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22. Seeing like an urban service operator: making urban circulations of matter and energy legible in the digital age

Morgan Mouton

Urban services are increasingly being integrated with digital technologies, under the auspices of the ‘smart city’ (Marvin et al., 2015; Picon, 2018). This trend has been brandished as a solution for more efficient resource management by industry actors and consulting firms (e.g., Ballard et al., 2018; Deloitte, 2019). For the proponents of ‘smart utilities’, digital technologies improve services for end-users, allow for real-time control of urban metabolism and increase overall system efficiency. By contrast, a growing number of in-depth analyses in cities of the global North (Levenda et al., 2015) and South alike (Guma, 2019; Pilo, 2021) have emphasised that the depoliticised vision offered by the proponents of smart cities conceals highly political questions that have to do with democracy, citizenship and socio-spatial justice (Sadowski and Levenda, 2020).

This chapter aligns with such calls to re-politicise urban service provision. More specifically, I will focus here on energy, water and waste-management services, and explore the ways in which they are undergoing forms of ‘digitalisation’. By this, I mean the integration of hardware within existing infrastructure (e.g., sensors) to generate data on the socio-technical system, as well as the use of new software to process and act on these new data (e.g., the use of algorithms to detect leaks in the system). Against this backdrop, I seek to explore the interplay between streams of data on the one hand, and streams of matter and energy on the other hand. More specifically, I draw attention to how data are generated to better identify, localise, quantify and/or visualise urban metabolism – and raise the question of how they ultimately lead to actual transformations of urban flows of matter and energy. In doing so, I answer to recent calls for better articulation of scholarship addressing infrastructures and the distribution of resource flows. Indeed, Coutard and Florentin (2022 and 2024) argue that while considerable progress has been made by urban political ecology scholars to examine the uneven distribution of natural resources by urban infrastructure, much less attention has been directed at the extraction, transformation, degradation and depletion of resources. Focusing on how infrastructures increasingly include digital technologies that facilitate the visualisation of resource metabolism is one way to contribute to these debates and work towards paying greater attention to the materiality of resources.

With these elements in mind, this chapter seeks to develop a research agenda for thinking about the digitalisation of urban services by drawing attention to several questions. Do data slow, accelerate and/or (re)direct urban flows? Are data produced evenly across territories? If not, what are the consequences for the blind spots of data generation – for service operators as well as for end-users? Throughout the chapter, I will mobilise James C. Scott’s (1998) concept of *legibility*. It will allow me to explore how data deriving from the digitalisation of urban services are instrumental to making urban circulations visible, thus rendering them *governa-*

ble. But it will also highlight the process of simplification that digitally enabled visualisations operate, and raise the questions of what is *not* made visible – and why.

In developing such research perspectives, the present chapter resolutely adopts a broad geographical scope, which balances scholarship produced on the North with examples taken from cities across Africa, Latin America, and South and Southeast Asia. The argument for further exploration of infrastructure provision in cities of the global South is now well established, with scholars responding to the call for a provincialisation of studies on infrastructure (Furlong and Kooy, 2017). The rationale behind this geographical decentring is that Southern urbanism offers more diverse and heterogenous infrastructural configurations (Lawhon et al., 2018), sometimes characterised by a high degree of service co-production (Moretto and Ranzato, 2017). Guma (2022) further advocates for the examination of marginal cities of the global South (i.e., geographically and economically peripheral spaces), where he contends that we might encounter unexpected and citizen-centric solutions to urban and infrastructural challenges. Overall, just as the ‘smart city’ agenda has taken a postcolonial turn in recent years (Datta, 2019), this chapter acknowledges that research on urban infrastructure and service provision also needs to account for Southern urbanism.

This chapter will first offer an account of the digitalisation that urban services are undergoing: what it means, which technologies are involved, and who deploys them (first section). I will then present key concepts for the analysis of digitalisation’s consequences on service delivery and urban metabolism, namely *legibility* and *(in)visibility*, highlighting that digitally enabled knowledge can be a source of empowerment, but also of discipline for end-users (second section). Finally, I will expand on three distinct, yet interrelated potential consequences of digitalisation: the centralisation, control and commodification of urban metabolism (third section), before offering concluding remarks and proposing a methodological approach, *digital ethnography*, to engage with the research perspectives raised throughout this chapter.

MAKING SENSE OF THE ‘DIGITALISATION’ OF URBAN SERVICES

International consulting firms are unambiguous: the future of infrastructure is digital (see, for instance, Deloitte, 2019; McKinsey & Company, 2019). One of them, Altran (2019), further claims that the ‘digital utilities market’ will reach USD 299 billion globally by 2025. City administrations have followed suit, and invested in software and hardware – what Luque-Ayala and Marvin (2020) call ‘urban operating systems’ – aiming at increasing the quality and environmental sustainability of urban services through the fine-tuning of urban infrastructure management. These market solutions rest on a key assumption: more data and more accurate information will lead to improved services (D’Amico et al., 2022).

Of course, this idea is far from new, and the collection of data on urban environments has played a major role in the design of urban infrastructures (the sizing of water drainage systems in 19th-century Europe provides a good example here: Chatzis, 1993) or in their management and maintenance (Denis and Florentin, 2019 and 2024). The ability to transmit data has also been a condition for the expansion of large technical systems – think for instance of how the telegraph was used to standardise Greenwich time throughout Great Britain, as a response to mounting expectations for the ever-growing railway network to offer more punctuality in the Victorian age (Morus, 2000). Nevertheless, digital technologies have brought new develop-

ments to infrastructure administrators' thirst for information, leading to a 'data revolution' (Kitchin, 2014a) that involves a dramatic change in the scale of how data are produced, centralised, curated, and analysed. From the early 1990s, scholars began to ponder how digital technologies would transform urban infrastructures, leading to increased automation of their management (Dupuy, 1992), but also to greater engagement (and intertwinement) with end-users (Picon, 1997). More recent research has brought finer documentation on how the diffusion of sensors across urban space ultimately works towards enabling the continuous and ubiquitous processing of data (Thrift, 2014; Tironi and Sánchez, 2015). Meanwhile, studies have emphasised that advocates of digital technologies therefore conjure imaginaries that combine the possibility of governing cities and their metabolism in real time (Kitchin, 2014b), and visions of satisfied, but also docile city dwellers (Vanolo, 2014). These top-down visions of urban governance highlight a crucial premiss of digitalisation: data production is a form of knowledge production, and thus taps into power issues.

For a number of years, scholarship on digitalisation was carried out under the umbrella of 'smart city' research, and reflections on 'smart infrastructures' remained speculative and/or focused on a very limited number of flagship projects (e.g., Songdo, Masdar city), leading the critique that 'actually existing' cities were being neglected (Shelton et al., 2015). Before going further, we can therefore examine a concrete example of what this chapter means by 'digitalisation' of infrastructure.

The Philippine city of Dapitan, in the Southern part of the archipelago, has recently signed a contract with a start-up company that quickly came to be called 'the Uber of garbage'. This company offers a mobile application named Hakoot, which allows residents to signal their intention of dropping off garbage in the street, to state the nature of this garbage (biodegradable or non-biodegradable), and to visualise the route and estimated time of arrival of the garbage trucks. While using an app prior to dropping waste will sound cumbersome to many, Dapitan residents appear to welcome this new service because the alternative is for them to be on the lookout for garbage-collection trucks: a municipal bylaw prevents them from disposing of their waste in advance (largely for public health reasons, and not least to avoid the proliferation of rats), and the trucks are often not on schedule – if they arrive at all. On the municipality's side, Hakoot can help optimise collection routes depending on demand, as well as adjust the size of the fleet that they send on a daily basis. In this city, where the poverty rate is higher than the national average – 27 percent versus 21 percent (Philippine Statistical Authority, 2021a, 2021b) – this technological intervention is seen as a way to mitigate the lack of resources (in both equipment and facilities) suffered by the municipal waste-management service (Philippine News Agency, 2019).

As illustrated by the example of Dapitan, the digitalisation of urban services can be shouldered by small, local companies, but bigger, transnational players are also very present in this market. In addition, the integration of digital technologies can occur at various points in the socio-technical system: in Dapitan, the system relies on GPS trackers that are placed on garbage-collection trucks, but also on residents' smartphones. In short, digitalisation will at times directly affect end-users' experience of the service, but it can also remain hidden from their view – when the bulk of transformations affects the professional practices of the workers operating and maintaining the system. Moreover, it is also notable that digital technologies are inscribed within already-existing materialities. Here, the introduction of digital technologies is well-suited to the peculiar form of the waste-management network, which can be characterised as a 'soft' network, following Debout (2012). The app embraces the 'centrifugal' nature of

waste-collection, since it allows a multitude of end-users to facilitate the collection and subsequent centralisation of waste. It also helps coordinate the fleet of trucks that constitute the central element of the network – while the digitalisation of other urban services might involve the integration of sensors into ‘hard’, possibly underground infrastructure. In short, processes of digitalisation are inscribed within the material features of urban infrastructures, even as they add new layers of materiality to these socio-technical systems.

LEGIBILITY AND THE POLITICAL ECONOMY OF (IN)VISIBILITY

In considering the social and political implications of digitalisation, this chapter makes the case that more attention needs to be placed on the production, curation and circulation of data. In this section, I seek to advance these debates by bringing forward two conceptual tools: *legibility* and *(in)visibility*. These concepts highlight the dialectics between efforts to govern through data (legibility) and users’ uneven capacity to take advantage of variable data coverage (*[in]visibility*).

Seeing Like an Urban Service Operator

Scholarship on smart cities has emphasised how city leaders’ decision to turn to new technologies is backed by strong socio-technical imaginaries and visions of urban future. Such visions may be infused with corporate techno-utopia (Söderström et al., 2014; Sadowski and Bendor, 2019), or stand on more citizen-centric ideals (Schröder et al., 2024). In short, investing in additional sensors or in artificial intelligence-enhanced resource-management software is embedded in a narrative of what service provision should be. But in turn, these technologies will generate and process data that offer distinct representations of urban services, highlighting certain aspects of service provision while obfuscating others. For instance, a ‘smart’ water-distribution system may help identify, quantify and spatialise the illegal tapping of water, while leaving service operators oblivious to the social, economic or health significance of diverted streams of water. This interaction between the discourses surrounding ‘smart utilities’ on the one hand, and the actual production of new data for urban services on the other hand, can affect urban metabolism, or so I will argue.

Conceptually, uneven data production and differential visibility of the various aspects that constitute a socio-technical system can be captured by James C. Scott’s (1998) notion of *legibility*. Central to this concept is the idea that ‘certain forms of knowledge and control require a narrowing of vision’ (Scott, 1998, p. 11) – in other words, that governability tends to go hand in hand with simplification. In analysing modern statecraft, Scott shows that, as public authorities sought to ‘standardise’ and ‘rationalise’ the societies they were trying to govern, they collected pieces of information that only amounted to snippets of complex social realities. The synoptic vision that ensued was therefore highly incomplete, but it was also performative. The idealised visions of society, backed with the force of law, imposed new realities (e.g., taxation mechanisms, land tenure organisations) that often unravelled actually existing forms of social organisation. And this gap between complex realities and simplistic techno-modernist visions, Scott argues, led to a number of ‘development fiascos’ (p. 3), where schemes intended to reorganise societies more efficiently and improve human livelihoods caused human tragedies, from economic breakdowns to armed conflicts between different segments of the population.

Urban services constitute an extension of urban governments, and thus echo the challenges faced by the latter, the organisational structures they embrace, and the practices they adopt (Lorrain, 2014). Consequently, issues of simplification and (in)visibility encountered by urban governments percolate through the provision of urban services. Rateau and Jaglin (2020) offer an illustration of how service providers simplify urban realities when they show how formal access to electricity masks a highly complex form of service provision in Cotonou and Ibadan, where an electricity meter may then be used by its owner to sell electricity to multiple households, while also coexisting with off-grid sources of electricity (e.g., solar panels). Simplifying reality, then, becomes a tool to manage highly complex urban societies: service providers may choose to tolerate (or even facilitate) informal practices when they allow them to outsource some aspects of service provision that would require a level of understanding that they do not possess and do not need to acquire to fulfil their objectives.

While the concept of legibility bears significance for ‘analogue’ urban service provision, I would like to argue that its heuristic value even increases as digitalisation progresses. Scholars have long underlined how digital technologies are embedded in power relations: they contribute to shaping political participation (Odendaal, 2006; Datta, 2018), or help reproduce or reshape longstanding forms of imperialism (Coudry and Mejias, 2019; Young, 2019; Mouton and Burns, 2021). ‘Legibility’ encapsulates this idea that the data generated by sensors reflect the service operator’s agenda and vision of reality, to the detriment of alternative visions. Moreover, it emphasises that smart utilities’ data are *simplifying* what service delivery means, thereby leaving some of its aspects unrepresented.

Navigating (In)visibility

Legibility, as conceptualised by Scott, refers to how governing bodies view the world. In *The Art of Not Being Governed* (Scott, 2010), the author engages with the other side of this coin and focuses on people who managed to remain ‘stateless’. Along the same line, I now wish to interrogate end-users’ agency with regards to digitalisation. (In)visibility is not a new topic of interest for those examining recent technological developments. For instance, when Burns and Andrucki (2021) reflect upon the labour that underpins the functioning of ‘smart cities’ (e.g., data production, collection, and analysis through open-data platforms), they show that part of this work is obscured, while another part is spectacularised. Putting low paid and devalued work under the spotlight emerges as a way to contest the social order reproduced within the urban environment. More generally, recent scholarship on digital practices has renewed feminist literature, highlighting how (in)visibility is negotiated and reshaped in the context of activism (Hildebrandt and Chua, 2017) and labour politics (Rand, 2019).

These examples show how digital technologies can be mobilised to contest, rather than enforce social order. Turning our attention to marginalised actors’ agency, we can highlight instances where alternative technologies are deployed, or existing ones subverted, in order to produce counter-discourses and paint a different picture. These debates have converged around the concept of *knowledge politics*, emphasising how digital technologies dictate which data are produced and how they are collected, to the extent that they influence the boundaries of our knowledge, but also, and perhaps more importantly, the legitimacy of knowledge claims (Elwood, 2010; Burns, 2015). For instance, new practices enabled by web-based geographic information technologies have resulted in individualised and experiential forms of geovisualisation that echo citizens’ preoccupations and perceptions rather than experts’ concerns

(Elwood and Leszczynski, 2013), and thus open new perspectives for *feminist* digital geographies. Meanwhile, participatory practices geographic information systems can and have also produced alternative forms of geovisualisation that are more collective in nature, and enable stronger community-university collaborations (Sheppard, 2005). Overall, as Young (2019, p. 1425) puts it:

By shaping the very epistemic horizon of what is knowable within digital spaces ... knowledge politics play a foundational role in shaping the types of political outcomes that are made possible through digital engagement.

In short, urbanites and infrastructure end-users can generate their own discourse over urban service provision and how they experience it. This is perhaps best illustrated in the case of transportation infrastructure, where *counter-mapping* initiatives have allowed marginalised citizens to evince the accessibility issues they face (Taylor and Hall, 2013), or empowered people with disabilities to have a say in urban design (Rebernik et al., 2021).

To conclude, ‘visibility is a double-edged sword’ (Brighenti, 2007, p. 335). When associated with the idea of social recognition, visibility can indeed be empowering and remains a prerequisite to demand and obtain new rights. Meanwhile, visibility has also been conceptualised as the enabler of discipline – Bentham’s panopticon offering a materialisation of this idea by emphasising how the dissymmetry of visibility between the guard and the inmate translates into control (Foucault, 2012 [1977]). In this tradition, visibility is not synonymous with empowerment, but rather with subjugation. Scholars who have set to analyse contemporary (and digitally-mediated) surveillance mobilise such a conceptualisation of (in)visibility (Lyon, 2001; Murakami Wood and Monahan, 2019).

On the one hand, increased visibility can help marginalised end-users document their struggles and back their claims for improved service. An illustration of this idea can be found in Palat Narayanan’s work (2019) documenting how a Delhi-based NGO lobbied the municipal authorities to move an informal community’s garbage-collection point to the adjacent main road, where the heap of refuse would draw more attention and encourage more regularity for waste-collection. Digital technologies can facilitate end-users’ struggle to be placed ‘on the map’, thus affecting urban metabolism as networks are extended, and resources circulated more widely. On the other hand, it can subject poorer end-users to close scrutiny, and facilitate repressive actions. The ability to visualise flows of matter and energy, sometimes in real time, gives service operators powerful repressive tools that can lead to individual or even community-wide disconnections (Mouton, 2015). With these considerations in mind, the next section will explore how increased legibility over circulations of matter and energy may transform urban metabolism.

CROSSING THE STREAMS: FROM BITS OF DATA TO NEW CIRCULATIONS OF MATTER AND ENERGY

The rest of this chapter discusses a number of avenues for the exploration of ICT-induced metabolic transformations in the urban fabric. Here, two paths are explored: first, I discuss the possibilities for infrastructural reconfigurations that digital technologies could allow; second, I draw attention to the more subtle changes induced as service operators shift from thinking

about urban metabolism in terms of flows (i.e., comprehending their origin and destination) to considering urban circulations in finer detail (i.e., comprehending their full trajectory).

Are Streams of Data Transforming Infrastructural Configurations?

When thinking about how new streams of data may contribute to a reshaping of urban metabolism (i.e., how they may alter streams of matter and energy within and beyond the city), a bold hypothesis would be that infrastructural systems themselves may evolve. In other words, digital technologies could prompt a veritable change of service-provision paradigms. In particular, the literature so far has advanced two major hypotheses: (1) the transition from large, centralised, and homogenous systems to small-scale, distributed and diversified forms of service provision; and (2) the development of cross-sectoral systems under the umbrella of ‘nexus’ approaches. Let us briefly examine these two ideas.

In an ethnographic inquiry into Delhi’s water-catchment systems, Drew (2020) shows that digitalisation can help challenge dominant discourses over centralised forms of service provision. In India’s capital city, British rulers largely dismantled pre-colonial water-catchment systems, and urban governments followed suit after the independence, under the umbrella of ‘modern’ visions of service delivery that relied on pipes and large water-treatment plants rather than small and distributed catchment technologies. In recent years, however, the Government of India’s ‘smart city’ initiative has sparked debates on the appropriateness of reviving wells, surface-catchment areas and an array of rainwater-harvesting systems, with some local actors calling for ‘an integration of “traditional practice” and “new technologies”’ (p. 445). In this example, digital technologies have the potential to make traditional water-catchment practices legible – in other words, to put them ‘on the map’ for public authorities by supplementing vernacular knowledge with precise data on water availability, rate of flow, etc. Here, this opportunity for new visualisations of the water system could lead to a more decentralised water-provision system, echoing the call for considering ‘beyond-the-network’ configurations (Coutard and Rutherford, 2015).

That being said, while infrastructure geographies are bound to be affected, there is nothing automatic about digital technologies leading to decentralised forms of service provision – decades of scholarship in science and technology studies have taught us this much (Bijker, 1997; Wyatt, 2008). As a case in point, a recent study of Lima’s water sector has highlighted that digital technologies can be synonymous with increased centralisation of service provision – meaning that they facilitate the expansion of the large technical system, to the detriment of auto-constructed and co-organised infrastructure (Hoefsloot et al., 2020). The authors document how digitalisation has translated, in the Peruvian capital city, in the diffusion of water meters that feed real-time consumption levels to GIS-based systems, thus offering the water provider unprecedented legibility over its network and over end-user practices. While Lima had built a strong tradition of co-construction for the water sector, digitalisation has marginalised what the authors call ‘expert-amateurs’ from the development, operation and maintenance of water-provision systems.

Similarly, scholars and practitioners alike have pondered how digital technologies can contribute to the integration and interfacing of infrastructures, thus establishing symbioses (Lorrain et al., 2017), or the so-called urban nexus (Monstadt and Coutard, 2019). The assumption (that needs to be critically assessed) is that, by deploying sensors to generate more data (and to do so with more accuracy) and by establishing digital platforms that allow for the

centralisation of these data, integrated monitoring and joint management of different sectors (e.g., any combination involving water, electricity, waste, heating, food or transportation) will help cities become more efficient and more sustainable (Luque et al., 2014). This idea has prompted scholars to envision what kind of sectoral synergies data integration could bring in the context of ongoing ‘smart city’ projects (Sukhwani et al., 2020). Such developments are far from established, however. By way of (counter-)example, upon examining a couple of urban experiments supposedly designed and controlled in a systematic and integrated manner, Cugurullo (2018) highlighted how disconnected and disarticulated their urban systems really were.

From Flow to Circulation: Ordering Urban Metabolism

Scholarship on how digital technologies reshape infrastructural configurations thus offers contrasted results. I propose turning our attention to subtler changes in urban metabolism. In other words, I will now focus not on the major infrastructural overhauls, but on a number of consequences that digital technologies may have for the regulation of existing flows of matter and energy. To think about such transformations, I mobilise a conceptual distinction introduced by Garcier et al. (2017). These authors contend that finer data can offset the vision of urban metabolism, from one consisting in *urban flows* (considering only points of departure and destinations) to one that instead calls attention to *urban circulations* (considering the specific ‘itinerary’ of matter or energy and tracing their whereabouts step by step). In the present *Handbook*, Desvaux offers a powerful illustration of how scholars can apprehend urban circulations by mobilising the concept of *metabolic pathways* to highlight ‘the chains of transformation and circulation’ that constitute urban flows. Overall, Garcier et al. remind us that producing maps, charts or statistics for the purpose of ‘naming, measuring and controlling’ flows and circulations is a highly political process. The shift towards finer understandings of urban metabolism is therefore bound to have major consequences for city dwellers.

One of these consequences has to do with service providers’ ability to *police* urban metabolism. Urban transformations, particularly when they involve a great deal of inequalities and violence, often require the backing of police forces tasked to impose social and economic order (Fauveaud, 2014). As city governments deploy strategies to polish their image as metropolises of global significance, urban infrastructures follow suit and need to reflect a certain urban order, characterised by efficiency and quality of service – to the detriment of ‘disorderly’ informal practices (Mouton, 2021). As service operators are increasingly able to get legibility of urban circulations of matter and energy, they become more proficient at policing urban metabolism: the diffusion of sensors allows them to instantly visualise ‘leaks’ in their system, thus transforming their handling of illegal water or electricity tapping. Indeed, a joint examination of the deployment of ‘smart grids’ in Kingston and Rio de Janeiro shows that securing the electricity grid can be the main driver for the digitalisation of the electricity network in Southern contexts (Pilo, 2021). In these two cities, smart metering devices are used by operators to navigate uncertain security conditions and contested state sovereignty: they enable the government of fraudulent behaviours through technological mediation, with minimal direct human interactions between consumers and service providers.

However, this ordering of urban metabolism needs not be exclusively a form of repression. Better legibility over the circulation of matter and energy can also foster the extension of market mechanisms for service provision. This idea is powerfully illustrated by Guma’s

work (2019) on water and electricity supply in Nairobi. Here, Guma highlights how digitally enhanced services can offer ‘segmented’ market-based solutions for service delivery in poorer areas of cities in the global South. By offering mobile payment, but also by using ICTs to offer more targeted programmes at the community level, service providers are able to expand their market shares and increase revenue collection. Chambers and Evans (2020) further argue that digital technologies (and more specifically the Internet of Things) reconfigure relationships between end-users and service providers through renewed trust over urban services and infrastructure. More specifically, ICTs emerge as a way to mitigate the unreliability of urban infrastructures in informal settlements: the availability of real-time data helps urbanites plan their days around fluctuations in service availability, and ultimately contributes to smoother interactions between providers and end-users. I view these examples as illustrations of how digital technologies can contribute to a political, social and/or economic reordering of urban territories – sometimes in diffuse ways, and sometimes through harsher and more evident disciplinary strategies.

CONCLUSION

In examining the integration of digital technologies with urban services, this chapter raised the question of how new flows of data can redefine our understanding of the urban, ultimately leading to the modification of energy and matter circulations in and around the city. To capture some of these epistemological shifts, I suggested using Scott’s (1998) concept of *legibility* as a way to emphasise how service operators use select data to ‘simplify’ urban metabolism enough to govern it. Here, the notion of simplification must be used with caution: digitalisation goes hand in hand with the production of additional data, and may result in a more fine-grained understanding of urban metabolism. Nevertheless, Scott’s concept highlights that these data remain utterly fragmented, and unable to render the social ties and practices in which urban services are embedded. Massive amounts of data may be fed into service operators’ systems, but these data are inscribed in a specific agenda, and therefore include a lot of blind spots.

From there, I drafted the contours of a research agenda that questions the implications of these epistemological changes for urban metabolism. In other words, how are new forms of legibility changing the governance of urban metabolism? Here, I suggest two lines of inquiry. The first one relates to major infrastructural reconfigurations that new data would render possible (e.g., the decentralisation of service provision, and/or the interfacing of different services), although at this stage evidence remains scarce to support this idea. The second transformation involves the ability of service providers to consider *urban circulations* instead of *urban flows* (i.e., to document the whereabouts of matter and energy in a fine-grained manner, instead of merely considering their points of departure and arrival). This new legibility over urban circulations could allow for processes of urban ordering, where previously informal and invisible circulations would be either suppressed or restructured as they are drawn into the realm of market mechanisms.

It is important to note that these outcomes are far from inevitable consequences of digitalisation. Alternative socio-technical systems could indeed bring very different consequences in terms of data generation, circulation and use, and therefore transform urban metabolism in contrasting ways. Imagining and investigating new socio-material structures and new forms of

government for digital networks and urban services emerges as a major challenge for scholars and practitioners alike (Lopez, 2022).

In concluding this chapter, I would like to offer some methodological considerations for the implementation of this research agenda. Exploring how data generation transforms the operation of utilities, and ultimately affects flows of matter and energy, requires paying attention to the epistemologies that subtend the digitalisation of service provision. More specifically, I argue that digital ethnography offers useful tools to explore the dynamics of (in)visibility within a given socio-technical system. As geography took a ‘digital turn’ (Ash et al., 2018) and offered expanding exposure to scholarship examining how digital technologies transform urban life, scholars started to unpack the broad category of ‘digital technologies’. This led to exciting research that documented and analysed different components of digital infrastructure: data and databases (Burns and Wark, 2019), algorithms (Seaver, 2017), or the practices that establish, maintain and operate this infrastructure (Castagnino, 2016; Denis, 2018), as well as the use of virtual spaces (Hine, 2017). Drawing on the science and technology studies tradition, digital ethnography encapsulates the impetus to take technology seriously, highlighting that it mediates social interactions, refracts power balances and reflects human values and epistemologies. Extending Star’s (1999) invitation to carry out an ‘ethnography of infrastructure’, digital ethnography draws attention to the (often unnoticed) digital artefacts that reflect social reality and produce social meaning.

Concretely, for the study of urban service provision, it can mean considering the online platforms that utilities set up to interact with end-users and analysing how they mediate this interaction, in particular through a selective display of information. But it also means studying how service operators collect data, how they categorise customers and areas of service (Bowker and Star, 2000), how they classify the different components of their infrastructure or the various groups that constitute their workforce. Overall, this chapter aligns with calls to pay attention to the materiality of infrastructure (McFarlane and Rutherford, 2008; Mitchell, 2011; Pilo’ and Jaffe, 2020), including the infrastructure itself and the documents produced by utilities, while also extending the scope of analysis to include the ‘virtual’ spaces that utility workers and end-users have to navigate to manage and use the service: online platforms, databases, visual representations and so on.

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