Check for updates

Re-engineering the City: Platform Ecosystems and the Capture of Urban Big Data

Sarah Barns*

Independent Researcher, Sydney, NSW, Australia

Today's digital platforms occupy sites of growing strategic significance in the daily lives of cities. Acting as infrastructures of urban exchange, platform services institute basic match-making capabilities between mobile subjects, whether for transportation, shopping, accommodation, dating, or, simply, public discourse. As is increasingly recognized, the nature of value exchange traded via these platforms extends beyond their immediate domain of service provision, whether transportation or accommodation, for example, to wider "data ecosystems" of users, producers, and consumers. It is the conditions instituted by platform services to govern data ecosystems that are the focus of this article and are, I argue, of critical importance to how big data can be leveraged in ways that expand new frontiers of urban science and more broadly, urban sustainability policy. The rise in platform urbanism means that urban big data are not simply as a diagnostic tool for monitoring and evaluating complex urban behaviors but can be co-opted in ways that actively engineers the scaling of data-driven platform services and their myriad codependencies. These conditions present significant challenges not only to informational policy but increasingly also to urban governance settings, where platform-mediated interactions facilitate powerful but unevenly shared territories of urban intelligence.

Keywords: platform governance, platform urbanism, big data, Uber, cybernetics, future mobility, internet of things

INTRODUCTION

Today's cities operate as complex informational ecosystems that are brokered and facilitated by myriad digital platforms and services. Enthusiasm toward the potentials of smart cities means that urban data is increasingly valued data is increasingly valued as a productive resource needed to facilitate transitions toward more resilient and sustainable urban societies (Townsend, 2013; Arup and UCL, 2014; Kitchin et al., 2015; Luque-Ayala and Marvin, 2015; Karvonen et al., 2019). This attention toward the diagnostic potentials of data-driven urban science and sustainability means that the governing conditions that shape how urban data are created, used, and monetized are becoming more critical to the effective performance of wider urban governance and policy settings.

The potentials of data-driven urban services are increasingly embraced by a broad cohort of urban decision-makers, sustainability scientists, technologists, researchers, and activists. Applications of urban data to accelerate transitions toward more sustainable futures are evident across a number of different fields. The capacity for cities to measure and benchmark their performance against emerging global sustainability standards, including UN Sustainable

Development Goals (SDGs) and related international standards [ISO (n.d)], increasingly depends on the quality of their data reporting at a range of different scales (Creutzig et al., 2019; Hawken et al., 2020). Framing cities as open systems, the field of "urban metabolism studies" sees the potential for urban big data to generate more sophisticated analyses of complex urban flows and resource intensities. This field envisions the city as a kind of dynamic metabolism of inputs and outputs, measured via advanced monitoring and remote sensing techniques that make use of real-time, location-aware platforms, and services that are increasingly entrenched into the fabric of everyday life. As Creutzig et al. argue, advocating for the upscaling of urban data for global climate solutions: "Crowd-sourced and big data, such as the movement of people tracked by cell phones, offer manifold new possibilities for assessing the inner working of a city, and the availability, quality and quantity of data is rapidly evolving" (Creutzig et al., 2019, p. 6). Sustainability scientists cite city planning offices, utilities, tax offices, building sensors, and other internet of things (IoT) services as important sources of big data, used as a means to understanding climate impacts on urban systems and to measure the efficacy of climate solutions (Lin and Cromley, 2015; McPhearson et al., 2016).

Data-driven services have also been embraced as the basis for a new kind of urban engineering, a field in which data functions as a critical infrastructure for a more "systems-aware" approach to designing solutions to urban challenges [Batty, 2013; Thakuriah et al., 2017; CUSP (n.d.)]. Big data, resulting from the digitization of more and more urban infrastructures, services, and experiences, are recognized as improving not only information flows but with it also greater capacity for learning and coordination by heterogeneous individuals (Bettencourt, 2013; Bettencourt and Brelsford, 2015). There is also, for many others, the potential for data-driven services to enable and encourage more participatory, citizen-centered decision-making, underpinned by a more "responsive" model of urban planning attuned to and engaged with local community sentiment (Kitchin, 2014a; Araya, 2015; Nonnecke et al., 2016; Thakuriah et al., 2017). The volume and veracity of big data are also widely acknowledged as central to the success of the circular economy, facilitating the tracking and monitoring of supply chain networks and consumer products (Perella, 2016; Gupta et al., 2019).

Across each of these examples, the digitization of urban flows and interactions is anticipated to create productive data that can be leveraged to support better decision-making and critical transformations in the design of cities. And yet, as attention toward platform business models, platform economy, and platform urbanism makes clear, many of today's digital platforms yield not just new data points or information flows that can enhance urban intelligence. They also raise complex new challenges to do with how data are used to capture and govern the informational landscapes of digitally mediated cities.

In *Platform Urbanism: Negotiating Platform Ecosystems in the Connected Lives of Cities* (Barns, 2020a), I discuss the historical evolution of digital platforms in the context of a hopeful orientation toward digital networks and data intelligence in reforming the design and management of contemporary cities. Benefiting from enthusiasm toward the potentials of open

informational networks and data-responsive intelligence, digital platforms have emerged to effectively re-engineer the production of urban data in ways that accelerate the uneven impacts of data-intensive services. The "capture" of urban intelligence by digital platforms, broadly now associated with the emergent field of as "platform urbanism," suggests that platform design strategies shaping how urban data are produced, consumed, and monetized are critical sites of struggle and contestation in the wider governance and reform of contemporary cities.

In this chapter, I summarize some key perspectives on urban data as a productive resource in the management of cities, and introduce key reasons why platform governance and platform-oriented data design is important to the future of data-driven urban sustainability and design. The challenges provoked by the rise of platform urbanism in the digital lives of cities augment existing critiques of data-driven urban intelligence, but they also suggest a need to consider the importance of information policy—including frameworks for data use and ownership—more centrally within urban sustainability and governance settings.

THE POLITICS OF URBAN DATA

It is important to contextualize this review by recognizing the many existing threads of critical research questioning the reformist potency of urban data. Describing narratives of "smart" data-driven urbanization as simply "corporate storytelling" or branding (Söderström et al., 2014), critical smart cities scholars have interrogated the role of data as a privileged mode of representation and knowledge-making (boyd and Crawford, 2012; van Dijck, 2014; Sumartojo et al., 2016). This critical approach tackles a perceived normative agenda embedded within the production of big data, by rejecting its veneer of objectivity and neutrality, and emphasizing instead what Kitchin and Lauriault (2014) have called the "sociotechnical assemblages" that frame and produce data itself (Kitchin and Dodge, 2011; Kitchin, 2014a,b). Visions of "smartness," in which urban big data becomes a tool for urban reform, is thus seen to progress narrow, technologist determinist ways of rendering urban complexity (Barns, 2012; Gabrys, 2014; Kitchin et al., 2015; Luque-Ayala and Marvin, 2015; McNeill, 2015; Shelton et al., 2015; Wiig, 2015; Leszczynski, 2016).

Concerned with the way "smart mentality" and "smart urbanism" are used as lenses through which to diagnose and improve urban conditions, critical urban studies scholars highlight how these renderings of cities, crafted through data-driven methods of smart city governance, will so often be positioned as necessary prerequisites for reform (Söderström et al., 2014; Vanolo, 2014; Luque-Ayala and Marvin, 2015; McNeill, 2015). Within smart city frameworks, this critique has noted the way technology giants have sought to advance relatively "top–down" managerial approaches to cities, which undermine many of the participatory potentials of crowd-sourced or open data associated with the proliferation of digital services. Many critics have argued that it is the very incapacity for technology actors to properly understand and accommodate the messy

complexities of cities and their human actors that have led to failures of smart city implementation, including an incapacity to scale up prototypes to form enduring innovations in urban decision making and governance (Greenfield and Kim, 2013; Hill, 2013; Luque-Ayala and Marvin, 2015; Shelton et al., 2015; Morozov and Bria, 2018).

In a sense, this critical position has restaged mid-twentieth century debates about the limits of objectification and commodification, and the dangers of an overly behaviorist approach to understanding urban society. The advance of cybernetics and systems-oriented theories in the mid-twentieth century, enthusiastically adopted not only as the basis from which to understand informational or machinic systems but also human societies more generally, prompted a wave of criticism from social scientists and humanities scholars concerned at how complex social dynamics were being represented. Critics of cybernetics argued this emergent discipline provided the means for technocratic managerialism to develop, in ways that, in the words of Theodore Rozak, envisaged "man [sic] and social life generally as communicating apparatus" subjected to the science of communication and control (Kline, 2015). Sheldon Wolin criticized the emergence of systems theories from cybernetics as being "without a concept of history," confined to perceiving states of equilibrium or homeostasis, but unable to address "age old problems of social and political dominations" (Wolin, 2006, p. 293). Likewise, philosopher of technology Jacque Ellul advocated against the *machinic episteme*, arguing that "technique pursues its own course more and more independently of man [sic]…[who] is reduced to the level of a catalyst" (Ellul, 1964).

Returning to these historical debates, Shannon Mattern has cautioned against the rise in urban informatics and data-driven urban science as a kind of "methodolatry," which presumes that all kinds of complex urban behavior can (or ought to) be neatly mapped into technical systems (Mattern, 2013). The problem with this model, Mattern argues, is that people's agency is largely reduced to that of consumers and generators of data and are thus subjected to what Hannah Arendt described as a kind of "sterile passivity" (Mattern, 2016, para 31). There is, she argues, an idolatry of method here, endemic to these calculative endeavors, focused more on the functional properties and approaches to measurement itself, rather than on any other particular underlying narrative or outcome (Mattern, 2016). Datafication presumes that all meaningful flows and activity can be sensed and measured, Mattern argues, without questioning the very nature of our stickiest urban problems and the questions they raise.

Debates over the relative potentials of, and limits to, quantified urban science thus continue to follow consistent themes (Krivy, 2018). Ultimately, these debates respond to a set of enduring questions: Can information really be relied upon as an appropriate measure or representation of urban interaction? And what are the consequences of applying scientific concepts relating to systems-based behaviors to understand the nature of cities? Can the human condition, in all of its messy complexity, be captured by a *bit*—or a "hu-bit" as Australian urbanist Stretton once described it—and what are the political and ethical consequences of translating the complex natures of

urban societies into informational ecosystems? These debates over the urban applications of big data continue to be plagued by what Harvey (1996, p. 322) has understood as "discursive struggles over representation," whether in relation to the internet of things and urban big data, or the emergence of cyber cities and virtual reality technologies of the 1990's (Boyer, 1996), or the cybernetics of the 1960's.

Today's data-driven models of urban analysis also present new challenges. The increasing "infrastructuralization" of urban platforms (Plantin et al., 2016) means that data-driven modes of analysis and decision-making are no longer confined to questions of representation—that is, to debates over whether information or data adequately "captures" the realities and complex dimensions of urban life for diagnostic or analytical purposes. Increasingly, big data ecosystems function in ways that actively produce and even accelerate particular urban behaviors and interactions, through a range of incentives, data-driven interfaces, and design interventions.

In the following sections, I examine the productive, performative implications of big data governance through the lens of "platform governance." Here, I discuss how platform governance facilitates asymmetrical conditions of data use and productivity, which accelerate the uneven scaling of data-driven urban intelligence. Conditions of platform governance, I argue, actively re-engineer the possibilities of urban intelligence, implicating the way diverse actors must access, integrate, and leverage big data via negotiations with increasingly powerful platform ecosystems.

GOVERNING URBAN BIG DATA THROUGH PLATFORM ECOSYSTEMS

The "platform ecosystem" is a term often used in business management literature to describe a diversity of relationships intermediated via a digital platform. It is associated with a shift in the nature of firm-level innovation in a digital age, from activities that take place *within* a traditional business structure to those that occur through relatively "open" forums of exchange by diverse external entities. Within business management literature, the platform ecosystem is seen to constitute an "entirely new blueprint for competition" (Tiwana, 2013). Critical to the contribution of platform ecosystems to business development are the kinds of rules put in place to ensure a company is able to benefit from, or leverage, diverse forms of external activity.

In a digitally mediated platform ecosystem, the key infrastructure that achieves this rule-based environment is the application programming interface (API). It is this rule-based operating infrastructure that enables ostensibly "open" forms of programmability to be achieved by digital platforms, while simultaneously ensuring the interactions these new platform innovations achieve also centralize or harvest any underlying data outputs (Helmond, 2015; Mackenzie, 2018; Raetzsch et al., 2019; Barns, 2020a). Facebook, as an iconic example, was able to morph its social media service into that of a platform ecosystem when it introduced the Facebook Developer Platform (FDP). This FDP encouraged developers to make use

of an underlying Facebook infrastructure, expressed through its API, to themselves create new widgets and Facebook "apps," which were, in turn, able to continuously extend the footprint of Facebook's data-harvesting capabilities across the internet. In this way, its platform ecosystem was expanded by external developers, who were acting independently to increase their own value and reach in the digital economy. Likewise, a company like Uber operates as a platform ecosystem through its digital app, which not only consists of its drivers and riders but also incorporates a variety of open source licenses, proprietary platforms (like Google Maps), data centers, cloud computing services, subsidiaries, and broader supply chains, whether of vehicle service providers or hotels, airports, and other industries integral to its capacity to deliver mobility services. Each user and beneficiary of Uber's platform ecosystem is incentivized to extend, for their own purposes, the reach of Uber's own data-harvesting capabilities and therefore the platform's urban footprint. Users can benefit from the service at hand (say, food delivery, or short trips, or urban mobility intelligence), while the platform itself grows in reach, capability, and intelligence, extended by its many diverse users' proliferating data trails.

To achieve these conditions, platform ecosystems must institute specific rules about how data can be accessed and used. These rules, which underpin conditions of "platform governance," are largely put in place through the infrastructure of a platform API. APIs will enable outside third parties to make use of, and access, underlying user data, but only under certain constrained conditions. For example, Uber makes available its 10 billion passenger trips via Uber Movement, and the Uber Movement API, which allows users to customize "views" of the data depending on their requirements (Barns, 2020b). The Uber API will also allow other websites, for example hotel websites or services, to facilitate direct access to Uber bookings. However, the full extent of data being generated through the Uber platform on a real-time daily basis will be kept private from these external digital users. This API infrastructure means that the company monopolizes the ever-expanding data value created when it expands its global reach, harvesting, and modulating globally scalar networked interactions in real-time. Platform intermediation has thus come to be recognized as a powerful mode of data commodification, value extraction, and data governance (Srnicek, 2016; Langley and Leyshon, 2017; Sadowski, 2019, 2020; Barns, 2020a).

Social media scholars, who have studied the operation and governance of platforms for a decade now, have focused attention on how social media platforms have essentially re-engineered the open web. Despite posturing as platforms facilitating open exchange, co-creation, and value sharing, companies like YouTube and Facebook have long been recognized to deliberately enforce highly structured conditions of exchange that politicize their perceived neutrality (Gillespie, 2010). As access to data has become a critical input to wider data-driven value chains, owners of digital platforms—whether basic services like email, social media platforms, or ride-sharing platforms, or internet of things sensing platforms—have further extended their reach in ways that maximize the value of underlying data and accelerate the intelligence of the platform itself (Helmond, 2015; Raetzsch

et al., 2019). Social media theorists understand the governing conditions of platform data through terms like "proprietary opacity" (Mackenzie, 2018), whereby the programmability of platforms, by virtue of their API, deliberately decentralize and extend conditions of data production while simultaneously recentralizing methods of data collection (Helmond, 2015).

Because of the value accorded to big data, platforms will not only act as gatekeepers to data access and use, but they will also institute particular incentives that essentially accelerate how much data are being generated through the platform. This reproductive exchange is critical to the production of platform scale. As van Dijck (2012) has written in relation to the rise of social media:

> What is important to understand about social network sites is how they activate relational impulses, which are in turn input for algorithmically configured connections—relationships wrapped in code—generating a kind of engineered sociality.

Where platforms benefit from the diversity, reach, and volume of digital interactions they accelerate among users, they are continuously modulated through product design strategies in order to incentivize and maximize interactions between users. To early pioneers of today's internet, this was known as a tactic of "intelligence amplification," which resulted from the advance of "internetworking" in asymmetrical ways (Licklider and Taylor, 1968). Today, asymmetrical conditions of access to urban data generated within platform ecosystems ensure those platforms with access to the most amount of data are able to monopolize the extension of AI and machine-learning technologies into new territories (Pasquale, 2016). Technology-based competition is thus characterized no longer as a "a battle of devices" but a "war of ecosystems" (Leminen et al., 2012).

Incentivized to maximize digital interactions between their users, the data governance conditions accelerated by social media platforms are now deeply embedded within conditions of everyday urbanism. This reflects not only technology innovations, like the rise in IoT and mobile broadband, but also the widespread advocacy of platform design strategy across digital entrepreneurship (Church, 2017). As such, new IoT platforms are actively positioned as tools for data cooptation. By connecting more and more "things," technology companies see the potential for ongoing "intelligence amplification" not only between connected selves but also everyday infrastructures, utilities, services, and other ambient conditions, instituting ongoing feedback loops between their connected "users," human or non-human. Underlying data can be on-sold or utilized within their own software offerings, extending the functionality of this software in ways that highly responsive to the needs of its users. The utility of the "thing" lies primarily in its data harvesting capability. With Internet-connected heart-rate monitors and smart thermostats, for example, personal information becomes of value to the data-oriented information economy (van der Zeeuw et al., 2019). Likewise, the integration of IoT sensors and services into home and security settings, urban utilities, and services means that more and more urban activities are bundled up as part of this "software as a service" (SaaS) model of service design.

Just as we may no longer own music, but stream it via online streaming services for monthly fees, so IoT is seen to transform many existing product categories—whether car tires or fridges or watering devices—into platform design opportunities.

The recent influence of major digital platforms such as Google, Facebook, and Amazon, as well as urban platforms like Uber, has thus not only been in the rapid scaling of these particular US technology companies and their accelerated capacity to extract more and more value from the minutiae of urban interaction, trading, and resource allocations. Their implementation of platform ecosystems has also facilitated a more widespread re-engineering of urban data markets away from more "open" ecosystems envisaged by original proponents of the web, and of real-time cities and urban informatics, to that of more disconnected, proprietary data holdings. In their wake, digital entrepreneurs are encouraged to adopt a "platform-play" in their strategic development of company business models, and platform-based digital architecture is widely advocated as a means to achieving digital scale (Simon, 2011; Tiwana, 2013; Choudary, 2015).

These shifts have important implications not only for urban analytics but also to the governance conditions that underpin city behavior and organization. At the firm level, platforms have been seen to deliberately shift employment practices toward a "gig economy" whereby relationships once considered to be defined as employment are now described as "partnerships" (Uber (n.d.)). As individual data points, platform users and their ways of interacting are more easily intermediated when they are individualized and presented as self-serving or market oriented—not only in service to the performance of the platform. Share economy platforms like Airbnb and Zipcar therefore, encourage their users to operate as "micropreneurs" (Botsman and Rodger, 2010), generating ever-expanding "network effects" the more users are brought into their ecosystem. Interface design tactics, like the red colored notification alert, act as "variable rewards" for users and encourage more obsessive engagement with social media platforms, while "pull to refresh" functionality acts as what interface designers describe as "dopamine-driven feedback loops" to promote ever increasing levels of user engagement (Haynes, 2018; Williams, 2018). In this way, platforms enlist their users to create their own value, extend their own networks, attract ever growing attention and "time spent online," and with it, the reach and data-harvesting capacity of their underlying data infrastructure.

PLATFORM GOVERNANCE AND URBAN BIG DATA

Conditions of platform governance ensure the extension of rule-based systems of digital interaction across diverse sites, selves, sensors, and situations. These rule-based conditions are relatively "ambient" in the sense that they are invisible to users who are encouraged to create their own value, content, and services in exchange for underlying data. While the cliché "if you're not paying for it, you're the product" has been known for some time, nevertheless, the degree at which major platforms now monopolize data production has heightened the governance implications of major platform ecosystems. As noted by Weyl and White (2014), strategies to promote data accumulation through conditions of platform intermediation undermine the often-presumed benefits of network effects and raises significant challenges for competition policy.

In this section, I want to summarize some critical implications of platform governance for the use of urban big data. At the beginning of this article, I addressed a relatively traditional fault line in the politics of urban big data, highlighting systemic tensions between, on the one hand, urban data scientists who recognize the potential for big data to be systematically used and analyzed to make better sense of underlying urban patterns and behaviors, and those who see data-driven urban science as particular, narrowly held view of what constitutes urban complexity. As I discussed, if urban citizens are simply data points, critics argue that there is a risk that they are viewed purely as consumers of data, in subsumptive or passive terms, through the calculative endeavors that are becoming endemic to algorithmic geographies. However, conditions of platform governance extend data-driven urban analysis from beyond the calculative to the performative, by engineering entanglements between commerce, code, and corporeality.

This has implications for how we view the politics of platforms. There is, for example, widespread interest in how platforms such as Uber act politically, by using a kind of "reverse innovation process" (Pelzer et al., 2019), or "permissionless innovation" (Chesborough and Alstyne, 2015) to extend their reach without the permission of existing regulatory authorities (Graham et al., 2017). Protocols and infrastructures of data governance also mean that platform governance not only exceeds but deliberately challenge the regulatory capacities of state actors (Swyngedouw, 2005). At the same time, they seek to position their data brokerage services as legitimate to wider modes of data-driven policy making. This echoes the "Janus-faced" nature of governance-beyond-the-state described by Swyngedouw (2005), which looks to institute rule-based systems relating to the "conduct of conduct" across networked conditions of participatory governance and in so doing, seeks to undermine and critique the "excess" of traditional state institutions.

Thus, Uber has used its data analytics to deliberately "grayball" officials seeking to use the app to fine drivers who may be illegally using the Uber app in cities where it has been banned (Wong, 2017). Likewise, a major platform like Airbnb has limited the ability for city authorities to access the information they need about usage of the platform, in order to enforce rules relating to short-term rentals (Wachsmuth and Weisler, 2018). As Wachsmuth (2019) has argued, data in this context becomes a "medium of struggle" between the platform and city authorities. At the same time, platforms seek to gain legitimacy for the insights they are afforded by uneven conditions of data access and machine-learning they institute. Positioning itself as a platform designed to solve urban mobility challenges, the Uber Movement platform shares selected and anonymized data it harvests from its platform as a "tool" for regulators, planners, and other transport users (Uber Movement, n.d.). The data delivered via this platform are sourced from the 10 billion trips taken on the platform,

and features "Uber Movement Speeds" that provides average street speed data to assist with data-driven urban planning. As Fran Bell, the head of data science at Uber has pointed out, "Uber tackles some of the world's most challenging data science problems at scale and in real time [...] We use data intelligently to build better experiences for our users and solve problems at scale" (Vorwerk, 2019).

According to the Uber website, Uber users will inadvertently participate in "upwards of hundreds" of experiments being run by Uber's data team on any one day (Uber, 2019). Long term, Uber seeks to position itself discursively as a "foundational platform" from which to evolve not only ride sharing but also future mobility services, in a world that is rapidly increasing its reliance on autonomous, data-driven services. Uber's ultimate goal is to become "the brokerage of all human movement in cities," an urban data platform that supports integrated, multimodal movement solutions and is capable as acting as the "operating system for everyday life in the city" (Hawkins, 2019: para 4).

The integration of distributed IoT platforms also illustrates a shift in how big data applications are being impacted by platform design models. The integration of IoT in urban management settings is critical to smart city frameworks while also being associated with a more "experimental" and bottom–up approach to urban management and design. IoT has been accompanied by citizen-sensing initiatives (Gabrys, 2014) and "urban living labs," which have incorporated experimental uses of IoT to explore the potential for improved data collection in areas such as water use, air quality monitoring temperature mapping, and citizen engagement (Bulkeley et al., 2016). These experimental approaches in citizen science are also associated with the urban transition movement, which seeks to accelerate the adoption of low-carbon and other urban sustainability initiatives.

However, IoT services also facilitate the extension of platform business models and data governance frameworks into more diverse environmental, domestic, and industry contexts and supply chains. By connecting more and more "things," technology companies are able to create ongoing feedback loops between their users, whose data can be on-sold or utilized within their own software offerings, extending the functionality of this software in ways that continue to adapt to its users. These create "software as a service" models that replace ownership transactions into subscription services, in which data is extracted as the basis for ongoing service transactions between buyers and sellers. As one example, a tire seller could add sensing capabilities to the tires its sells, which over time can be used to provide predictive analytics as a service to its tire consumers. The new tire "owner" is thus locked into ongoing contracts to support more predictive maintenance of the product it has purchased. With Internet-connected heart-rate monitors and smart thermostats, as another example, personal information becomes of value to the data-oriented information economy (van der Zeeuw et al., 2019).

In the smart home marketplace, major technology companies are extending their reach into new service domains. The smart home is increasingly associated with the extension of Amazon and Google-based data ecosystems via IoT devices such as Alexa and Google Home. These platforms institute their own API systems in order to ensure that underlying data are integrated into a rapidly evolving platform ecosystem, as evidenced by Google's purchase of Nest. When Google purchased the smart thermostat company in 2014, Nest had already opened up its API to external developers, but the purchase allowed the Nest ecosystem to contribute to the wider Google data ecosystem. Over the past 5 years, Nest has become more and more integrated into the Google ecosystem as a Google product and as of 2019, requires Google Assistant as a central enabler of its suite of smart home products (Statt and Bonn, 2019). This approach allows Google to better manage the data inputs it receives from consumer uses of its smart home products, in effect "training" them to better respond to the personalized needs of its users. Google executive Rishi Chandra describes this as a future of "ambient computing" where smart home devices are in symbiotic relationship with their users, and where computing power is not limited to a device but an "assemblage" of connected devices.

The implication of this approach is, however, that disparate data sets associated with different data platforms become less transferable and interoperable. As one paper has noted: "Interconnecting heterogeneous devices and services provided by different vendors and providing seamless interoperations across the available platforms still remains a big challenge" (Santofimia et al., 2018). Despite a great deal of enthusiasm about the potential of connected infrastructures and IoT futures, mainstream business commentators recognize the capacity for these connected services to simply replicate the market dynamics that have seen the rise in giant platform companies of the internet (Economist, 2019). Or, as one commentator has observed:

> Imagine driving through dense city traffic using roads without any lane dividers, crosswalks, or signals. It would be utter chaos. That is the reality of the current state of IoT. There is a lack of holistic information design. (Anonymous, 2018)

CONCLUSION

The emergence of global platform ecosystems represents a significant shift in the wider meaning, significance, and applications of big data in urban settings. Rather than analyzing urban ecosystems as "open" and subjected to more intensive information flows, access to urban data is increasingly subjected to more complex negotiations with APIs and platform protocols and rules, which determine levels of data access available (Wachsmuth and Weisler, 2018; Raetzsch et al., 2019). Data, in other words, is a medium of struggle and negotiation, used by platforms to undermine the regulatory competency of state-based institutions by both limiting external access and exceeding state-based data competencies.

If data becomes a site of contestation, likewise, data-driven modes of platform governance also implicate the terrain of "ambient computing," the assemblage of devices and sensors that we interact with daily, hourly, as enacting conditions of intimate enclosure. These facilitate continuous, self-learning feedback loops that incorporate ways of knowing, seeing, interacting, moving, and transacting in cities. Here, citizens, as platform users, are not simply passive consumers of data; their sites of complex entanglements not simply reduced to

data points in an abstracted systems view of the city. Instead, we continuously modulate and cocreate digitally intensive lives, linking corporeal tendencies and machine-learning algorithms in highly performative, coconstitutive ways. In this context, negotiations around data access, including negotiations with platforms and platform APIs, need to become more and more critical to future efforts to enlist and "scale up" the potential of urban big data. These challenges will only become more critical as urban big data is used to better understand, measure, evaluate, and transition urban societies toward more resilient, climate-adapted futures.

AUTHOR CONTRIBUTIONS

FUNDING

REFERENCES

Anonymous (2018). "*IoT is Eating the World: IoT and Rest APIs.*" *IOT for All.* Available online at: https://www.iotforall.com/iot-rest-api/ (accessed January 20, 2020).

Araya, D. (2015). *Smart Cities as Democratic Ecologies*. London: Palgrave Macmillan. doi: 10.1057/9781137377203

Arup, L. C., and UCL (2014). *Delivering the Smart City: Governing Cities in the Digital Age*. London: Arup.

Barns, S. (2012). Retrieving the spatial imaginary of real-time cities. *Des. Philos. Pap.* 10, 147–156. doi: 10.2752/089279312X13968781797913

Barns, S. (2020a). *Platform Urbanism: Negotiating Platform Ecosystems in Connected Cities*. Singapore: Palgrave Macmillan. doi: 10.1007/978-981-32-9725-8

Barns, S. (2020b). "Joining the dots: platform intermediation and the recombinatory governance of Uber's ecosystem," in *Urban Platforms and the Future City: Transformations in Infrastructure, Governance, Knowledge, and Everyday Life*, eds J. Stehlin, K. Ward, A. McMeekin, J. Kasmire, and M. Hodson (London; New York, NY: Routledge). doi: 10.1007/978-981-32-9725-8_7

Batty, M. (2013). *The New Science of Cities*. Cambridge, MA: MIT Press. doi: 10.7551/mitpress/9399.001.0001

Bettencourt, L. (2013). *The Uses of Big Data in Cities*. Santa Fe Institute Working Paper.

Bettencourt, L. M. A., and Brelsford, C. (2015). Industrial ecology: the view from complex systems. *J. Ind. Ecol.* 91, 195–197. doi: 10.1111/jiec.12243

Botsman, R., and Rodger, R. (2010). *What's Mine is Yours: The Rise of Collaborative Consumption*. Manhattan, NY: HarperBusiness.

boyd, d., and Crawford, K. (2012). Critical questions for big data: provocations for a cultural, technological, and scholarly phenomenon. *Inf. Commun. Soc.* 15, 662–679. doi: 10.1080/1369118X.2012.678878

Boyer, M. C. (1996). *Cyber Cities: Visual Perception in the Age of Electronic Communication*. New York, NY: Princeton Architectural Press.

Bulkeley, H., Coenen, L., Frantzeskaki, N., Hartmann, C., Kronsell, A., Mai, L., et al. (2016). Urban living labs: governing urban sustainability transitions. *Curr. Opin. Environ. Sustainability* 22, 13–17. doi: 10.1016/j.cosust.2017.02.003

Chesborough, H., and Alstyne, M. (2015). Permissionless innovation. *Commun. ACM* 58, 24–26. doi: 10.1145/2790832

Choudary, S. P. (2015). *Platform Scale: How an Emerging Business Model Helps Startups Build Large Empires with MinimumInvestment*. Platform Thinking Labs.

Church, Z. (2017). Platform strategy, explained. *MIT Sloan Management School.* Available online at: https://mitsloan.mit.edu/ideas-made-to-matter/platform-strategy-explained (accessed Jan 20, 2020).

Creutzig, F., Lohrey, S., Bai, X., Baklanov, A., Dawson, R., Dhakal, S., et al. (2019). Upscaling urban data science for global climate solutions. *Global Sustainability* 2, 1–25. doi: 10.1017/sus.2018.16

CUSP (n.d.). *About the Centre for Urban Science and Progress.* Available online at: http://cusp.nyu.edu/about-us/ (accessed January 20, 2020).

Economist (2019, September 19). How the world will change as computers spread into everyday objects. *The Economist.* Available online at: https://www.economist.com/leaders/2019/09/12/how-the-world-will-change-as-computers-spread-into-everyday-objects.

Ellul, J. (1964). The Technological Society. Trans. *J. Wilkinson.* New York, NY: Vintage Press.

Gabrys, J. (2014). Programming environments: environmentality and citizen sensing in the smart city. *Environ. Plann. D Soc. Space* 32, 30–48. doi: 10.1068/d16812

Gillespie, T. (2010). The politics of platforms. *New Media Soc.* 12, 347–364. doi: 10.1177/1461444809342738

Graham, M., Hjorth, L., and Lehdonvirta, V. (2017). Digital labour and development: impacts of global digital labour platforms and the gig economy on worker livelihoods. *Transfer Eur. Rev. Labour Res.* 23, 135–162. doi: 10.1177/1024258916687250

Greenfield, A., and Kim, N. (2013). *Against the Smart City (The City is Here for you to Use)*. Amazon Kindle Edition.

Gupta, S., Chen, H., Hazen, B. T., Kaur, S., and Santibañez Gonzalez, E. D. R. (2019). Circular economy and big data analytics: a stakeholder perspective. *Technol. Forecasting Soc. Change* 144, 466–474. doi: 10.1016/j.techfore.2018.06.030

Harvey, D. (1996). *Justice, Nature and the Geography of Difference*. Oxford: Blackwell.

Hawken, S., Han, H., and Pettit, C. (2020). *Open Cities Open Data: Collaborative Cities in the Information Era*. Singapore: Palgrave Macmillan. doi: 10.1007/978-981-13-6605-5

Hawkins, A. (2019). Uber will spend $200 million to expand its Uber Freight trucking venture. *The Verge.* Available online at: https://www.theverge.com/2019/9/9/20856812/uber-freight-200-million-expansion-chicago-headquarters

Haynes, T. (2018). *Dopamine, Smartphones and You: A Battle for Your Time. Harvard Science in the News.* Harvard University.

Helmond, A. (2015). The platformization of the web: making web data platform ready. *Soc. Media Soc.* 1:2056305115603080. doi: 10.1177/2056305115603080

Hill, D. (2013). *On the Smart City: Or, A Manifesto for Smart Citizens Instead. City of Sound.* Available online at: https://www.cityofsound.com/blog/2013/02/on-the-smart-city-a-call-for-smart-citizens-instead.html (accessed January 20, 2020).

ISO (n.d.). *Goal 11: Sustainable Cities and Communities*. Genoa: International Standards Organisation.

Karvonen, A., Federico, C., and Federico, C. (2019). *Inside Smart Cities: Place, Politics and Urban Innovation*. London; New York, NY: Routledge. doi: 10.4324/9781351166201

Kitchin, R. (2014a). The real-time city? Big data and smart urbanism. *GeoJournal* 79, 1–14. doi: 10.1007/s10708-013-9516-8

Kitchin, R. (2014b). *The Data Revolution: Big Data, Open Data, Data Infrastructures and Their Consequences*. London: Sage. doi: 10.4135/9781473909472

Kitchin, R., and Dodge, M. (2011). *Code/Space: Software and Everyday Life*. Cambridge, MA: MIT. doi: 10.7551/mitpress/9780262042482.001.0001

Kitchin, R., Lauriault, T., and McArdle, G. (2015). "Smart cities and the politics of urban data," in *Smart Urbanism*: Utopian Vision or False Dawn? eds S. Marvin, A. Luque-Ayala, and C. McFarlane (London: Routledge).

Kitchin, R., and Lauriault, T. P. (2014). Towards critical data studies: Charting and unpacking data assemblages and their work. *The Programmable City Working Paper 2 SSRN*. Available online at: http://ssrn.com/abstract=2474112.

Kline, R. (2015). *The Cybernetics Moment: Or Why We Call Our Age the Information Age*. Baltimore, MD: John Hopkins University Press.

Krivy, M. (2018). Towards a critique of cybernetic urbanism: the smart city and the society of control. *Plann. Theory Pract.* 17, 8–30. doi: 10.1177/1473095216645631

Langley, P., and Leyshon, A. (2017). Platform capitalism: the intermediation and capitalization of digital economic circulation. *Finance Soc.* 2, 11–31. doi: 10.2218/finsoc.v3i1.1936

Leminen, S., Westerlund, M., Rajahonka, M., and Siuruainen, R. (2012). "Towards IOT ecosystems and business models," in *Internet of Things, Smart Spaces, and Next Generation Networking,* eds S. Andreev, S. Balandin, and Y. Koucheryavy (Heidelberg: Springer), 15–26. doi: 10.1007/978-3-642-32686-8_2

Leszczynski, A. (2016). Speculative futures: cities, data, and governance beyond smart urbanism. *Environ. Plann. A* 48, 1691–1708. doi: 10.1177/0308518X16651445

Licklider, J. C. R., and Taylor, R. (1968). The computer as a communication device. *Sci. Technol.* 76, 21–31.

Lin, J., and Cromley, R. G. (2015). Evaluating geo-located twitter data as a control layer for areal interpolation of population. *Appl. Geogr.* 58, 41–47. doi: 10.1016/j.apgeog.2015.01.006

Luque-Ayala, A., and Marvin, S. (2015). Developing a critical understanding of smart urbanism? *Urban Stud.* 52, 2105–2116. doi: 10.1177/0042098015577319

Mackenzie, A. (2018). From API to AI: Platforms and their opacities. *Inf. Commun. Soc.* 22, 1989–2006. doi: 10.1080/1369118X.2018.1476569

Mattern, S. (2013). Methodolatry and the art of measure: the new wave of urban science. *Places J.* doi: 10.22269/131105

Mattern, S. (2016). Instrumental city: The View From Hudson Yards, circa 2019. *Places J.* doi: 10.22269/160426

McNeill, D. (2015). Global firms and smart technologies: IBM and the reduction of cities. *Trans. Inst. Br. Geogr.* 40, 562–574. doi: 10.1111/tran.12098

McPhearson, T., Haase, D., Kabisch, N., and Gren, Å. (2016). Advancing understanding of the complex nature of urban systems. *Ecol. Indic.* 70, 566–573. doi: 10.1016/j.ecolind.2016.03.054

Morozov, E., and Bria, F. (2018). *Rethinking the Smart City: Democratising Smart Technology*. New York, NY: Rosa Luxemburg Foundation.

Nonnecke, B., Bruch, M., and Crittenden, C. (2016). *IoT and Sustainability: Practice, Policy and Promise Public Symposium*. Center for Information Technology Research in the Interest of Society and the Banatao Institute, University of California Berkeley, Berkeley, CA, United States.

Pasquale, F. (2016). Two narratives of platform capitalism. *Yale Law and Policy Review,* 35, 309–319. Available online at: https://digitalcommons.law.yale.edu/cgi/viewcontent.cgi?article=1716&context=ylpr (accessed January 20, 2020).

Pelzer, P., Frenken, K., and Boon, W. (2019). Institutional entrepreneurship in the platform economy: how Uber tried (and failed) to change the Dutch taxi law. *Environ. Innovation Soc. Transitions* 33, 1–12. doi: 10.1016/j.eist.2019.02.003

Perella, M. (2016). *Big Data and Circular Economy: The Revolution Will be Circular*. Ethical Corporation. Available online at: http://www.ethicalcorp.com/big-data-and-circular-economy-revolution-will-be-circular (accessed January 20, 2020).

Plantin, J.-C., Lagoze, C., Edwards, P. N., and Sandvig, C. (2016). Infrastructure studies meet platform studies in the age of Google and Facebook. *New Media Soc.* 20, 293–310. doi: 10.1177/1461444816661553

Raetzsch, C., Pereira, G., Vestergaard, L. S., and Brynskov, M. (2019). Weaving seams with data: conceptualizing city APIs as elements of infrastructures. *Big Data Soc.* 6:2053951719827619. doi: 10.1177/2053951719827619

Sadowski, J. (2019). *Landlord 2.0: Tech's New Rentier Capitalism*. One Zero on Medium.

Sadowski, J. (2020). *Too Smart: How Digital Capitalism is Extracting Data, Controlling Our Lives, and Taking Over the World* Cambridge, MA: MIT Press.

Santofimia, M. J., Villa, D., Aceña, O., del Toro, X., Trapero, C., Villanueva, F. J., et al. (2018). Enabling smart behavior through automatic service composition for internet of things–based smart homes. *Int. J. Distrib. Sens. Networks* 14:1550147718794616. doi: 10.1177/1550147718794616

Shelton, T., Zook, M., and Wiig, A. (2015). The actually existing smart city. *Cambridge J. Reg. Econ. Soc.* 8, 13–25. doi: 10.1093/cjres/rsu026

Simon, P. (2011). *The Age of the Platform: How Amazon, Apple, Facebook, and Google Have Redefined Business*. Motion Publishing.

Söderström, O., Paasche, T., and Klauser, F. (2014). Smart cities as corporate storytelling. *City* 18, 307–320. doi: 10.1080/13604813.2014.906716

Srnicek, N. (2016). *Platform Capitalism*. Cambridge: Polity.

Statt, N., and Bonn, D. (2019). *Google Nest: Why Google Finally Embraced Nest as its Smart Home Brand*. The Verge.

Sumartojo, S., Pink, S., Lupton, D., and LaBond, C. H. (2016). The affective intensities of datafied space. *Emot. Space Soc.* 21, 33–40. doi: 10.1016/j.emospa.2016.10.004

Swyngedouw, E. (2005) Governance innovation and the citizen: the janus face of governance beyond-the-state. *Urban Stud.* 42, 1991–2006. doi: 10.1080/00420980500279869

Thakuriah, P., Tilahun, N., and Zellner, M. (2017). *Seeing Cities Through Big Data: Research, Methods and Applications in Urban Informatics*. Cham: Springer. doi: 10.1007/978-3-319-40902-3

Tiwana, A. (2013). *Platform Ecosystems: Aligning Architecture, Governance, and Strategy*. Murgan Kaufmann.

Townsend, A. (2013). *Smart Cities: Big Data, Civic Hackers and the Quest for a New Utopia*. New York, NY: Norton.

Uber (2019). *Facts and Figures as at December 2018*. Available online at: https://www.uber.com/en-PK/newsroom/company-info/ (accessed January 20, 2020).

Uber (n.d.). *Uber Guidelines for Third Party Data Requests and Service of Legal Documents*. Available online at: https://www.uber.com/en-AU/legal/data-requests/guidelines-for-third-party-data-requests/en/ (accessed September 22, 2019).

Uber Movement (n.d.). *Let's Find Smarter Ways Forward, Together*. Available online at: https://movement.uber.com/

van der Zeeuw, A., van Deursen, A. J., and Jansen, G. (2019). Inequalities in the social use of the internet of things: a capital and skills perspective. *New Media Soc.* 21, 1344–1361. doi: 10.1177/1461444818821067

van Dijck, J. (2012). Facebook as a tool for producing sociality and connectivity. *Telev. New Media* 13, 160–176. doi: 10.1177/1527476411415291

van Dijck, J. (2014). Datafication, dataism and dataveillance: big data between scientific paradigm and ideology. *Surveill. Soc.* 12, 197–208. doi: 10.24908/ss.v12i2.4776

Vanolo, A. (2014). Smartmentality: the smart city as disciplinary strategy. *Urban Stud.* 51, 883–898. doi: 10.1177/0042098013494427

Vorwerk, M. (2019). *Data Science at Scale: A Conversation with Uber's Fran Bell*. Uber Engineering Blog. Available online at: https://eng.uber.com/data-science-at-scale-a-conversation-with-ubers-fran-bell/

Wachsmuth, D. (2019). "Data and the lack of data in the politics of the platform economy," in *Presentation to University of Toronto Faculty of Information*. Available online at: https://dci.ischool.utoronto.ca/2019/09/03/prof-wachsmuth-data-and-the-lack-of-data-in-the-politics-of-the-platform-economy/ (accessed January 20, 2020).

Wachsmuth, D., and Weisler, A. (2018). Airbnb and the rent gap: gentrification through the sharing economy. *Environ. Plann. A Econ. Space* 50, 1147–1170. doi: 10.1177/0308518X18778038

Weyl, E. G., and White, A. (2014). "Let the best 'One' win: policy lessons from the new economics of platforms," in *Coase-Sandor Institute for Law and Economics Working Paper* (Chicago, IL). doi: 10.2139/ssrn.2524368

Wiig, A. (2015). IBM's smart city as techno-utopian policy mobility. *City* 19, 258–273. doi: 10.1080/13604813.2015.1016275

Williams, J. (2018). *Stand Out of our Light: Freedom and Resistance in the Attention Economy*. Cambridge: Cambridge University Press. doi: 10.1017/9781108453004

Wolin, S. (2006). "Whose Utopia?" in *The Universitas Project:* Solutions for a Post-Technological Society, ed E. Ambasz (New York, NY: MOMA), 291–293.

Wong, J. (2017). Grey ball: how uber used secret software to dodge the law. *The Guardian*. Available online at: https://www.theguardian.com/technology/2017/mar/03/uber-secret-program-greyball-resignation-ed-baker