Data-driven, networked urbanism

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Abstract

For as long as data have been generated about cities various kinds of data-informed urbanism have been occurring. In this paper, I argue that a new era is presently unfolding wherein data-informed urbanism is increasingly being complemented and replaced by data-driven, networked urbanism. Cities are becoming ever more instrumented and networked, their systems interlinked and integrated, and vast troves of big urban data are being generated and used to manage and control urban life in real-time. Data-driven, networked urbanism, I contend, is the key mode of production for what have widely been termed smart cities. In this paper I provide a critical overview of data-driven, networked urbanism and smart cities focusing in particular on the relationship between data and the city (rather than network infrastructure or computational or urban issues), and critically examine a number of urban data issues including: the politics of urban data; data ownership, data control, data coverage and access; data security and data integrity; data protection and privacy, dataveillance, and data uses such as social sorting and anticipatory governance; and technical data issues such as data quality, veracity of data models and data analytics, and data integration and interoperability. I conclude that whilst data-driven, networked urbanism purports to produce a commonsensical, pragmatic, neutral, apolitical, evidence-based form of responsive urban governance, it is nonetheless selective, crafted, flawed, normative and politically-inflected. Consequently, whilst data-driven, networked urbanism provides a set of solutions for urban problems, it does so within limitations and in the service of particular interests.

Key words: big data, data analytics, governance, smart cities, urban data, urban informatics, urban science

Introduction

There is a rich history of data being generated about cities concerning their form, their citizens, the activities that take place, and their connections with other locales. These data have been generated in a plethora of different ways, including audits, cartographic surveying, interviews, questionnaires, observations, photography, and remote sensing, and are quantitative and qualitative in nature, stored in ledgers, notebooks, albums, files, databases, and other media. Data about cities provide a wealth of facts, figures, snapshots and opinions that can be converted into various forms of derived data, transposed into visualisations, such as graphs, maps, and infographics, analyzed statistically or discursively, and interpreted and turned into information and knowledge. As such, urban data form a key input for understanding city life, solving urban problems, formulating policy and plans, guiding operational governance, modelling possible futures, and tackling a diverse set of other issues. For as long as data have been generated about cities then, various kinds of data-informed urbanism have been occurring.

A new era is, however, presently unfolding wherein data-informed urbanism is increasingly being complemented and replaced by data-driven, networked urbanism. Here, urban operational governance and city services are becoming highly responsive to a form of networked urbanism in which big data systems are prefiguring and setting the urban agenda and are influencing and controlling how city systems respond and perform. In short, we are moving into an era where cities are becoming ever more instrumented and networked, their systems interlinked and integrated, and the vast troves of data being generated used to manage and control urban life. Computation is now routinely being embedded into the fabric and infrastructure of cities that, on the one hand, is producing a deluge of contextual and actionable data, and on the other acts on such data in real-time. Moreover, data that used to be the preserve of a single domain are increasingly being shared across systems enabling a more holistic and integrated view of city services and infrastructures. As such, cities are becoming knowable and controllable in new dynamic ways, responsive to the data generated about them. I thus argue that data-driven, networked urbanism is the key mode of production for what have widely been termed smart cities.

In this paper I provide a critical overview of data-driven, networked urbanism focusing in particular in particular on the relationship between data and the city, rather than network infrastructure, computational or urban issues. The paper starts by setting out how cities are being instrumented and captured as big urban data, how these data are being used to manage and control cities, and how data-driven, networked urbanism is underpinning the emergence of smart cities. This is then followed by a critical examination of a number of problematic issues related to data-driven, networked urbanism, including: the corporatisation of governance (data ownership, data control, data coverage and access); the creation of buggy, brittle, hackable urban systems (data security, data integrity); social, political, ethical effects (data protection and privacy, dataveillance, and data uses including social sorting and anticipatory governance); and technical data issues (data quality; veracity of urban data models and data analytics; data integration and interoperability).

Big data and smart cities

Since the start of computing era urban data have been increasingly digital in nature, either digitized from analogue sources (manually entered or scanned) or born digital, generated by digital devices, stored as digital files and databases, and processed and analyzed using various software systems such as information management systems, spreadsheets and stats packages, and geographic information systems. From the 1980s onwards, public administration records, official statistics, and other forms of urban data were released predominately in digital formats and processed and analyzed through digital media. However, these data were (and continue to be) generated and published periodically and often several months after generation.

In cases such as exhaustive datasets - for example, detailed maps or national censuses - new surveys are very infrequent (e.g., 10 years for censuses) and their publication might be 18-24 months after collection, and longer for specific subsets. For domain specific issues, such as transport and traffic flows or public transportation usage, surveys are conducted every few years, using a limited spatial and temporal sampling framework. Only a handful of datasets are published monthly (e.g. unemployment rates) or quarterly (e.g. GDP), with most being updated annually due to the effort required to generate them. These data typically have poor spatial resolution, referring to large regions or the nation, and little disaggregation (e.g., by population classes or economic sectors). In cases where data generation is more frequent, such as remote sensing, only occasional snapshots are bought by city administrations due to their licensing costs. In other cases, such as consumer purchasing (as evidenced in credit card transactions) the data was largely black-boxed within a financial institution. In other words, whilst there was a range of urban digital data available to urban managers and policy makers from the 1980s through to 2000s , along with increasingly sophisticated software such as GISs to make sense of them, sources of data were temporally, spatially and domain (scope) limited.

Post-Millennium, the urban data landscape has been transformed, with a massive step change in the nature and production of urban data, transitioning from small data to big data, wherein the generation of data is continuous, exhaustive to a system, fine-grained, relational, and flexible (see Table 1) across a range of domains (Kitchin 2014a). From a position of relative data scarcity, the situation is turning to one of data deluge. This is particularly the case with urban operational data wherein traditional city infrastructure, such as transportation (e.g., roads, rail lines, bus routes, plus the vehicles/carriages) and utilities (e.g., energy, water, lighting), have become digitally networked, with grids of embedded sensors, actuators, scanners, transponders, cameras, meters and GPS producing a continuous flow of data about infrastructure conditions and usage (constituting what has been called the Internet of Things). Many of these systems are generating data at the individual level, tracking individual travel passes, vehicle number plates, mobile phone identifiers, faces and gaits, buses/trains/taxis, meter readings, etc (Dodge and Kitchin 2005). These are being complemented with big data generated by: (a) commercial companies such as mobile phone operators (location, app use), travel and accommodation sites (reviews), social media sites (opinions, photos, personal info, location), transport providers (routes, traffic flow), website owners (clickstreams), financial institutions and retail chains (purchases), and private surveillance and security firms (location, behaviour) that are increasingly selling and leasing their data through data brokers, or making their data available through APIs (such as Twitter and Foursquare); (b) crowdsourcing (e.g., Open Street Map) and citizen science (e.g., personal weather stations) initiatives, wherein people collaborate on producing a shared data resource or volunteer data. Other kinds of more irregular urban big data include digital aerial photography via planes or drones, or spatial video, LiDAR (light detection and ranging), thermal or other kinds of electromagnetic scans of environments that enable the mobile and real-time 2D and 3D mapping of landscapes. And whilst official statistics are largely still waiting to undergo the data revolution (Kitchin 2015), the generation of public administration data has been transformed through the use of e-government online transactions that produce digital data at the point-of-collection.

Table 1: Comparing small and big data

	Small data	**Big data**
Volume	Limited to large	Very large
Velocity	Slow, freeze-framed/bundled	Fast, continuous
Variety	Limited to wide	Wide
Exhaustivity	Samples	Entire populations
Resolution and identification	Course & weak to tight & strong	Tight & strong

Relationality	Weak to strong	Strong
Flexible and scalable	Low to middling	High

Source: Kitchin (2014b)

We are at start of this new big data era and the flow and variety of urban data is only going to grow and diversify. Moreover, whilst much of these data presently remain in silos and are difficult to integrate and interlink due to varying standards and formats, they will increasingly be corralled into centralised systems such as inter-agency control rooms for monitoring the city as a whole (e.g., Centro De Operacoes Prefeitura Do Rio in Rio de Janeiro, Brazil, a data-driven city operations centre that pulls together into a single location real-time data streams from thirty agencies, including traffic and public transport, municipal and utility services, emergency and security services, weather feeds, information generated by employees and the public via social media, as well as administrative and statistical data, and is overseen by a staff of 180 data operatives -- see Figure 1 for examples of urban control rooms), or what have been termed City Operating Systems (or City OS, such Microsoft's *CityNext*, IBM's *Smarter City*, Urbiotica's *City Operating System*, and PlanIT's *Urban Operating System*; see Figure 2). The latter are effectively Enterprise Resource Planning (ERP) systems designed to coordinate and operate the activities of large companies repurposed for cities. With the advent of the open data movement some of these data will also feed into public-facing urban dashboards that provide a mix of interactive visualisations of real-time, public administration and official statistical data (Kitchin et al. 2015a, see Figure 3).

Further, the production of these new big data have been accompanied by a suite of new data analytics designed to extract insight from very large, dynamic datasets, consisting of four broad classes: data mining and pattern recognition; data visualization and visual analytics; statistical analysis; and prediction, simulation, and optimization (Miller 2010; Kitchin 2014b). These analytics rely on machine learning (artificial intelligence) techniques and vastly increased computational power to process and analyze data. Moreover, they enable a new form of data-driven science to be deployed that rather than being theory-led seeks to generate hypotheses and insights 'born from the data' (Kelling *et al.* 2009). This is leading to the development of 'urban informatics' (Foth 2009), an informational and human-computer interaction approach to examining and communicating urban processes, and 'urban science', a computational modelling approach to understanding and explaining city processes that builds upon and radically extends quantitative forms of urban studies that have been

Figure 1: Urban control rooms (Rio de Janeiro, Sydney, Glasgow and London)[1]

Figure 2: City Operating Systems (Microsoft CityNext, IBM Smarter Cities, Urbiotica City Operating System and PlanIT Urban Operating System) [2]

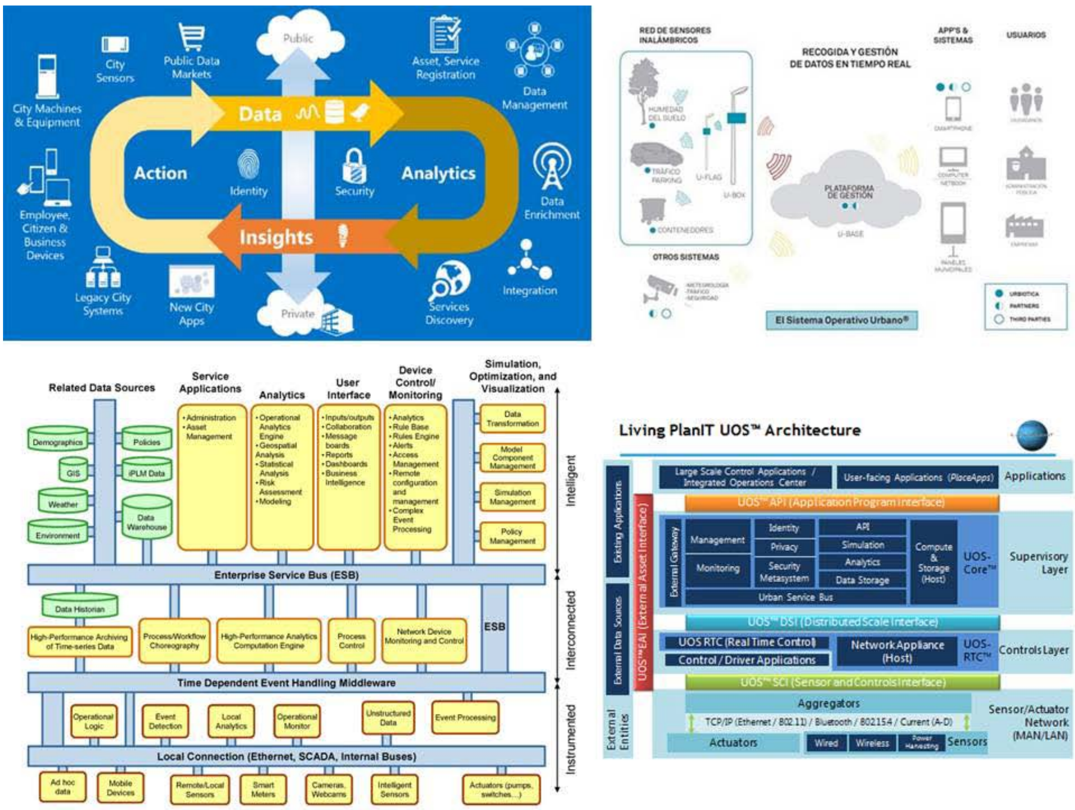


Figure 3: Urban dashboards (Dublin, London, Amsterdam)[3]

practised since the 1950s, blending in geocomputation, data science and social physics (Batty 2013). Whereas urban informatics is more human-centred, interested in understanding and facilitating the interactions between people, space and technology, urban science promises to not only make sense of cities as they presently are (by identifying relationships and urban 'laws'), but to also predict and simulate likely future scenarios under different conditions, potentially providing city managers with value insight for planning and development decision-making and policy formulation.

Urban big data, city operating systems, urban informatics, and urban science analytics provide the basis for a new logic of urban control and governance -- data-driven, networked urbanism -- that enables real-time monitoring and steering of urban systems and the creation of what has widely been termed smart cities. The notion of a smart city can be traced back to experiments with urban cybernetics in the 1970s (Flood 2011; Townsend 2013), the development of new forms of city managerialism and urban entrepreneurship, including smart growth and new urbanism, in the 1980s and 90s (Hollands 2008, Wolfram 2012, Söderström et al., 2014, Vanolo 2014), and the fusing of ICT and urban infrastructure and development of initial forms of networked urbanism from the late 1980s onwards (Graham and Marvin 2001, Kitchin and Dodge 2011). As presently understood, a smart city is one that strategically uses networked infrastructure and associated big data and data analytics to produce a:

- *smart economy* by fostering entrepreneurship, innovation, productivity, competiveness, and producing new forms of economic development such as the app economy, sharing economy and open data economy;
- *smart government* by enabling new forms of e-government, new modes of operational governance, improved models and simulations to guide future development, evidence-informed decision making, better service delivery, and making government more transparent, participatory and accountable;
- *smart mobility* by creating intelligent transport systems and efficient, inter-operable multi-modal public transport;
- *smart environments* by promoting sustainability and resilience and the development of green energy;
- *smart living* by improving quality of life, increasing safety and security, and reducing risk;
- *smart people* by creating a more informed citizenry and fostering creativity, inclusivity, empowerment and participation (Cohen 2012; Hollands 2008; Townsend 2013).

In short, the smart city promises to solve a fundamental conundrum of cities – how to reduce costs and create economic growth and resilience at the same time as producing sustainability and improving services, participation and quality of life – and to do so in commonsensical, pragmatic, neutral and supposedly apolitical ways by utilising a fast-flowing torrent of urban data and data analytics, algorithmic governance, and responsive, networked urban infrastructure. Moreover, much more information is being placed into the hands of the public to aid decision-making, navigation and participation through a plethora of locative social media (apps that tell them about the city and which they can contribute to), open data sites, public dashboards, hackathons, and so on.

The notion of smart cities, and the mode of data-driven, networked urbanism, has not, however, been universally welcomed and has been subject to a number of critiques.

First, smart city initiatives treat cities as a set of knowable and manageable systems that act in largely rational, mechanical, linear and hierarchical ways and can be steered and controlled (Kitchin et al., 2015). Second, smart city initiatives are largely ahistorical, aspatial and homogenizing in their orientation and intent, treating cities as if they are all alike in terms of their political economy, culture, and governance (Greenfield 2013). Third, an emphasis is placed on creating technical rather political/social solutions to urban problems thus overly promoting technocratic forms of governance (Moronez 2013). Fourth, the project of producing smart cities tends to reinforce existing power geometries and social and spatial inequalities rather than eroding or reconfiguring them (Datta 2015). Fifth, the approach fails to recognize the politics of urban data and the ways in which they are the product of complex socio-technical assemblages (Kitchin 2014b). Sixth, the smart city agenda is being overly driven by corporate interests who are using it to capture government functions as new market opportunities (Hollands 2008). Seventh, networking city infrastructure potentially creates buggy, brittle, and hackable urban systems (Kitchin and Dodge 2011; Townsend 2013). And finally, data-driven, networked urbanism produces a number of activities that have profound social, political, ethical consequences, including dataveillance and extensive geosurveillance, social and spatial sorting, and anticipatory governance (Graham 2005; Kitchin 2014a).

In the rest of this paper, I want to concentrate on the last four critiques, and in particular their associated data issues (rather than other aspects of the technical stacks of urban socio-technical assemblages, and wider political-economic framing and effects), including technical data issues, as way of further illustrating some of the challenges posed by data-driven, networked urbanism and the need to further examine the relationship between data and the city.

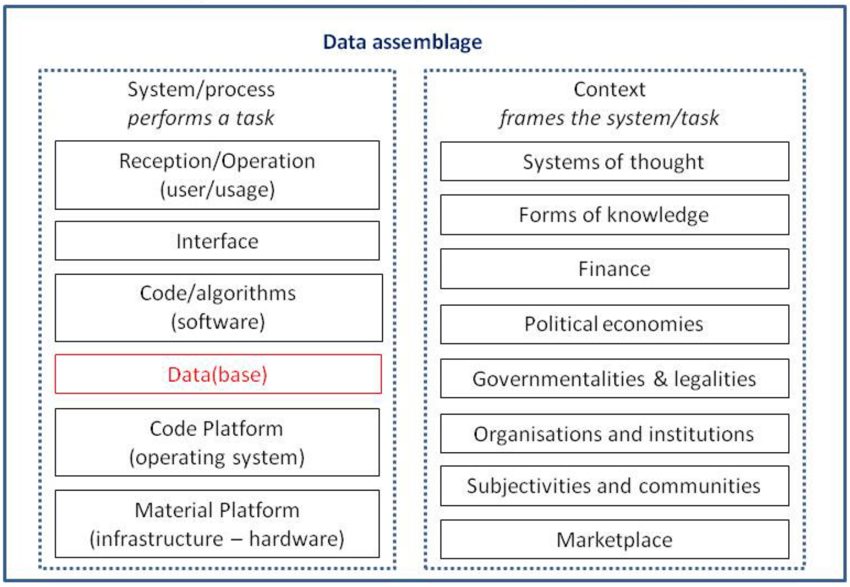
Data and the City

The politics of urban data

One of the key arguments for adopting a data-driven approach to urban governance is that it provides a strong evidence-based approach to decision-making, system control, and policy formation, rather than one that is heavily anecdotal, clientelist or localist. How an urban system/infrastructure is run is thus less open to political influence and instead is driven by objective, neutral facts in a technocratic, commonsensical, pragmatic way. Technical systems and the data they produce are objective and non-ideological and thus politically benign. Sensors, networked infrastructure, and computers have no inherent politics -- they simply measure a value, communicate those values, and process, analyze and display the data using scientific principles; producing measurements, records and information that reflect the truth about cities. And while data from social systems, such as social media platforms (e.g., Twitter), are inherently more subjective and noisy, they provide a direct reflection of the views, interactions and behaviour of people, in contrast to official surveys which reflect what people say they do or think (or what they think the surveyor wants to hear), thus providing better ground truthing of social reality. As such, big data about cities can be taken at face value and used unconditionally shed light on cities and to manage and control urban systems and infrastructure and guide urban policy.

The reality is somewhat different for two reasons. First, there are a number of technical issues concerning data coverage, access and quality that means that the view data presents of the city is always partial and subject to caution. Second, data are the products of complex socio-technical assemblages that are framed and shaped by a range of technical, social, economic and political forces and are designed to produce particular outcomes (Kitchin 2014b; see Figure 4). On the one hand, what data are produced, how they are handled, processed, stored, analyzed and presented is the result of a particular technical configuration and how it is deployed (e.g., where sensors are located, their field of view, their sampling rate, their settings and calibration, etc). On the other, how a system is designed and run is influenced by systems of thought, technical know-how, the regulatory environment, funding and resourcing, organisational priorities and internal politics, institutional collaborations, and marketplace demand. In other words, a data assemblage possesses a ‘dispositif’, defined by Foucault (1977: 194) as a: ‘thoroughly heterogeneous ensemble consisting of discourses, institutions, architectural forms, regulatory decisions, laws, administrative measures, scientific statements, philosophical, moral and philanthropic propositions.’ For Foucault, a dispositif is inherently political producing what he terms ‘power/knowledge’, that is knowledge that fulfils a strategic function. In other words, urban big data are never neutral and objective, but rather are situated, contingent, relational, and framed and used contextually to try and achieve certain aims and goals (to monitor, enhance, empower, discipline, regulate, control, produce profit, etc.). Or to put it another way, urban data are never raw but are always already cooked to a particular recipe for a particular purpose (Bowker 2005; Gitelman 2013). As such, data-driven, networked urbanism is thoroughly political seeking to produce a certain kind of city. It is thus necessary when examining urban big data to critically unpack their associated data assemblage (including the entire technical stack - infrastructure, platform, software/algorithms, data, interface) to document how it is constituted and works in practice to produce urban processes and formations, and for whose benefit.

Figure 4: A data assemblage



Data access, data ownership and data control

As already noted, much of the data presently being generated about cities are produced by commercial companies, such as mobile phone operators, and private utility and transport companies. For them, their data are a valuable commodity that provides competitive advantage or an additional revenue stream if sold/leased, and they are under no obligation to share freely the data they generate through their operations with city managers or the public. As noted in 2014 by the British Minister for Smart Cities, Dan Byles MP[4], the privatisation of public services in the UK and elsewhere has also meant the privatisation of their associated data unless special provision was made to ensure it was shared with the city or made open. Similarly, access to data within public-private partnerships and semi-state agencies, or state agencies operating as trading funds (such as the Met Office and Ordnance Survey in the UK who generate significant operating costs by selling data and services), can be restricted or costly to purchase. Consequently key framework datasets (e.g., detailed maps) can have limited access and data concerning transportation (e.g., bus, rail, bike share schemes, private tolls), energy, and water be entirely blackboxed. Even within the public sector, data can be siloed within particular departments and not be shared with other units within the organisation, or be open for other institutions or the public to use. As such, whilst there might be a data revolution underway, access to much of that data is limited, and there are a number of issues that need to be explored with respect to data ownership and data control, especially with respect to procurement and the outsourcing or privatisation of city services. Moreover, even if all data were to be open and shared it needs to be acknowledged that there are still many aspects about cities where data generation is weak or absent. For example, in a recent audit of Dublin datasets to determine whether the city was in a position to apply for ISO37120 (the ISO standard for city indicators) data could only be sourced for 11 of 100 indicators sought (predominately because the data sought was either privatised or released at an inappropriate scale).

Data security and data integrity

One of the prime anxieties of networking infrastructure and ubiquitous urban computing is the creation of systems and environments which are inherently buggy and brittle and are prone to viruses, glitches, crashes, and security hacks (Kitchin and Dodge 2011; Townsend 2013). As Mims (2013) notes, any networked device is open to be hacked and its data stolen and used for criminal purposes, or corrupted, or controlled remotely, or misdirected, or to spy on its users. The media report almost daily on large-scale data breaches of commercial companies and state agencies and the theft of valuable personal data, with several incidents of city infrastructure such as traffic management systems being hacked, disabled and controlled (Paganini 2013). As Townsend (2013) notes, the notion of smart cities takes two open, highly complex and contingent systems — cities and computing — and binds and networks them together, meaning that data-driven, networked urbanism has in-built vulnerabilities. Moreover, as urban systems evolve to become more complex, interconnected and interdependent these vulnerabilities potentially multiply (Townsend 2013). Creating secure big urban data systems is thus set to be a significant on-going task if public trust in their purported benefits are to be gained and maintained. Another significant element in upholding trust in data-driven, networked urbanism is how and what purposes the data are deployed.

Data uses

Urban big data are presently being used to undertake a diverse range of tasks, some of which seem relatively benign, such as monitoring city lighting with the aim of improving the quality of light and reducing its cost, and others more clearly political, such as directing policing activity. A significant concerns is that as more and more data about cities and their citizens are generated, privacy becomes eroded. Privacy is considered a basic human right, a condition that people expect and value in developed countries. Yet, as sensors, cameras, smartphones, and other embedded and mobile devices generate evermore data it becomes increasingly difficult to protect, with individuals leaving ever greater quantities of digital footprints (data they themselves leave behind) and data shadows (information about them generated by others). Such troves of data are amenable to dataveillance, a mode of surveillance enacted through sorting and sifting datasets in order to identify, monitor, track, regulate, predict and prescribe (Clarke 1988; Raley 2013), and geosurveillance, the tracking of location and movement of people, vehicles, goods and services and the monitoring of interactions across space (Crampton 2003). Given the always-on nature of many of these systems, and the tracking of unique identifiers, such dataveillance and geosurveillance are becoming continuous and fine-grained with, for example, mobile phone companies always knowing the location of a phone whilst it is not powered down (Dodge and Kitchin 2005). Moreover, as data minimization norms become relaxed there are anxieties that data are being shared, combined and used for purposes for which they were never intended. In particular, the last twenty years have witnessed the rapid growth of a number of data brokers who capture, gather together and repackage data for rent (for one time use or use under licensing conditions) or re-sale, and produce various derived data and data analytics.

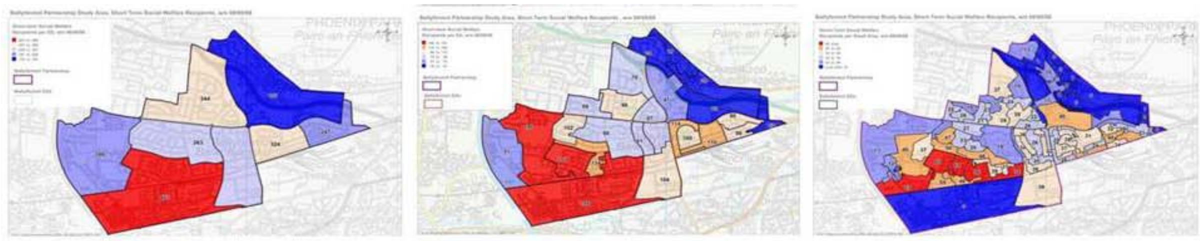
Whilst focusing on different markets, these data brokers seek to mesh together off-line, online and mobile data to provide comprehensive views of people and places and to construct personal and geodemographic profiles (Goss 1995; Harris et al., 2005). These profiles are then used to predict behaviour and the likely value or worth of an individual and to socially sort them with respect to credit, employment, tenancy and so on (Graham 2005). The concern is that these firms practice a form of 'data determinism' in which individuals are not profiled and judged just on the basis of what they have done, but on the prediction of what they might do in the future using algorithms that are far from perfect, and yet are black-boxed and lack meaningful oversight and remediate procedures (Ramirez 2013). Such anticipatory governance can have far reaching effects. For example, a number of US police forces are now using predictive analytics to anticipate the location of future crimes and direct patrols, and to identify individual most likely to commit a crime in the future, designating them pre-criminals (Stroud 2014). In such cases, a person's digital footprints and data shadow does more than follow them; it precedes them. Data assemblages then do not act as cameras reflecting the world as it is, but rather as engines shaping the world in diverse ways (Mackenzie 2008).

Technical data issues

Beyond data always being political and often restricted in access and limited in scope, it is important to recognize that there are also a number of technical issues that place constraints on the extent to which cities are knowable and controllable. Generating data is always an open process. Approaches, methodologies, procedures, standards, and equipment are designed, tested, negotiated, and debated. The data produced are shaped by technical instruments, protocols, scientific norms, and scientist behaviour and organisational processes, meaning they contain instrument and human error and bias. Moreover, generating data always involves a process of abstraction (capturing particular measurements from the sum of all possible data), representation (converting what is being measured into a readable form (e.g., numbers, a wave pattern, a scatterplot, a stream of binary code, etc.)), and often generalisation (e.g., into a set of categories) or calibration (transformed to compensate for suspected error/bias). With any dataset then there are questions concerning data veracity and quality and how accurately (precision) and faithfully (fidelity) the data represent what they are meant to (especially when using samples and proxies), and how clean (error and gap free), untainted (bias free), consistent (few discrepancies), and reliable (the measurement instrument consistently produces the same quality of results) the data are (Goodchild 2009, Kitchin 2014b). Further, because data are generated in so many different ways, using a plethora of instruments and standards, it remains difficult to join them together to produce a more holistic picture. As such, it impossible to measure the 'truth' of cities, but rather only generate partial, selected views from particular vantage points. And what those views show can be dirty, gamed, and faked.

Likewise, urban data models are created, with ontologies constructed rather than essential (existing as a natural truth) and data analytics are selected, different parameters selected and tweaked, and protocols applied. There are therefore questions as to the veracity of models and analytics and the extent to which they shape the findings produced. To be clear, urban informatics and urban science are seeking to produce as much insight as possible, with as much validity as achievable, and they do provide useful knowledge. However, they nonetheless produce a particularised vision and explanation of the city. Moreover, the output they produce is open to misinterpretation and ecological fallacies. With respect to cities, one of the most common types of ecological fallacy is introduced by the Modifiable Areal Unit Problem (MAUP) (Openshaw 1984), wherein the statistical geography used to display aggregate data can have a marked effect on the pattern of observations, and thus the conclusions drawn (see Figure 5). Likewise, altering the classification boundaries, or altering the number of classes, can have a similar effect. How data are classified and the scale at which they are displayed can thus have a dramatic effect on how a city is understood and how this feeds into how it is governed. While these effects are well understood by academic statisticians, they are much less so within the policy community, and they are mostly overlooked or ignored in applied research.

Figure 5: Mapping the same data at three different administrative scales



Conclusion

We are entering an era where computation is being routinely embedded into urban environments and networked together, and people are moving about with smartphones that ensure always available connectivity and access to information. These devices and infrastructures are producing and distributing vast quantities of data in real-time, and they are also responsive to these data and the analytics undertaken on them enabling new kinds of monitoring, regulation and control. Cities then are becoming data-driven and are enacting new forms of algorithmic governance. However, the data and algorithms underpinning them are far from objective and neutral, but rather are political, imperfect, and partial. The smart cities that data-driven, networked urbanism purports to create are then smart in a qualified sense. Their production and operation is based on much more data and derived information than previous generations of urbanism, but it is a form of urbanism that is nonetheless still selective, crafted, flawed, normative and politically-inflected. Moreover, while the instrumental rationality of data-driven, networked urbanism promotes urban knowledge and management rooted in a quite narrowly framed ‘episteme (scientific knowledge) and teche (practical instrumental knowledge)’, it is important that other forms of knowing, such as ‘phronesis (knowledge derived from practice and deliberation) and metis (knowledge based on experience)’ (Parsons 2004: 49) are not silenced, providing both a counter-weight to the limits of smart cities and positions from which to reflect on, critique and recast the production of data-driven, networked urbanism. Indeed, whilst data-driven, networked urbanism undoubtedly provides a set of solutions for urban problems, we also have to recognize that it has a number of shortcomings and a number of potential perils. The challenge facing urban managers and citizens in the age of smart cities is realise the benefits of planning and delivering city services using a surfeit of data, evidence and real-time responsive systems whilst minimizing any pernicious effects. To do that we have to be as smart about data and data analytics as we would like to be about cities.

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Notes

1. Sources of figures: top-left: http://ipprio.rio.rj.gov.br/centro-de-operacoes-rio-usa-mapas-feitos-pelo-ipp/; bottom-left: http://www.dailytelegraph.com.au/news/nsw/sydney-under-watch-new-cameras-in-the-wake-of-thomas-kellys-kinghit-death/story-fni0cx12-1226777921307; top- right: http://www.eveningtimes.co.uk/news/13273769.Officers_get_the_whole_picture_at_new_centre/; bottom-right: http://archinect.com/news/article/75835110/who-s-your-data-urban-design-in-the-new-soft-city

2. Sources of figures: top-left: http://www.urenio.org/2013/10/22/microsoft-citynext/; bottom-left: http://www.urenio.org/2011/06/29/ibm-redbooks-smarter-cities-series/; top-right: http://www.plataformaarquitectura.cl/cl/02-308620/nuevo-contexto-urbano-espacios-publicos-flexibles-10-principios-basicos; bottom-right: http://raptorsme.tumblr.com/post/42271513343/the-uos-tm-architecture-the-controls-and

3. Sources of figures: left: http://www.dublindashboard.ie/; top-right: http://citydashboard.org/london/; bottom-right: http://visual.ly/city-dashboard-amsterdam

4. https://www.youtube.com/watch?v=3E3RpGMKbhg

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