Smart Cities in the Post-algorithmic Era

Integrating Technologies, Platforms and Governance

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9. A world of data: Underworlds and health challenges in the age of smart cities

Snoweria Zhang, Fábio Duarte and Carlo Ratti

9.1 INTRODUCTION

Technology has always had life-changing impacts on city development, and the popularization of digital technologies indubitably adds new dimensions to urban dwelling. In waves, twentieth-century scholars have speculated that electronic media would render physical spaces obsolete or, at the very least, diminish their role in social life. This prognosis has proven to be untrue. Digital technologies have, in fact, become integral tools in placemaking and identity construction (Duarte, 2018). In today's digital platforms, search results center around one's geo-location and prior preferences; news is delivered not only in real-time but also based on site-specific tastes and the proclivities of individuals. Personal behaviors can adapt in response to situations and environments: an individual might leave work later to beat traffic or avoid the rain, letting real-time information dictate their decision-making rather than routine or habit. This astounding level of precision means that technological platforms are able to gather information and provide live feedback, which in turn generates unprecedented opportunities for cities and their denizens to evaluate their milieus. With newly available data, historically unseen dimensions of urban life are now rendered visible. In turn, planners can use these technological services to empower individual citizens.

In the physical realm, infrastructures and networks that were previously thought of as obsolete can be repurposed with the aid of new data and tools. The emergence of the Internet of Things (IoT), digital technologies embedded in physical space, and smart materials that react to the environment all indicate that there is hardly any divide between physical and digital domains. More frequently, digital technologies have infiltrated the physical realm of urban environments, forming a complete convergence of bits and bricks tied together by cheap, small, and powerful computers. It is expected that more than $108 billion worth of investment will have been dedicated to smart urban technologies by 2020 (Vanky, 2014). The melding of emergent technologies and existing infrastructures is at the core of this chapter.

However, there is another aspect of the so-called smart cities that requires a critical approach: the ease of access and the abundance of data is a double-edged sword. While digital technologies can be transformative in the ways we use and manage urban infrastructures and problems, the right to privacy will be entirely redefined (Svenonius, 2018). The astronomical amounts of data that pervade our daily lives are no longer just an additional layer resting on top of the urban fabric – a layer that we could eventually remove. With information technology permeating through multiple aspects of social life, avoiding sharing information about oneself and abstaining from social media platforms are no longer sufficient for protecting one's privacy. In most current frameworks, opting out is already impossible. Instead, an urban dweller's mere existence makes one visible to the all-seeing eyes of data. This ability to sense is empowering and threatening at the same time, and cities ought to vigilantly negotiate a moving balance – one that enables them to provide the necessary service without intruding upon the privacy and agency of citizens. How smart city endeavors choose to synthesize these two opposing goals will be crucial for their future development.

In this chapter, we will focus on public health as one key dimension of the smart city movement. Jane Jacobs (1961) marvels at cities' ability to cope with health problems with a combination of hygiene and microbiology, telecommunications, and public health measures. Jacobs' representation of cities and their potentials is especially pertinent in the digital age, where the availability and concentration of data are enhanced by the capacity for interpretation. With the aid of data-driven tools, small design decisions can change the course of a city's history and development. Therefore, through the lens of public health and Underworlds, a project jointly developed by the Senseable City Lab and the Alm Lab at MIT, we will examine the potentials and polemics of smart cities and data-enabled urban design. The project combines genomics, robotics, and urban planning to tackle public health problems. It gives us the ability to more accurately evaluate the effectiveness of public policies while allowing citizens to gain new insights into their own behavioral patterns. Of course, the growing ability to generate and record high dimensional data also raises the question of ownership and privacy, which we will critically explore in the latter half of the chapter.

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9.2 UNDERWORLDS

In the 1850s, London suffered a severe outburst of cholera. As hundreds of infected Soho residents perished, doctors floundered in their search for the source of the disease. With little to no systematic knowledge in microbial life, identifying the precise cause of cholera took decades and was thwarted by countless hurdles along the way. John Snow, a successful anesthesiologist fascinated by cholera, spent his spare time drawing maps of infected neighborhoods in an attempt to identify the origin of the disease. Eventually, after much contentious debate with some of the most prominent medical professionals in London, Snow traced the source to a water pump on Broad Street. Soiled clothes contaminated by a diseased baby in the neighborhood had spilled some of their contents into the area's drinking water supply. Eventually, removing the handle of that water pump prevented many more from being infected and thus began the course of modern epidemiology. Snow's maps are widely considered the first instance of disease mapping at the city scale.

John Snow's tale is a prime example of how small design interventions can reveal and solve big problems. Underworlds, an ongoing project at MIT, is a contemporary rendition of Snow's story. The project combines urban analysis, robotics, bioengineering, and genomics to paint a microbial portrait of the urban environment. To study health trends and disease patterns at a fine-grained spatial and temporal level, researchers at the Senseable City Lab and Elm Lab designed bespoke robots that dive into city sewage to sample its bacterial content. The network of automatic samplers works underground to collect data about health trends at a high resolution, which gives researchers unprecedented tools to analyze the many facets of urban dwelling and public health. These *in situ* sampling instruments can help build a database of geo-tagged bacteria profiles and spatially relate them to chronic health conditions. As human gut microbial communities have been associated with many diseases and could be used as indicators of nutritional status and overall health, this trove of rarely collected data will allow a city's hidden dimensions in public health to unfold and tell tales of their own. Of course, since they work mostly in sewage, the robots are aptly nicknamed Mario, Luigi, and Yoshi.

Since Snow's era, scientists have certainly realized and appreciated the amount of information available in sewage and wastewater. Yet, the gathering and analysis of data have been anything but easy. Typically, existing methods rely on samples from wastewater treatment facilities. While these downstream samples are able to provide some insight, the facilities where they are collected are situated so far away from city centers that the presence of human bacteria drops to 20–30 percent (Newton et al., 2015). By sampling closer to where the wastewater is produced, Underworlds more accurately captures information that is reflective of the varying realities of different neighborhoods. In fact, about 50–70 percent of bacteria in upstream sewage water, where Underworlds devices operate, are of human origin. With this increased level of accuracy, Underworlds is able to sample at a much higher resolution and closer to real time.

One of the inceptional goals for this project was to identify contagious disease outbreaks. In an interview with the Canadian Broadcasting Corporation (2016), Underworlds researcher Jessica Snyder said, "long before people visit doctors' offices, they visit the toilet. So a highly contagious pathogen, such as norovirus or Ebola, could be identified soon after infection – and treatment could be targeted at that neighborhood." This not only helps health professionals identify risks sooner, but it also means that information that is typically not available at such a fine-grained level can be made available to researchers. Eric Alm, one of the principal investigators of the Underworlds project, argues that bacteria from sewage can help scientists gather crucial information on the spread of antibiotic-resistant genes. Moreover, the Underworlds paradigm allows health professionals to move beyond the individual and analyze trends and patterns at an urban scale. Other than refining our present ability to detect and respond to pathologies, the technologies described here will give life to a data platform that aims to guide public health policy, municipal strategy, urban planning, and epidemiological science in a larger sense. In this vision, the platform self-perpetuates and evolves, allowing governments and corporate entities to use it as a foundation for answering emerging questions in ways that venture beyond the current framework. As a result, cities are able to measure the effects of policy changes and other public health interventions, such as a sugar tax and bans on certain substances.

The combination of scientific measures and public policy is an invaluable tool for effecting change. In Kuwait, sugar consumption among children, especially via soft drinks, is one of the highest in the world. The figure almost doubled between 1991 and 2005, from 19 to 37 kg per person per year (Honkala, 2013). Likewise, Kuwaitis have some of the highest salt intakes in the world (Jawaldeh and Al-Khamaiseh, 2018). High salt intake can result in a variety of health issues, especially cardiovascular diseases, due to increased blood pressure (Jawaldeh and Al-Khamaiseh, 2018). The Kuwaiti government, in response, has implemented legislative measures to combat the problem at an urban scale, but the effects of these laws and regulations are not yet clear. In this regard, upstream wastewater sampling can provide a unique opportunity to help analyze if particular neighborhoods' salt intake has diminished as a response to regulatory changes. In addition, Underworlds allows government officials to treat public health concerns as a spatial problem and, in conjunction with demographic information, to pinpoint the areas where an issue is more dire.

On the other side of the world, Massachusetts is situated at the epicenter of the opioid crisis. As a result, the primary interest there for Underworlds is to identify spikes in heroin usage. This not only helps governments to better deploy law enforcement, it more importantly helps cities to efficiently distribute health resources to areas in need. In the case of heroin usage, specifically, users frequently are not aware of the precise composition of the product they consume. For instance, one of the most insidious aspects of the opioid crisis stems from heroin laced with fentanyl (Somerville et al., 2017), which is much more potent and has a different metabolite than heroin (Boleda et al., 2009). Where illicit drugs are concerned, traditional methods such as surveys and self-reporting are not particularly useful or accurate. Meanwhile, contents in the sewage contain much of the information that researchers need and are not subject to response bias. As Ort et al. (2014) demonstrate, wastewater analysis is already producing interesting results that allow researchers to collect information that can be difficult to gather otherwise. Yet, due to the amount of work involved, the aforementioned study only samples one week of data every year for three years. The lack of both spatial and temporal repetition inevitably leads to gaps in the narrative. Comparatively, analyzing sewage content at a neighborhood level, as in Underworlds' case, is much more precise and reflective of human activities, particularly in the case of illicit drug usage. As an interesting corollary, Massachusetts is on the verge of fully legalizing recreational use of marijuana. With this move, cities might be interested in measuring usage patterns of marijuana and other drugs with the change in marijuana's legal status.

Using sewage to analyze the bacterial composition of a city is not an entirely new technology. The aforementioned study by Ort et al. uses samples collected at wastewater facilities across 23 European cities to analyze drug-use patterns for a few different illicit drugs, from cocaine to Methylenedioxymethamphetamine (MDMA). It is clear that opportunities are abundant in the drains. Similar to John Snow's mapping of the London cholera outbreak, sampling at a system level can frequently lead to solutions to problems that were previously thought of as mysteries. Steven Johnson's *Ghost Map* (2006, p. 96) argues that "a city and a bacterium are each situated at the very extreme boundaries of the shapes that life takes on earth . . . with the exception of the earth's atmosphere, the city is life's largest footprint. And microbes are its smallest." If we are able to combine and connect clues from both ends of the extremity of the urban fabric, then the insight has the potential to solve salient urban problems.

The true potency of a smart sewage system, however, is not just in detecting illicit drug usage and salt intake; it manifests at the scope of public health. In an interview with Sophie Weiner (2016), Underworlds researcher Mariana Matus argues that "often, data from the people with the most problems isn't recorded, because they don't go to the doctor. But everyone contributes to the biology of the sewage system, whether they think about it or not." This is a byproduct of the Big Data movement that projects like Underworlds have begun to harvest. Rather than inventing new technologies with a high barrier to entry, cities can investigate ways to tap into existing infrastructure and resources. This is not least because it would be cost-effective; it provides inclusive opportunities to those whose voices are often not heard through glossy, high-tech endeavors. Luque-Ayala and Marvin (2015, p. 2111) point out that when it comes to smart urbanism, one of the biggest problems is that "the data do not accurately reflect the social world and instead there are significant gaps, with little or no signal coming from particular communities." Smart city projects that shift the focus away from pricey gadgetry and instead onto existing but perhaps formerly inaccessible information can be inherently more egalitarian. If accessibility and equal representation are hallmarks of successful urban projects, then reappropriating existing infrastructure can play an important role in achieving that goal.

More broadly speaking, the paradigm set forward by projects like Underworlds is an important tool for developing narratives for smart cities in the face of unknowns. "Existing research in the field has focused on the technical, engineering, and economic dimensions of smart systems. This research tends to have a 'problem solving' focus, concerned with achieving optimal outcomes for smart systems under current technical, political and market conditions" (Luque-Ayala and Marvin, 2015, p. 2107). Currently, almost all major information-technology companies have a "smart city" package to offer, and governments throughout the world are buying off-the-shelf solutions. However, these products primarily focus on optimizing urban systems and services and improving management – operating within a framework that views "smartness" as a synonym of efficiency, economy, and profitability. While such traits are relevant aspects of city management and are not insidious per se, positioning efficiency as the focal point of smart city initiatives risks driving public agendas by corporate interests. Underworlds, on the other hand, is galvanized by an existing problem (to measure the salt and sugar intake in Kuwaiti residents), but its open-endedness has afforded many other unforeseen discoveries. Instead of problem solving, the project utilized existing infrastructure to mine for potential questions and to fill knowledge gaps in the process. As we generate and exchange new information, "smartness" should also help us understand different human behaviors that arise when confronted with unexpected situations. In addition, the ability to collaborate with governments and to use existing frameworks to invent novel methods is crucial in establishing a sustainable future for smart city development. In this manner, Underworlds mines new knowledge without lumbering infrastructural reinventions and can be replicable across sites.

In a decade where urban development is defined by new technologies, cities ought to be exceptionally mindful of its existing fabric and the opportunities it holds. Adopting the ability to mine these potentials and inherent "smartness" is likely to yield more equitable and sustaining results.

9.3 DESIGN OF THE DATA COLLECTION SYSTEM

In order to understand the physical sewage network underground and to characterize human activities above ground, MIT researchers from across disciplines started with mapping the existing infrastructure. The output of this work helps describe the catchment areas of the collected samples and allows for the deduction of biological and urban planning conclusions. Underground sewer networks and the flow direction of sewer are modeled and visualized in a digitized system.

In modeling the sewage network, the maps of sewer network and the elevations of pipes are required. All the information is geo-referenced and then formatted as geometric networks with proper connectivity rules. Once a geometric network is built, the flow direction and the upstream network (which then determines the catchment area) can be calculated. In the analysis, we also distinguish sewer, stormwater, and the combined systems in order to ensure the quality of data collections. The result is a dragnet medical screening method to measure the bacteria profile produced by the humans in a given residential sector of a city. The geo-tagged database of bacteria profiles will enable later work heat mapping human health within metropolitan areas. To resolve the where and how of residential wastewater sampling for bacteria, a sampling point was selected, the time of day to sample was determined, and an automated tool was engineered. Geographic information system (GIS) expertise guided the selection of a sampling point by cross-referencing the city's wastewater network maps with census data, identifying a catchment with a residential land use > 90 percent and a population > 2,000. Deployed in the selected location, the sampling instrument integrated motion and filtration sub-systems to concentrate bacteria on a filter, capturing a representative fraction of the flow's microbial community. The instrument's ability to collect an authentic representative was comparable to direct processing of the raw wastewater.

This in turn allows researchers to address the significant medical and data science challenges to deploy a network of *in situ* sampling instruments, build a database of geo-tagged bacteria profiles, and translate the measure profiles to chronic health conditions.

Throughout the project, researchers worked through four iterations of prototypes. As the robots' primary work milieus are city sewage, they are nicknamed Mario, Luigi 1.0, Luigi 2.0, and Yoshi. While the initial prototypes require the collected samples to be promptly transported to MIT for filtration and testing, Yoshi is designed to be easily customizable for various deployments and capable of staying inside the manhole. Sensors and microcontrollers help enable time-based sampling. PWM (Pulse Width Modulation)-based pump control allows the user to change pumping speed and enable dynamic sampling in which pumping speed needs to dynamically vary depending on the flow rate of sewage.

The communication network is a critical part of integrating a distributed network of sampling devices. A communication module is installed below the manhole cover and connected to a sampling device via a wired cable. The device transmits sensor data and other system parameters indicating its state such as remaining battery level, wastewater volume in the sampling bottle, etc. The researcher can receive data through either Zigbee-based or cellular network-based communication from each sampling device in real-time, change system parameters such as sampling time, sampling rate, and sampling volume, and initiate sampling of each device. The sampling devices equipped with a communication module are then able to share sensor data and communicate with a central control station designed to oversee the operation of the sampling devices during deployment.

9.4 DATA IN THE AGE OF PRIVACY

We are situated in a pivotal moment as smart city initiatives gain impetus worldwide. Endeavors like Underworlds are being developed at a time when scrutiny on data ownership has gained renewed civic interest. The recent spike in public distrust towards companies that harbor our information is a salient barometer for future directions of the discourse. Frequently, with more thorough services, there is also mounting concern over personal privacy. Increasingly high resolution and accuracy in our digital footprints are enabling both citizens and governments to make more informed decisions – decisions about things ranging from choosing a restaurant to national security. Therefore, for the remaining portion of the chapter, we will critically examine some of the privacy concerns that arise with the growing reliance on and ability to capture data at the urban scale.

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As discussed earlier in this chapter, the wastewater samples and responses collected upstream are much more comprehensive and less biased than those gathered by traditional data collection methods in epidemiology. For instance, health authorities currently monitor the emergence and spread of influenza and gastroenteritis-related outbreaks through samples of hospitalized patients, but this limits surveillance until long after the time of infection. For instance, given the large movement of people in the annual Hajj pilgrimage to Mecca in Saudi Arabia, timely information on these diseases is crucial for public health in the Gulf region. However, while these conventional approaches (e.g. surveys or *ex post facto* sampling) might harbor more inaccuracies, they also inherently allow for the subjects to refuse participation. In the process of removing the "personal" from the information harvesting processes, smart data collection methods have, in conjunction, eliminated user agency and the opportunity for subjects to make an active decision about the rights to their information. In fact, most users are frequently unaware that their data profiles are culled and commercialized. This may not appear to be a grave issue in isolated instances. As a general policy, however, denying a user the opportunity to refuse participation is a concerning yet prevalent practice in recent cases. The digital age has rendered data a valuable currency. So far, private data harvesters such as Google and Facebook have dominated the landscape. The open data movement, while commendable for facilitating access, has yet to become a game changer; the information that has been "opened" so far was already available in one form or another (urban Geographic Information System, for example). As the open data movement gains momentum and more proprietary information gets unlocked, ownership over one's data and privacy will likely become a contentious point.

Where Underworlds is concerned, similar polemics over data privacy and civil liberty arose in the research process. At the scope of urban epidemiology, Underworlds has implemented a series of projects ranging from tracking infectious diseases (influenza, rotavirus, etc.) to the emergence of antibiotic resistance and the effects of policy on public health (e.g. obesity). Especially in Kuwait, the project has served to expand cutting-edge genomics and the capacity for urban informatics immensely. Through the refinement of digital urban technologies, Michael Batty's (1997) vision of the "computable city" has evolved into the reality of what Rob Kitchin and Martin Dodge (2011) refer to as a combination of code and urbanism. Our dynamic ability to sense a city's activity, understand its fluctuations, and deliver tailored responses to meet the needs of the urban environment has increased tenfold. Underworlds, in particular, is able to add entirely new dimensions to our ability to capture the behaviors and needs of urban populations. The project's rapid, geo-localized monitoring of a population's aggregate biological signature as present in the sewers offers new possibilities for the study of urban health and sanitation patterns. This is especially salient in the case of non-communicable diseases, because biomarkers for conditions such as obesity and diabetes can be measured at an unprecedented spatial and temporal resolution.

At the urban level, Underworlds provides a fine-grained contextualization of health-related data by correlating biometrics with comparatively more static variables such as demographics, wealth distribution, and urban density coefficients. While it is Underworlds' intellectual prerogative to sequence the city and to capture a community's collective metabolism, the researchers are also duly aware of its privacy implications. Health information at the resolution of neighborhoods and blocks can be easily packaged and commercialized. The immense capital potential and personal liability make projects like Underworlds full of exploitative dangers. Finding the sweet spot between providing fast and accurate services and protecting privacy is a balancing act and a rather difficult one. This is especially pertinent when data is used predictively, which is frequently the case with today's technological products. Underworlds, for instance, can contribute tremendously to predicting epidemics and other human health trends, but it can also reveal extremely private behavioral patterns. Even at the neighborhood level, identifying differences in the consumption of certain substances can unintentionally stigmatize particular areas of the city.

How, then, might research projects mitigate this polemic? Of course, there is a confounding factor between being able to identify, monitor, and implicate individuals versus actively using the data to do so. Currently, privacy concerns are allayed through two means: aggregate data collection methods or laws that explicitly protect an individual's right to privacy. Typically, smart city projects take solace in their use of aggregated and anonymous data. It is certainly true that researchers go to great lengths to de-identify the data they receive, and any scrutiny analogizing these efforts with surveillance is appeased with the presumed anonymity. As a baseline metric, the amount of data collected in Underworlds is not enough to assemble individual genomes. In addition, each sample contains on average 4,000 households. While it is a drastic improvement in spatial resolution from samples collected at wastewater treatment plants, it is too blurry for any individual's profile to be readily revealed. However, even when single entities cannot be identified through aggregated data representations, other types of insidious ramifications can still arise. For instance, Sanfeliu et al. (2010) discuss the possibility to select persons "without focusing on the concrete characteristics of the individual." In this sense, datasets can be used to form biases and reinforce stereotypes without overt personal identification markers. While there exist legal frameworks for the protection of data privacy, they don't usually apply in cases where the data is anonymous. Furthermore, when actionable decisions are made based on the data, mistakes and biases can proliferate quickly and at a scale that is difficult to control.

Consequently, individual anonymity in data collection can be comforting to the general public but does not completely eliminate troubling results. Legislatures concerning privacy, on the other hand, already exist to a large extent for many other aspects of our daily lives, but the problem is that they have trouble keeping pace with the wave of digital gadgets that emerge from research labs, technology giants, or international conglomerates. Legal definitions of privacy and its infringement are comparatively clear in the physical realm, but there is substantial contestation over what privacy truly means in the digital domain. For instance, in most cases involving law enforcement, DNA "abandoned" at crime scenes is no longer private property – similar to hair or fingerprints left in public (Joh, 2006). The problem arises when this kind of thinking is applied to projects like Underworlds. By extension of the "abandoned DNA" logic, information that one flushes into the public sewage system could be equally considered as belonging to the public. Despite reassurances from researchers that the data is collected at an aggregate level, the ability to freely gather content and to zoom into 4,000 households at a time is still quite chilling. This kind of information, when combined with other profiling tools, can give one the ability to focus in on relatively small social groups in unwarranted ways. The sharing of health information has proven to be essential for ensuring effective public health measures, and Underworlds can certainly offer immense benefits as cities become increasingly digitized. However, the perils around privacy as discussed above indicate that a public debate is much needed.

In the United States in particular, there has been a cultural and legal shift in the way that data privacy is considered. Many data-collecting agencies appease users by promising that they will not be using the data for the purpose of identifying individuals, even when they have the ability to do so. However, a few recent cases in law enforcement can shed light on the shifting role technology plays in private citizenship. In fact, the Supreme Court, in its 2018 session, faced a crucial decision that proved to be a key precedent for future data-related cases. In *Carpenter v. United States*, Timothy Ivory Carpenter was involved in a number of RadioShack and TMobile robberies. During the investigation and conviction, the police department used location data obtained from cellphone towers as evidence that he had been near the robbery sites at the time of the crime. However, since law enforcement did not obtain a search warrant, the granting of which requires probable cause, the case went all the way up to the Supreme Court. The argument mainly centered on the government's use of cellphone data without a warrant and whether it violated Carpenter's Fourth Amendment rights. The Fourth Amendment of United States Constitution states that "[t]he right of the people to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures, shall not be violated, and no Warrants shall issue, but upon probable cause, supported by Oath or affirmation, and particularly describing the place to be searched, and the persons or things to be seized" (2002, pp. 44–5).

Arguments from both sides mostly fell into two categories: that about the third-party doctrine and the public's understanding of their own privacy. The government argued that since the plaintiff had turned over their cellphone data willingly to a third party (in this case, the phone company), he has forgone the right to privacy claims. In other words, there exists no need for a search warrant because the privacy claims were unfounded in the first place. In further argument, the government claims that the user of a cellphone service should not have any assumption of privacy, since he signed over his data to the company in an agreement. However, in opposition, Chief Justice John Roberts argued in the opinion of the court that today's technology has become so extensive and complex, "the fact that such information is gathered by a third party does not make it any less deserving of Fourth Amendment protection."[1] In fact, the Wireless Communication and Public Safety Act of 1999 states that "every telecommunications carrier has a duty to protect the confidentiality of proprietary information of, and relating to . . . customers" (47 U.S. Code § 222). Broadly, this provision could mean that in a world where everything and everyone is a sensor, the individual data collectors are potentially also charged with the duty of data protection.

This is precisely the kind of challenges faced by Underworlds. Anonymity and legislation are not necessary and sufficient guarantees for complete privacy. In fact, many studies (e.g., Ahas et al., 2010; Isaacman et al., 2011; Xu et al., 2017) have developed methods for estimating home and work locations from Call Detail Record datasets collected in Singapore. For instance, Xu et al. (2017) identified home locations as the most used cellphone tower between 19:00 and 06:00. While crude, these methods are already able to reveal intimate and perhaps even incriminating details about an individual.

In a sense, the privacy concerns that arise with these types of smart city projects is not that someone now has access to our information, but rather that they have the tools to be able to decode it and draw conclusions from it – particularly information that we did not elect to put out there. In

[1] https://www.supremecourt.gov/opinions/17pdf/16-402_h315.pdf.

Underworlds' terms, the fact that researchers are collecting the contents of our sewage is not what is most concerning; the night soil men of Victorian England actually made a good living performing similar tasks. Rather, what alarms most privacy enthusiasts is the fact that researchers are gathering the contents of sewage and extracting information from it, most likely information that we do not even have ourselves. The legal gray area, at least in the United States, is that it is unclear to what extent the constructed data belongs to an individual and can be protected as a right. What this means is that the perspective on civic participation has changed; every citizen is a sensor and can be sensed. To some degree, this has always been true, but the growing ability to interpret the troves of information and to make decisions based on it is the basis of the new existential dread. It is the prerogative of any smart city development to negotiate this potential danger.

9.5 CONCLUSION

While scientists and those involved in the smart city endeavors are excited about the prospect of having unprecedented data, the general public is becoming increasingly wary. Researchers, technology companies, governments, and the like need to find ways to express the usefulness of Big Data without compromising the right to privacy. The current narratives (i.e. anonymity and aggregation) would not be sufficient in ensuring public trust as the technological capabilities grow. To a large extent, the onus is on the producers and guardians of technology to clearly communicate to users their precise data footprint. In addition, ownership of an individual's data will demand more critical engagement and public discourse. This extends beyond the raw data that is being collected by platforms; it also must include information that can be inferred. Moderating privacy is made even more challenging by the fact that the concepts and definitions involved (i.e. how we conceive of privacy) are highly volatile and will certainly change, likely in very short time spans, as new technology emerges. Therefore, who gets to make these decisions will play a key role in smart cities' development.

It is indisputable that Big Data and their urban reincarnations have the ability to redefine the city fabric of the future. Projects like Underworlds, especially, are quickly reformulating the way we conceive of infrastructure and our relationship with it. Smart city ventures that expand upon existing paradigms have the advantage of quick deployment and adoption. Consequently, existing information can be gathered, analyzed, and interpreted to reveal useful facets about unseen dimensions of urban life. This ability to systematize data at a fine spatial and temporal resolution will prove to be extremely valuable, especially in areas where other mechanisms are not readily available. With a sensible eye toward how these endeavors respond to and evolve with the blurring boundary between public and private, they will allow cities and their citizens to collectively harness the boundless opportunities smart cities promise.

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