Geovisualization*, *50*(1), 28–36. https://doi.org/10.3138/carto.50.1.06

Creating the smart cities of the future: A three-tier development model for digital transformation of citizen services (pp. 1–15). (2019). PwC. https://www.pwc.com/gx/en/sustainability/assets/creating-the-smart-cities-of-the-future.pdf

d'Aquin, M., Davies, J., & Motta, E. (2015). Smart cities' data: Challenges and opportunities for semantic technologies. *IEEE Internet Computing*, *19*(6), 66–70. https://doi.org/10.1109/MIC.2015.130

Daga, E., d'Aquin, M., Adamou, A., & Motta, E. (2016). *Addressing exploitability of Smart City data*. 1–6. https://doi.org/10.1109/ISC2.2016.7580764

Data. (n.d.). MK:Smart. Retrieved November 8, 2020, from http://www.mksmart.org/data/

Data are transforming how cities operate. (2014, November 2). *The Economist*. https://www.businessinsider.com/data-is-slowly-changing-the-way-cities-operate-2014-10?r=US&IR=T

DataPress. (2015, May 19). Whereabouts London, by Future Cities Catapult. *London Datastore News*. https://data.london.gov.uk/blog/whereabouts-london-by-future-cities-catapult/

de Melo, A. T. (2018). Exemplifying. In C. Lury, R. Fensham, A. Heller-Nicholas, S. Lammes, A. Last, M. Michael, & E. Uprichard (Eds.), *Routledge handbook of interdisciplinary research methods* (pp. 90–94). Routledge.

Deakin, M., & Al Waer, H. (2011). From intelligent to smart cities. *Intelligent Buildings International*, *3*(3), 133–139. https://doi.org/10.1080/17508975.2011.586673

Del Casino, V. J., & Hannah, S. P. (2006). Beyond the 'binaries': A methodological intervention for interrogating maps as representational practices. *ACME: An International Journal for Critical Geographies*, *4*(1), 34–56.

Dodge, Martin, Kitchin, R., & Perkins, C. (2011). *The map reader: Theories of mapping practice and cartographic representation.* Wiley-Blackwell.

Dodge, Martin, McDerby, M., & Turner, M. (Eds.). (2008). *Geographic visualization: Concepts, tools and applications*. Wiley.

Dodge, M., & Kitchin, R. (2000). Exposing the "second text" of maps on the net. *Journal of Computer-Mediated Communication*, *5*(4).

Dolphijn, R., & Van der Tuin, I. (2012). *New materialism: Interviews & cartographies*. Open Humanities Press.

Edney, M. H. (2015). Cartography and its discontents. *Cartographica: The International Journal for Geographic Information and Geovisualization*, *50*(1), 9–13. https://doi.org/10.3138/carto.50.1.02

Evans, L., & Saker, M. (2019). *Location-based social media: Space, time and identity.* Palgrave.

Ferreira, N., Poco, J., Vo, H. T., Freire, J., & Silva, C. T. (2013). Visual exploration of big spatio-temporal urban data: A study of New York City taxi trips. *IEEE Transactions on Visualization and Computer Graphics*, *19*(12), 2149–2158.

Flyvbjerg, B. (2006). Five Misunderstandings About Case-Study Research. *Qualitative Inquiry*, *12*(2), 219–245. https://doi.org/10.1177/1077800405284363

Frequently asked questions. (n.d.-a). Future Cities Catapult. Retrieved November 14, 2020, from https://futurecities.catapult.org.uk/faqs/

Frequently asked questions. (n.d.-b). Office of National Statistics. Retrieved November 14, 2020, from https://www.ons.gov.uk/census/2011census/2011censusdata/2011censususerguide/frequentlyaskedquestions

Galloway, A. R. (2013). The poverty of philosophy: Realism and Post-Fordism. *Critical Inquiry*, *39*(2), 347–366. https://doi.org/10.1086/668529

Gambs, D. (2013). Experimental Research Methods After Critique: On the Example, Affirmative Methods, and Making Connections. *Cultural Studies ↔ Critical Methodologies*, *13*(5), 383–389. https://doi.org/10.1177/1532708613495803

Gardner, Z. (2014, December 19). The Year of Open Data. *London Datastore News*. https://data.london.gov.uk/blog/the-year-of-open-data/

Gerlach, J. (2017). Mapping as performance. In A. J. Kent & P. Vujakovic (Eds.), *The Routledge Handbook of Mapping and Cartography* (pp. 90–100). Routledge.

Gibson, D. V., Kozmetsky, G., & Smilor, R. W. (Eds.). (1992). *The Technopolis phenomenon: Smart cities, fast systems, global networks*. Rowman & Littlefield Publishers.

Gieryn, T. F. (2006). City as truth-spot: Laboratories and field-sites in urban studies. *Social Studies of Science*, *36*(1), 5–38.

Giffinger, R., Fertner, C., Kramar, H., Kalasek, R., Pichler-Milanović, N., & Meijers, E. (2007). *Smart cities: Ranking of European medium-sized cities* (pp. 1–25). Centre of Regional Science, Vienna University of Technology.

Glasmeier, A., & Christopherson, S. (2015). Thinking about smart cities. *Cambridge Journal of Regions, Economy and Society*, *8*(1), 3–12. https://doi.org/10.1093/cjres/rsu034

Gleeson, B. (2013). What role for social science in the 'urban age'?: Debates and developments. *International Journal of Urban and Regional Research*, *37*(5), 1839–1851. https://doi.org/10.1111/1468-2427.12058

Goodchild, M. F. (2007). Citizens as sensors: The world of volunteered geography. *GeoJournal*, *69*(4), 211–221. https://doi.org/10.1007/s10708-007-9111-y

Graham, M. (2017). Digitally augmented geographies. In R. Kitchin, T. P. Lauriault, & M. W. Wilson (Eds.), *Understanding spatial media* (pp. 44–55). SAGE Publications.

Graham, S., & Marvin, S. (2001). *Splintering urbanism: Networked infrastructures, technological mobilities and the urban condition*. Routledge.

Gratton, P. (2014). *Speculative realism: Problems and prospects [E-reader version]*. Bloomsbury Academic. Central, http://ebookcentral.proquest.com/lib/warw/detail.action?docID=1685640

Griffiths, H. (2019). *Smart city demonstrators: A global review of challenges and lessons learned* (pp. 1–110). Future Cities Catapult. https://futurecities.catapult.org.uk/wp-content/uploads/2018/03/Hyperconnected_smart-city-demonstrators_v3.pdf

Gruen, A. (2013). SMART Cities: The need for spatial intelligence. *Geo-Spatial Information Science*, *16*(1), 3–6. https://doi.org/10.1080/10095020.2013.772802

Haas, P. M. (1992). Introduction: Epistemic communities and international policy coordination. *International Organization*, *46*(1), 1–35.

Haas, P. M. (2001). Policy knowledge: Epistemic communities. In N. J. Smelser & B. Baltes (Eds.), *International Encyclopedia of the Social and Behavioral Sciences* (Vol. 17, pp. 11587–11586).

Haklay, M. (2013). Neogeography and the delusion of democratisation. *Environment and Planning A: Economy and Space*, *45*(1), 55–69. https://doi.org/10.1068/a45184

Halpern, O., LeCavalier, J., Calvillo, N., & Pietsch, W. (2013). Test-Bed Urbanism. *Public Culture*, *25*(2), 272–306. https://doi.org/10.1215/08992363-2020602

Halpern, O. (2014). *Beautiful data: A history of vision and reason since 1945*. Duke University Press.

Halpern, O, & Günel, G. (2017). FCJ-215 Demoing unto Death: Smart Cities, Environment, and Preemptive Hope. *The Fibreculture Journal*, *29*, 1–23. https://doi.org/10.15307/fcj.29.215.2017

Halpern, O, LeCavalier, J., Calvillo, N., & Pietsch, W. (2013). Test-bed urbanism. *Public Culture*, *25*(2 70), 272–306. https://doi.org/10.1215/08992363-2020602

Hammersley, M. (2011). *Methodology: Who needs it?* SAGE Publications.

Harding, S. G. (1987). Introduction: Is there a feminist method? In S. G. Harding (Ed.), *Feminism and methodology: Social science issues* (pp. 1–14). Indiana University Press.

Harley, J. B. (1988a). Maps, knowledge and power. In D. E. Cosgrove & S. Daniels (Eds.), *The iconography of landscape: Essays on the symbolic representation, design and use of past environments* (10. print, pp. 277–312). Cambridge University Press.

Harley, J. B. (1988b). Silences and secrecy: The hidden agenda of cartography in early modern Europe. *Imago Mundi*, *40*, 57–76.

Harley, J. B. (1989). Deconstructing the map. *Cartographica*, *26*(2), 1–20.

Harman, G. (2002). *Tool-being: Heidegger and the metaphyics of objects*. Open Court.

Harman, G. (2005). *Guerrilla metaphysics: Phenomenology and the carpentry of things*. Open Court.

Harman, G. (2010). Technology, objects and things in Heidegger. *Cambridge Journal of Economics*, *34*(1), 17–25. https://doi.org/10.1093/cje/bep021

Harman, G. (2011a). On the undermining of objects: Grant, Bruno, and radical philosophy. In L. Bryant, N. Srnicek, & G. Harman (Eds.), *The speculative turn: Continental materialism and realism* (pp. 21–40). re.press.

Harman, G. (2011b). The road to objects. *Continent*, *3*(1), 171–179.

Harman, G. (2011c, January 24). The case for objects. *Object-Oriented Philosophy*. https://doctorzamalek2.wordpress.com/2011/01/24/the-case-for-objects/

Harman, G. (2012a). On vicarious causation. In R. Mackay (Ed.), *Collapse: Philosophical research and development* (Reissued edition, Vol. 2, pp. 187–221). Urbanomic.

Harman, G. (2012b). The Well-Wrought Broken Hammer: Object-Oriented Literary Criticism. *New Literary History*, *43*(2), 183–203.

Harman, G. (2013). Undermining, overmining, and duomining: A critique. In J. Sutela (Ed.), *Add Metaphysics* (pp. 40–51). Aalto University Digital Design Laboratory.

Harman, G. (2018). *Object-oriented ontology: A new theory of everything*. Pelican Books.

Harris, R., Sleight, P., & Webber, R. (2005). *Geodemographics, GIS and neighbourhood targeting*. Wiley.

Højer, L., & Bandak, A. (2015). Introduction: The power of example. *Journal of the Royal Anthropological Institute*, *21*(S1), 1–17. https://doi.org/10.1111/1467-9655.12173

Hollands, R. G. (2008). Will the real smart city please stand up? Intelligent, progressive or entrepreneurial? *City*, *12*(3), 303–320. https://doi.org/10.1080/13604810802479126

Hollands, R. G. (2015a). Critical interventions into the corporate smart city. *Cambridge Journal of Regions, Economy and Society*, *8*(1), 61–77. https://doi.org/10.1093/cjres/rsu011

Hollands, R. G. (2015b). Critical interventions into the corporate smart city. *Cambridge Journal of Regions, Economy and Society*, *8*(1), 61–77. https://doi.org/10.1093/cjres/rsu011

Howell, K. (2013). *An introduction to the philosophy of methodology*. SAGE Publications Ltd. https://doi.org/10.4135/9781473957633

Hudson, L., Kortuem, G., Wolff, A., & Law, P. (2016). Smart Cities MOOC: Teaching citizens how to co-create smart cities. *4th International Conference on ICT for Sustainability (ICT4S)*. 4th International Conference on ICT for Sustainability (ICT4S), Amsterdam, The Netherlands. http://oro.open.ac.uk/46951/

Hudson-Smith, A., Crooks, A., Gibin, M., Milton, R., & Batty, M. (2009). NeoGeography and Web 2.0: Concepts, tools and applications. *Journal of Location Based Services*, *3*(2), 118–145. https://doi.org/10.1080/17489720902950366

Hügel, S. (2017). From the garden city to the smart city. *Urban Planning*, *2*(3), 1–4. https://doi.org/10.17645/up.v2i3.1072

Introducing the ERC-funded Programmable City project. (n.d.). *The Programmable City*. Retrieved October 27, 2020, from https://progcity.maynoothuniversity.ie/about/

Jain, A. (2010). Data clustering: 50 years beyond K-means. *Pattern Recognition Letters*, *31*, 651–666.

Joining. (n.d.). In *GIS Dictionary*. ESRI. Retrieved September 5, 2020, from https://support.esri.com/en/other-resources/gis-dictionary/search/

Kar, A. K., Ilavarasan, V., Gupta, M. P., Janssen, M., & Kothari, R. (2019). Moving beyond smart cities: Digital nations for social innovation & sustainability. *Information Systems Frontiers*, *21*(3), 495–501. https://doi.org/10.1007/s10796-019-09930-0

Karvonen, A., & van Heur, B. (2014). Urban laboratories: Experiments in reworking cities. *International Journal of Urban and Regional Research*, *38*(2), 379–392. https://doi.org/10.1111/1468-2427.12075

Kimbell, L. (2013). The object strikes back: An interview with Graham Harman. *Design and Culture*, *5*(1), 103–117. https://doi.org/10.2752/175470813X13491105785703

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

Kitchin, R. (2015). Making sense of smart cities: Addressing present shortcomings. *Cambridge Journal of Regions, Economy and Society*, *8*(1), 131–136. https://doi.org/10.1093/cjres/rsu027

Kitchin, R. (2016). Thinking critically about and researching algorithms. *Information, Communication & Society, 20*(1), 14-29.

Kitchin, R. (2017). *Urban science: A short Primer* (Working Paper No. 23; The Programmable City, pp. 1–13). National University of Ireland Maynooth.

Kitchin, R., Coletta, C., Evans, L., Heaphy, L., & MacDonncha, D. (2017). Smart cities, epistemic communities, advocacy coalitions and the 'last mile' problem. *Information Technology, 59*(6), 275-284.

Kitchin, R., & Dodge, M. (2007). Rethinking maps. *Progress in Human Geography*, *31*(3), 331–344.

Kitchin, R., Gleeson, J., & Dodge, M. (2012). Unfolding mapping practices: A new epistemology for cartography. *Transactions of the Institute of British Geographers*, *38*(3), 480–496.

Kitchin, R., Lauriault, T. P., & McArdle, G. (2015). Knowing and governing cities through urban indicators, city benchmarking and real-time dashboards.

Regional Studies, Regional Science, *2*(1), 6–28. https://doi.org/10.1080/21681376.2014.983149

Kitchin, R., Lauriault, T. P., & Wilson, M. W. (Eds.). (2017a). *Understanding spatial media* (1st edition). SAGE Inc.

Kitchin, R., Lauriault, T. P., & Wilson, M. W. (2017b). Understanding spatial media. In R. Kitchin, T. P. Lauriault, & M. W. Wilson (Eds.), *Understanding spatial media* (pp. 1–21). SAGE Publications.

Kontokosta, C. E., Johnson, N., & Schloss, A. (2016). *The quantified community at Red Hook: Urban sensing and citizen science in low-income neighborhoods*. 1–8.

Koonin, S.E. (2013). *The promise of urban informatics* (pp. 1–19). CUSP.

Koonin, S. E. (2013). *The Center for Urban Science + Progress: The promise of urban informatics* (pp. 1–19). The Center for Urban Science and Progress.

Koonin, S. E., & Holland, M. J. (2014). The value of big data for urban science. In J. Lane, V. Stodden, S. Bender, & H. Nissenbaum (Eds.), *Privacy, Big Data, and the Public Good: Frameworks for Engagement* (pp. 137–152). Cambridge University Press. https://doi.org/10.1017/CBO9781107590205

Lammes, S. (2017). Digital mapping interfaces: From immutable mobiles to mutable images. *New Media & Society*, *19*(7), 1019–1033.

Latimer, J., & Munro, R. (2018). Generalizing. In C. Lury, R. Fensham, A. Heller-Nicholas, S. Lammes, A. Last, M. Michael, & E. Uprichard (Eds.), *Routledge handbook of interdisciplinary research methods* (pp. 306–310). Routledge.

Latour, B. (2004). Why has critique run out of steam? From matters of fact to matters of concern. *Critical Inquiry*, *30*(2), 225–248.

Laurent, B., & Pontille, D. (2019). Towards a study of city experiments. In C. Coletta, L. Evans, L. Heaphy, & R. Kitchin (Eds.), *Creating smart cities* (pp. 90–103). Routledge.

Law, J. (2003). *Making a mess with method*. Centre for Science Studies, Lancaster University. http://www.comp.lancs.ac.uk/sociology/papers/Law-Making-a-Mess-with-Method.pdf

Leydesdorff, L., & Deakin, M. (2011). The Triple-Helix Model of smart cities: A neo-evolutionary perspective. *Journal of Urban Technology*, *18*(2), 53–63. https://doi.org/10.1080/10630732.2011.601111

Leszczynski, A. (2012). Situating the geoweb in political economy. *Progress in Human Geography*, *36*(1), 72–89. https://doi.org/10.1177/0309132511411231

Leszczynski, A. (2014). On the neo in neogeography. *Annals of the Association of American Geographers*, *104*(1), 60–79. https://doi.org/10.1080/00045608.2013.846159

Leszczynski, A. (2015). Spatial media/tion. *Progress in Human Geography*, *39*(6), 729–751. https://doi.org/10.1177/0309132514558443

Lezaun, J., Marres, N., & Tironi, M. (2016). Experiments in participation. In U. Felt, R. Fouché, C. A. Miller, & L. Smith-Doerr (Eds.), *Handbook of Science and Technology Studies* (Vol. 4, pp. 195–222). The MIT Press.

Lowrie, M., & Lüdemann, S. (2015). Introduction. In M. Lowrie & S. Lüdemann (Eds.), *Exemplarity and singularity: Thinking through particulars in philosophy, literature and law* (pp. 1–15). Routledge.

Luque-Ayala, A., & Marvin, S. (2015). Developing a critical understanding of smart urbanism? *Urban Studies*, *52*(12), 2105–2116. https://doi.org/10.1177/0042098015577319

Mackenzie, A. (2012). More parts than elements: How databases multiply. *Environment and Planning D: Society and Space*, *30*(2), 335–350. https://doi.org/10.1068/d6710

Mackenzie, A., & McNally, R. (2013). Living multiples: How large-scale scientific data-mining pursues identity and differences. *Theory, Culture & Society*, *30*(4), 72–91.

MacKenzie, A., & Munster, A. (2019). Platform seeing: Image ensembles and their invisualities. *Theory, Culture & Society*, *36*(5), 3–22. https://doi.org/10.1177/0263276419847508

Map: The 8 types of Londoner. (2014, November 5). *CityMetric*. https://www.citymetric.com/horizons/map-8-types-londoner-446

Marres, N., Lezaun, J., & Tironi, M. (2016). Experiments in participation. In U. Felt, R. Fouché, C. Miller, & L. Smith-Doerr (Eds.), *The Science and Technology Studies Handbook* (4th ed., pp. 195–222). MIT Press.

Massumi, B. (2002). *Parables for the virtual: : Movement, affect, sensation*. Duke University Press.

Mattern, S. (2013a). Methodolatry and the art of measure. *Places Journal*, *November*. https://placesjournal.org/article/methodolatry-and-the-art-of-measure/#0

Mattern, S. (2013b, November). Methodolatry and the art of measure: The new wave of urban data science. *Places Journal*. https://placesjournal.org/article/methodolatry-and-the-art-of-measure/

Mattern, S. (2015). Mission control: A history of the urban dashboard. *Places Journal*, *March*. https://placesjournal.org/article/mission-control-a-history-of-the-urban-dashboard/

Mattern, S. (2016). Instrumental city: The view from Hudson Yards, circa 2019. *Places Journal*. https://placesjournal.org/article/instrumental-city-new-york-hudson-yards/

Mattern, S. (2017). Response to Alberto Corsín Jiménez's "Ethnography: A Prototype." *Words in Space*. http://wordsinspace.net/shannon/2017/03/07/response-to-alberto-corsin-jimenezs-ethnography-a-prototype/

McArdle, G., & Kitchin, R. (2016). The Dublin dashboard: Design and development of a real-time analytical urban dashboard. *ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences*, *IV-4/W1*, 19–25. https://doi.org/10.5194/isprs-annals-IV-4-W1-19-2016

McCosker, A., & Wilken, R. (2014). Rethinking 'big data' as visual knowledge: The sublime and the diagrammatic in data visualisation. *Visual Studies*, *29*(2), 155–164. https://doi.org/10.1080/1472586X.2014.887268

McNeill, D. (2015a). Global firms and smart technologies: IBM and the reduction of cities. *Transactions of the Institute of British Geographers*, *40*(4), 562–574. https://doi.org/10.1111/tran.12098

McNeill, D. (2015b). Global firms and smart technologies: IBM and the reduction of cities. *Transactions of the Institute of British Geographers*, *40*(4), 562–574. https://doi.org/10.1111/tran.12098

McNeill, D. (2016). IBM and the visual formation of smart cities. In S. Marvin, A. Luque-Ayala, & C. McFarlane (Eds.), *Smart urbanism: Utopian vision or false dawn?* (pp. 34–51). Routledge.

Meillassoux, Q. (2008). *After finitude: An essay on the necessity of contingency* (R. Brassier, Trans.). Continuum.

Meskin, J., & Shapiro, H. (2014). To give an example is a complex art: Agamben's pedagogy on the paradigm. *Educational Philosophy and Theory*, *46*(4), 421–440.

Microsoft CityNext: Technical reference model overview (pp. 1–53). (2013). Microsoft Corporation.

Mills, C. W. (1959). *The sociological imagination* (Fortieth Anniversary Edition). Oxford University Press.

Milton Keynes Futures 2050 Commission. (2016). *Milton Keynes: Making a great city greater* (pp. 1–72). www.mkfutures2050.com

MK:Smart (pp. 1–11). (2017). MK:Smart. http://www.mksmart.org/wp-content/uploads/2017/07/MKSmart-brochureFINAL.pdf

Moir, E., Moonen, T., & Clark, G. (2014). *What are future cities? Origins, meanings and uses* (pp. 1–99). Foresight & Future Cities Catapult. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/337549/14-820-what-are-future-cities.pdf

Mora, L., Bolici, R., & Deakin, M. (2017). The first two decades of smart-city research: A bibliometric analysis. *Journal of Urban Technology*, *24*(1), 3–27.

Moreira, J. M., de Carvalho, A. C. P. L. F., & Horváth, T. (2019). *A General Introduction to Data Analytics*. John Wiley & Sons.

Moriceau, J. L. (2010). Generalizability. In A. J. Mills, G. Durepos, & E. Wiebe (Eds.), *Encyclopedia of Case Study Research* (pp. 420–422). Sage Publications.

Morton, T. (2011). Here comes everything: The promise of object-oriented ontology. *Qui Parle: Critical Humanities and Social Sciences*, *19*(2), 163–190.

Morton, T. (2012a). An object-oriented defense of poetry. *New Literary History*, *43*(2), 205–224.

Morton, T. (2012b). *The ecological thought*. Harvard University Press.

Morton, T. (2013). *Realist magic: Objects, ontology, causality*. Open Humanities Press.

Moustaka, V., Vakali, A., & Anthopoulos, L. G. (2018). A systematic review for smart city data analytics. *ACM Computing Surveys*, *51*(5), 1–41. https://doi.org/10.1145/3239566

Nam, T., & Pardo, T. A. (2011). Conceptualizing smart city with dimensions of technology, people, and institutions. *Proceedings of the 12th Annual International Digital Government Research Conference: Digital Government Innovation in Challenging Times*, 282–291.

Niaros, V. (2016). Introducing a taxonomy of the "smart city": Towards a commons-oriented approach? *Triple C*, *14*(1), 51–61.

Nonko, E. (2019, February 5). Hudson Yards promised a high-tech neighborhood—It was a greater challenge than expected. *Metropolis*. https://www.metropolismag.com/cities/hudson-yards-technology-urbanism/

NYU CUSP Unveils First-of-its-Kind 'Urban Observatory' in Downtown Brooklyn. (2014, October 28). *The Center for Urban Science & Progress*. https://cusp.nyu.edu/press/nyu-cusp-unveils-first-kind-urban-observatory-downtown-brooklyn/

O'Reilly, T. (2005, September 30). What Is Web 2.0: Design patterns and business models for the next generation of software. *O'Reilly*. https://www.oreilly.com/pub/a/web2/archive/what-is-web-20.html

Ojo, A., Curry, E., & Zeleti, F. A. (2015). A tale of open data innovations in five smart cities. *2015 48th Hawaii International Conference on System Sciences*, 2326–2335. https://doi.org/10.1109/HICSS.2015.280

Open University. (2014, July 9). [The National Archives]. Higher Education Funding Council for England. https://webarchive.nationalarchives.gov.uk/20140712170700/http://www.hefce.ac.uk/whatwedo/invest/funds/catalyst/catalystfundprojects/ou/

Osman, A. M. S. (2018). A novel big data analytics framework for smart cities. *Future Generation Computer Systems*, *91*(2019), 620–633.

Park, R. E. (1967). The city: Suggestions for the investigation of human behavior in the urban environment. In R. E. Park, E. W. Burgess, & R. D. McKenzie (Eds.), *The city*. The University of Chicago Press.

Parker, C. J. (2014). *A Framework of Neogeography*. Springer International Publishing. https://doi.org/10.1007/978-3-319-03503-1_2

Paroutis, S., Bennett, M., & Heracleous, L. (2014). A strategic view on smart city technology: The case of IBM Smarter Cities during a recession. *Technological Forecasting and Social Change*, *89*, 262–272. https://doi.org/10.1016/j.techfore.2013.08.041

Perkins, C. (2003). Cartography: Mapping theory. *Progress in Human Geography*, *27*(3), 341–351.

Perkins, C. (2004). Cartography—Cultures of mapping: Power in practice. *Progress in Human Geography*, *28*(3), 381–391.

Perkins, C. (2018). Critical cartography. In A. Kent & P. Vujakovic (Eds.), *The Routledge handbook of mapping and cartography* (pp. 80–89). Routledge.

Pham, D. T., Dimov, S. S., & Nguyen, C. D. (2005). Selection of K in K-means clustering. *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, *219*(1), 103–119.

Pickles, J. (2011). Texts, hermeneutics and propaganda maps. In Martin Dodge, R. Kitchin, & C. Perkins (Eds.), *The Map Reader* (pp. 400–406). John Wiley & Sons, Ltd. https://doi.org/10.1002/9780470979587.ch52

Platt, J. (2007). Case study. In W. Outhwaite & S. P. Turner (Eds.), *The SAGE Handbook of Social Science Methodology* (pp. 101–120). SAGE Publications Ltd.

Polczynski, M., & Polczynski, M. (2014). Using the k -Means Clustering Algorithm to Classify Features for Choropleth Maps. *Cartographica: The International Journal for Geographic Information and Geovisualization*, *49*(1), 69–75.

Rabari, C., & Storper, M. (2015). The digital skin of cities: Urban theory and research in the age of the sensored and metered city, ubiquitous computing and big data. *Cambridge Journal of Regions, Economy and Society*, *8*(1), 27–42. https://doi.org/10.1093/cjres/rsu021

Ragin, C. C. (1992a). “Casing” and the process of social inquiry. In C. C. Ragin & H. S. Becker (Eds.), *What is a case? Exploring the foundations of social inquiry* (pp. 217–226). Cambridge University Press.

Ragin, C. C. (1992b). Introduction: Cases of “what is a case?” In C. C. Ragin & H. S. Becker (Eds.), *What is a case? Exploring the foundations of social inquiry* (pp. 1–20). Cambridge University Press.

Ragin, C. C. (2009). Reflections on casing and case-oriented research. In D. Byrne & C. C. Ragin (Eds.), *The SAGE handbook of case-based methods* (pp. 522–534). SAGE.

Reddy, C. K., & Vinzamuri, B. (2014). A survey of partitional and hierarchical clustering algorithms. In C. C. Aggarwal & C. K. Reddy (Eds.), *Data clustering: Algorithms and Applications* (pp. 87–110). CRC Press.

Redrawing London’s boundaries with data. (2014, October 23). Whereabouts London. https://futurecities.catapult.org.uk/2014/10/23/redrawing-londons-boundaries-with-data/

Ricker, B. (2017). GIS. In R. Kitchin, T. P. Lauriault, & M. W. Wilson (Eds.), *Understanding spatial media* (pp. 25–34). SAGE Publications.

Robinson, A. (1952). *The look of maps: An examination of cartographic design*. Esri Press. http://public.ebookcentral.proquest.com/choice/publicfullrecord.aspx?p=3238276

Romualdo-Suzuki, L. (2016). *Data for London: A city data strategy* (pp. 1–36). Greater London Authority. https://data.london.gov.uk/dataset/data-for-london-a-city-data-strategy

Rose, G. (2019). Look InsideTM: Corporate Visions of the Smart City. In K. Fast, A. Jansson, J. Lindell, L. Ryan Bengtsson, & M. Tesfahuney (Eds.), *Geomedia studies: Spaces and mobilities in mediatized worlds* (pp. 97–113). Routledge.

Rose-Redwood, R. (2015). Looking "beyond" power?: J.B. Harley's legacy and the powers of cartographic world-making. *Cartographica: The International Journal for Geographic Information and Geovisualization*, *50*(1), 54–57.

Rossetto, T. (2015). Semantic ruminations on 'post-representational cartography.' *International Journal of Cartography*, *1*(2), 151–167.

Rossetto, T. (2019). *Object-oriented cartography: Maps as things*. Routledge.

Rugkhapan, N. T., & Murray, M. J. (2019). Songdo IBD (International Business District): Experimental prototype for the city of tomorrow? *International Planning Studies*, *24*(3–4), 272–292. https://doi.org/10.1080/13563475.2019.1650725

Sadowski, J., & Bendor, R. (2019). Selling Smartness: Corporate Narratives and the Smart City as a Sociotechnical Imaginary. *Science, Technology, & Human Values*, *44*(3), 540–563. https://doi.org/10.1177/0162243918806061

Sarantakos, S. (2012). *Social Research* (4th ed.). Palgrave Macmillan.

Scharl, A. (2007). Towards the geospatial web: Media platforms for managing geotagged knowledge repositories. In A. Scharl & K. Tochtermann (Eds.), *The geospatial web: How geobrowsers, social software, and the Web 2.0 are shaping the network society* (pp. 3–14). Springer.

Scroxton, A. (2014, October 23). Mayor of London Boris Johnson opens London Datastore 2 for developers. *Computer Weekly*. https://www.computerweekly.com/news/2240233228/Mayor-of-London-Boris-Johnson-opens-London-Datastore-2-for-developers

Singleton, A. D., & Spielman, S. E. (2014). The past, present, and future of geodemographic research in the United States and United Kingdom. The Professional Geographer, 66(4), 558–567. https://doi.org/10.1080/00330124.2013.848764

Smart cities: Background paper (BIS/13//1209; pp. 1–47). (2013). Department for Business Innovation & Skills.

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/246019/bis-13-1209-smart-cities-background-paper-digital.pdf

Smart cities: Frost & Sullivan value proposition (pp. 1–27). (2019). Frost & Sullivan. https://ww2.frost.com/wp-content/uploads/2019/01/SmartCities.pdf

Smart city strategies: A global review (pp. 1–44). (2017). Future Cities Catapult. https://futurecities.catapult.org.uk/wp-content/uploads/2017/11/GRSCS-Final-Report.pdf

Söderström, O., Paasche, T., & Klauser, F. (2014). Smart cities as corporate storytelling. *City*, *18*(3), 307–320. https://doi.org/10.1080/13604813.2014.906716

Sui, D., & Goodchild, M. (2011). The convergence of GIS and social media: Challenges for GIScience. *International Journal of Geographical Information Science*, *25*(11), 1737–1748. https://doi.org/10.1080/13658816.2011.604636

Swords, J., & Liu, X. (2015). Visualizing urban and regional worlds: Power, politics, and practices. *Environment and Planning A: Economy and Space*, *47*(6), 1235–1240. https://doi.org/10.1177/0308518X15594895

Taylor Buck, N., & While, A. (2017). Competitive urbanism and the limits to smart city innovation: The UK Future Cities initiative. *Urban Studies*, *54*(2), 501–519. https://doi.org/10.1177/0042098015597162

Thrift, N. (2008). *Non-Representational Theory: Space, Politics, Affect*. Routledge.

Tironi, M.. (2020). Prototyping public friction: Exploring the political effects of design testing in urban space. *The British Journal of Sociology*, *71*(3), 503–519. https://doi.org/10.1111/1468-4446.12718

Tironi, M., & Sánchez Criado, T. (2015). Of sensors and sensitivities: Towards a cosmopolitics of “smart cities”? *Tecnoscienza*, *6*(2), 89–108.

Tironi, M., & Valderrama, M. (2018). Unpacking a citizen self-tracking device: Smartness and idiocy in the accumulation of cycling mobility data. *Environment and Planning D: Society and Space*, *36*(2), 294–312. https://doi.org/10.1177/0263775817744781

Tkacz, N. (2012). From open source to open government: A critique of open politics. *Ephemera: Theory and Politics in Organization*, *12*(4), 386–405.

Townsend, A.M. (2015). *Making sense of the new urban science* (pp. 1–31).

Townsend, A.M. (2009). Foreword. In M. Foth (Ed.), *Handbook of research on urban informatics: The practice and promise of the real-time city* (pp. xxiii–xxvii). IGI Global.

Townsend, A.M. (2014). *Smart cities: Big data, civic hackers, and the quest for a new utopia*. W.W. Norton & Company.

Townsend, A.M. (2015). *Making sense of the new urban science* (pp. 1–31). Data & Society Research Institute. http://www.spatialcomplexity.info/files/2015/07/Making-Sense-of-the-New-Science-of-Cities-FINAL-2015.7.7.pdf

Townsend, A.M., Maguire, R., Tester, J., & Crawford, M. (2010). *A planet of civic laboratories: The future of cities, information, and inclusion* (p. 6). Institute for the Future. https://www.iftf.org/fileadmin/user_upload/downloads/IFTF_Rockefeller_CivicLaboratoriesMap.pdf

Urban informatics: A new science for better cities. (2014, March 27). https://warwick.ac.uk/insite/urban_informatics_lecture/

Valdez, A.-M., Cook, M., Langendahl, P.-A., Roby, H., & Potter, S. (2018). Prototyping sustainable mobility practices: User-generated data in the smart city. *Technology Analysis & Strategic Management*, *30*(2), 144–157. https://doi.org/10.1080/09537325.2017.1297399

Valdez, A.-M., Cook, M., & Potter, S. (2018). Roadmaps to utopia: Tales of the smart city. *Urban Studies*, *55*(15), 3385–3403. https://doi.org/10.1177/0042098017747857

Valdez, A.-M., Cook, M., Potter, S., & Langendahl, P.-A. (2015). Exploring participatory visions of smart transport in Milton Keynes. *Proceedings of the Institution of Civil Engineers*, 1–7. https://doi.org/10.1680/jensu.15.00020

Valdez Juarez, A.-M., & Potter, S. (2014). *Big data without Big Brother: Emerging issues in smart transport in Milton Keynes*. Digital Economy All-Hands Conference 2014, Imperial College, London. http://oro.open.ac.uk/41925/

Viitanen, J., & Kingston, R. (2014). Smart cities and green growth: Outsourcing democratic and environmental resilience to the global technology sector. *Environment and Planning A: Economy and Space*, *46*(4), 803–819. https://doi.org/10.1068/a46242

Wachsmuth, D. (2014). City as Ideology: Reconciling the Explosion of the City Form with the Tenacity of the City Concept. *Environment and Planning D: Society and Space*, *32*(1), 75–90. https://doi.org/10.1068/d21911

Weber, S. (2008). *Benjamin's -abilities*. Harvard University Press.

Whereabouts London. (n.d.). Retrieved September 13, 2020, from http://whereaboutslondon.org/#/about

Whereabouts London Bitbucket. (n.d.). [Bitbucket]. Retrieved July 23, 2015, from https://bitbucket.org/fcclab/command-line-k-means-data-clusterer/wiki/Home

Whereabouts London GitHub. (n.d.). GitHub. Retrieved November 14, 2020, from https://github.com/FutureCitiesCatapult/command-line-k-means-data-clusterer

Wigley, E., & Rose, G. (2020). Will the real smart city please make itself visible? In K. S. Willis & A. Aurigi (Eds.), *The Routledge companion to smart cities* (pp. 301–312). Routledge.

Wiig, A. (2015). IBM's smart city as techno-utopian policy mobility. *City*, *19*(2–3), 258–273. https://doi.org/10.1080/13604813.2015.1016275

Wiig, A. (2016). The empty rhetoric of the smart city: From digital inclusion to economic promotion in Philadelphia. *Urban Geography*, *37*(4), 535–553. https://doi.org/10.1080/02723638.2015.1065686

Wilson, M. W., & Graham, M. (2013a). Neogeography and volunteered geographic information: A conversation with Michael Goodchild and Andrew Turner. *Environment and Planning A: Economy and Space*, *45*(1), 10–18. https://doi.org/10.1068/a44483

Wilson, M. W., & Graham, M. (2013b). Situating neogeography. *Environment and Planning A: Economy and Space*, *45*(1), 3–9. https://doi.org/10.1068/a44482

Wolff, A., Gooch, D., Mir, U., Cavero, J., & Kortuem, G. (2015). *Removing barriers for citizen participation to urban innovation*. Digital Cities, Limerick, Ireland. http://oro.open.ac.uk/id/eprint/43854

Wolff, A., Valdez, A. M., Barker, M., Potter, S., Gooch, D., Giles, E., Miles, J., & Nijholt, A. (2017). Engaging with the Smart City Through Urban Data Games. In *Playable cities: The city as digital playground* (pp. 47–66). Springer Nature Singapore.

Wood, D., & Fels, J. (1986). Designs on signs: Myth and meaning in maps. *Cartographica*, *23*(3), 54–103.

Wood, D., & Fels, J. (2011). Reflection essay: Designs on signs/myth and meaning in maps. In Martin Dodge (Ed.), *Classics in cartography: Reflections on influential articles from cartographica* (pp. 261–270). Wiley-Blackwell.

Woods, E., & Goldstein, N. (2014). *Navigant Research Leaderboard Report: Smart City Suppliers* (pp. 1–52). Navigant Consulting.

Wu, J. (2012). *Advances in k-means clustering: A data mining thinking*. Springer-Verlag.

Zelt, T., Narloch, U., Eikmanns, B., & Ibel, J. (2019). *The smart city breakaway: How a small group of leading digital cities is outpacing the rest* (Think:Act, pp. 1–20). Roland Berger GMBH. https://www.rolandberger.com/en/Publications/Smart-City-Strategy-Index-Vienna-and-London-leading-in-worldwide-ranking.html

Zook, M. (2017). Crowd-sourcing the smart city: Using big geosocial media metrics in urban governance. *Big Data & Society*, *4*(1), 1–13. https://doi.org/10.1177/2053951717694384