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Article

Expert-Amateurs and Smart Citizens: How Digitalization Reconfigures Lima's Water Infrastructure

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Abstract
In Lima, residents are fundamental co-creators of the urban water infrastructure, taking up various roles in the operation, maintenance, and expansion of the water distribution system. As Lima's potable water company presses the transition from decentralized and auto-constructed to centralized and digital, this article explores how the implementation of digital infrastructure reconfigures the role of residents in the water distribution system. Our analysis draws on an ethnographic research approach, using formal and informal interviews, and focus groups in three areas representing Lima's diversity in settlement categories and types of water consumers. By analyzing the digitalization of Lima's water infrastructure through the perspective of its residents, this research contributes to understanding how top-down, digital governance practices mediate the agency and everyday experiences of people living in Southern cities. We observe that the digitalization of the water infrastructure marginalizes the participation of the 'expert-amateur,' a crucial role in the development of urban in the Global South, while providing more space for the 'smart citizen' to engage in infrastructuring. This article concludes that to overcome the perpetual creation of the center and the periphery through digitalization, urban infrastructure management should be sensitive to residents' diverse strategies in managing resources.

Keywords
auto-construction; digitalization; expert-amateurs; Lima; Peru; smart cities; smart citizens; water infrastructure

Issue
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1. Transitioning from Fragmented towards Integrated Infrastructure

This article explores how the water infrastructure of Lima transforms materially and organizationally as SEDAPAL, Lima's potable water and sewerage company, presses the transition from decentralized and auto-constructed to centralized and digital and what this means for the roles of urban residents in the process of infrastructuring. The history of Lima's infrastructural growth is one of auto-construction. In the absence of government service provision in the city-becoming, residents have created fragmented networks of water distribution systems with a large variety in materials, efficiency, and functioning. These auto-constructed systems have different iterations, some are more, and some are less controlled, but in almost all cases, they are communal in nature. As a result, the water infrastructure in Lima is a patchwork of planned as well as auto-constructed infrastructures, only connected by the water that flows through them.

One of the primary objectives of SEDAPAL is to unify these different water distribution systems and create one homogeneous infrastructure that services all of the city's residents. Aside from expanding the water pipes

within the city, SEDAPAL aims to achieve an integrated and centralized infrastructure by implementing digital information technologies. The digital, in this case, refers to the collection of technologies used to generate, distribute, analyze, and use data for infrastructural management (Star & Ruhleder, 1996). This includes data acquisition technologies, such as meters and sensors, and the geo-information systems—digital by nature—used for the management and analysis of water-related data. Under the banner of creating a more efficient and easily controllable network, SEDAPAL has implemented digital information and data acquisition systems, making it possible to monitor the operational and commercial sides of the infrastructure in one web-based geo-information system (SEDAPAL, 2015). These digital infrastructures make the system legible, albeit to various degrees, and facilitate the centralization of Lima's water management (Hoefsloot, Pfeffer, & Richter, 2019).

The implementation of digital infrastructures works towards achieving what Graham and Marvin (2001, p. 73) have called the "modern infrastructure ideal." They argue that the modernist image of fully integrated and standardized infrastructure, as developed in Western countries, has been exported as ideal for infrastructural provision to colonial and post-colonial cities. However, since the 1980s, neo-liberal politics have led to the unbundling of these integrated infrastructures, resulting in unequal service provision where urban elites are connected and urban poor are disconnected. In Graham and Marvin's work, this transition from integrated towards splintered is presented as characteristic of our time. However, Coutard (2008), drawing specifically on case studies in the Global South, argues that many cities have always been unbundled, and their infrastructures are fragmented and segregated. While the normative imaginary of centralized and universal service provision continues to be a powerful tool in shaping infrastructural planning worldwide, Coutard (2008, p. 1818) suggests that in Southern cities, "recent evolution does not involve a passage from an integrated system to an unbundled one, but rather a passage from one more or less unbundled system to another." Bulkeley, McGuirk, and Dowling (2016) argue that to understand the implications of smart city developments for urban residents, research should engage more directly with the material politics on the development of digital infrastructures. This requires opening up to the diverse forms of agency at work in the process of infrastructuring and asking who is included and who benefits from technological transformations (Bulkeley et al., 2016).

Hence, to understand the social implications of these dynamics, we have to unpack how they play out in specific socioeconomic and material structures and reconfigure the script of the infrastructure. The concept of the script (Akrich, 1992) refers to the embedded logic of the socio-material structure that steers the interaction with users (Jelsma, 2006). The script of the infrastructure prescribes roles for users and technology as 'actors' in a play. Yet, the script is continuously rewritten through users who change the system according to their own logic or the implementation of new technologies (Jelsma, 2006). Previous scholarship in smart urbanism has foregrounded how digital infrastructures re-inscribe the governing of flows within the city by integrating physical and information systems spatially and hierarchically (Marvin & Luque-Ayala, 2017); the implications of smart city policies in urban development (Verrest & Pfeffer, 2018); and emphasized how the general rhetoric of the smart city prioritizes an increase in surveillance and efficiency (Kitchin, Maalsen, & McArdle, 2016; Luque-Ayala & Marvin, 2015; Vanolo, 2014). Yet, there is a need to understand how these integrative transformations affect residents' influence, control, and self-determination in urban development (Marvin & Luque-Ayala, 2017). The imaginary of the smart city is so strongly coupled to high-tech innovations and private-public partnerships that the resident is often not considered or simply conceptualized as a 'data provider' (Calzada, 2018; Vanolo, 2016). With sensing applications in mobile devices, homes, vehicles, and city-wide infrastructures, residents are continually producing data that are incorporated into smart city products (Rabari & Storper, 2015). Data is created while residents simply perform their daily routines (Calzada, 2018).

Today, the discourse about the smart city is shifting towards a more resident-centered framework in which people are no longer seen as instrumental to the technological development of the city but as their co-developers (Calzada, 2018). This strongly resonates with the development in Western cities, where urban planning has moved from modernist master plans to smart cities and is now progressively allowing for diverse forms of resident participation in the construction of urban space. Hajer and Dassen (2014) argue that the truly smart city should integrate residents in the process of developing infrastructure. They reason that, with an increasingly educated society, the community is a valuable source of information and energy, and its collective intelligence should be harvested.

Vanolo (2016) describes how the resident, and their role, is imagined differently in various discourses the smart city. Within the neoliberal discourse of the smart city, the 'smart citizen' is a homogeneous category of people who are digitally connected, educated, and willing to participate (Vanolo, 2016). Optimistic about the potential of digital technologies to empower and democratize, it is argued that the smart city amplifies the voice of residents in the planning and construction of urban space (Shelton & Lodato, 2019). Nevertheless, Shelton and Lodato (2019) explain, the smart citizen has to adhere to the confinement of the technocritical and neoliberal political and material practices of the smart city. Only those who can invoke particular forms of expertise tied to policy-making or technological development can participate. Effectively, less privileged residents who do not have this form of professional or institutional cap-

ital are overlooked or excluded (Shelton & Lodato, 2019; Tenney & Sieber, 2016). Hence, 'smart citizenship' is a reductionist and exclusionary category, reserved only for those who are privileged to be documented as citizens of the city and have the education and capital to participate in the digitalized system. However, in Southern cities, also non-registered and non-connected residents have always been active as fundamental co-creators of the city (Button, 2017; Holston, 1991). As builders, managers, and maintenance workers, they have constructed and operated urban infrastructures, living through its many iterations (Simone, 2019). Kuznetsov and Paulos (2010) introduce the character of the 'expert-amateur,' emphasizing the fact that the people who are involved in these community constructions have advanced knowledge about the artifact or system they co-construct. Yet, they do so outside of the professionalized and commercial sphere. The expert-amateur is oftentimes autodidact or has gained their knowledge and skills while learning from peers.

Therefore, mindful of these differences in the positions and capacities that residents can have within urban infrastructure, we ask: How does the digital infrastructure reconfigure the roles within the water distribution system in Lima, now imagined as centralized and digital, rather than decentralized and auto-constructed? By analyzing the digitalization of Lima's water infrastructure through the perspective of its residents, this research contributes to understanding how top-down, digital governance practices mediate the agency and everyday experiences of people living in Southern cities.

We specifically zoom into two technologies implemented in Lima's water infrastructure: the household water meter and the customer contact center. These two technologies are now standard practice in many cities worldwide, yet play a crucial role in the digitalization of the water infrastructure through their production of data. The meter produces numerical data about water consumption within the city. The customer contact center allows SEDAPAL to register textual and visual data about the functioning of the water infrastructure. Due to their relative fine spatial (households rather than water sectors) and temporal scales (monthly for the meters and continuous for the customer contact center), they provide insights into water consumption patterns and operational issues. Most importantly, the meter and the customer contact center function as an interface between the consumer and service provider (Pilo', 2017). By measuring the household water consumption and the registration of the type and location of the complaints submitted by residents, the meter and the customer contact center translate the interaction of Lima's residents with the water infrastructure into data. The data produced by these technologies allow for the registration of problems and water flows that were illegible before their implementation and are, therefore, important in the production and redefinition of relationships within the infrastructure (Kragh-Furbo & Walker, 2018).

2. Methodology

Six months of fieldwork in Lima during 2019 and 2020 form the empirical basis of this article. It is part of a larger research project focusing on the implementation and impacts of digital infrastructure in Lima's water management. This research project employed an iterative ethnographic strategy for data collection and analysis. 25 interviews were conducted with experts in the field, including engineers working for SEDAPAL, academics, and representatives of community and civil society organizations. The interviews varied in structure and focus, depending on the context of the conversation and person interviewed. We then conducted seven focus groups (FG) with residents asking them about how they access water, administer their consumption, and perceive the digitalization of the water infrastructure. Residents from three areas were invited: José Carlos Mariategui, Barrios Altos, and Miraflores. These three areas were selected to represent the city's diversity in socioeconomic development, geography, and degree of formalization (Figure 1). José Carlos Mariategui, situated on the periphery of Lima, has developed mostly during the last two decades through the process of auto-construction, as will be described further below. The majority of José Carlos Mariategui's residents live in conditions of extreme poverty. Barrios Altos, the 'high neighborhoods,' is one of the oldest areas of Lima. Lending its name from the fact that it is situated on a small hill and thus higher than the main square of the city, the neighborhoods historically developed as housing for the non-noble families of the early colony. Although it has gone through many different phases in the past, today, it is a middle and low-income neighborhood. The third district where we conducted our research, Miraflores, is the city's main upper-class residential district and forms the center for Lima's tourism industry. Modern high-rise apartment complexes characterize it.

This research specifically focused on these three areas to compare the different roles of residents in the water infrastructure across urban classes and living conditions. Previous research has analyzed issues related to water infrastructure, water access, and water use amongst the urban poor in Lima and Latin America (Allen et al., 2017; Brown & Pena, 2016; Fernández-Maldonado, 2008). Yet, few studies have included the practices and perspectives of the urban middle class and elite in discussing the process of infrastructuring. The participants in the focus groups thus represent users of auto-constructed infrastructures and digitalized and integrated infrastructures. Since the focus groups attracted more older adults than youth, we organized an additional focus group with Limeños aged 18–30.

Additionally, we organized two meetings with experts in the field to discuss the technological development of the water infrastructure and generate knowledge about the possible futures for Lima's water distribution system. The first meeting included experts from dif-

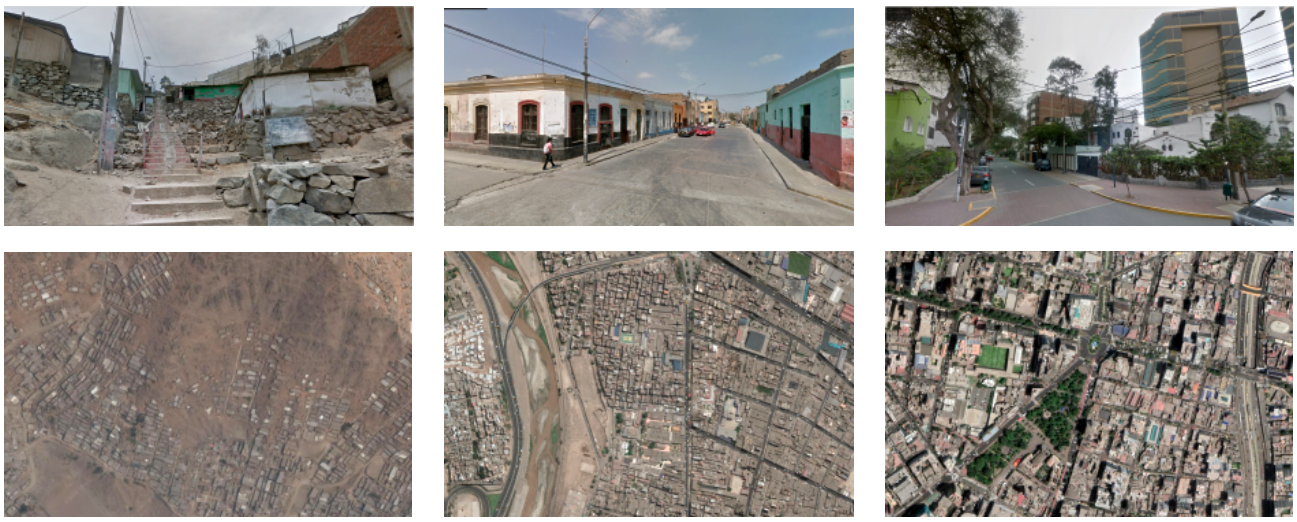


Figure 1. Areal and street views of the three research areas. Source: Google Earth and Google Maps.

ferent strands of government, academia, and civil society groups. The second expert meeting was with researchers and engineers of SEDAPAL. The focus groups and expert meetings lasted between one and two-and-a-half hours and were recorded and transcribed.

We used the analogy of the 'script' (Akrich, 1992) to analyze how the design of the infrastructure defines the roles of, and interactions amongst, residents and technology within the system as it transitions from decentralized and auto-constructed to centralized and digital. Jelsma (2006) conceptualizes the script as a prescriptive force that steers the behavior of a technology's users in a certain direction that matches its inscribed logic and redistributes roles, responsibilities, and power within the socio-technical network. Thus, the script of the infrastructure shapes the role of a person within the system and encourages certain 'desirable' actions while discouraging 'undesirable' use (Jelsma, 2006). The infrastructural script can be moralizing in the sense that it steers towards practices that align with its embedded normative framework. By making the 'better' option more convenient, residents are nudged towards conforming with the 'integrated infrastructural ideal' (Koop, van Dorssen, & Brouwer, 2019). Nevertheless, this relationship is bi-directional. The users of the system, in this case, the residents of Lima, might envision different roles for themselves and re-inscribe the infrastructure through their actions and based on their experience and situated knowledge (Akrich, 1992; Rose et al., 2018).

Using Atlas.ti™, we conducted a thematic analysis of the focus group transcripts as well as the individual interviews, coding for different roles within the infrastructural development (planning, construction, operation, maintenance, and replacement) as the main themes and paying specific attention to narratives that explained people's perception of, and attitude towards, the implementation and use of digital infrastructures for the administration of water consumption. Three main themes emerged out of the analysis process: (i) How people have auto-constructed their domestic and communal water infrastructures, (ii) how the meter and the customer contact center changes the script for the operation of the infrastructure, and (iii) how the meter and customer contact center redefine the roles of, and interaction between, SEDAPAL and Lima's water consumers based on embedded norms. These three themes correspond with the three result Sections 3.1, 3.2, and 3.3. Throughout the text, translated quotes from the verbatim transcripts illustrate the residents' experiences and interactions with the digital infrastructure and complement our empirical data with findings from the literature.

3. Results

3.1. Lima Built by Expert-Amateurs: Residents as Engineers, Constructors, and Maintainers

Like other Latin American metropoles, Lima has grown mainly through the building of dwellings, neighborhoods, and infrastructure by its residents (Amin, 2014; Caldeira, 2017; Fernández-Maldonado, 2008; Holston, 2009). In this section, we analyze the script of the auto-constructed infrastructure and illustrate how, depending on their geographical location and socioeconomic context, residents have shaped the water distribution system to fit their needs and inscribed according to their own logic, with SEDAPAL often only having very little formal influence as the provider of water to the central dis-

tribution point or vendor of water to the trucks that serve the area.

Lima's urban expansion was particularly fast from the 1950s to the 1970s, during which internal migration towards the city was particularly large (Ioris, 2012). Due to the lack of available housing to accommodate the growing number of residents in Lima, people started to organize themselves, occupying barren lands on the fringe of the city, building their first settlements, and constructing primary infrastructure such as water and electricity networks (Ioris, 2012). This form of auto-constructed urbanization continues today. With every new generation, the peripheral edge of the city has moved further outwards and upwards, stretching over the hills surrounding the city. In general, Lima's most impoverished families live in the farthest and most precarious dwellings.

Although this form of urban and infrastructural development is especially prevalent in the newly urbanized areas in the city's periphery, auto-construction also exists in the heart of the city and its most affluent neighborhoods. As Caldeira (2017) argues, the 'urban periphery' is not by definition physically located on the urban fringes. Peripheral urbanization and auto-construction can exist in all geographical locations. Holston (1991) describes auto-construction as the process in which people construct neighborhoods under precarious circumstances, physically, legally, and socially, and slowly consolidate their right to the city through the formalization of their dwellings. The auto-construction of housing and infrastructure is impactful; not only because it is the construction of something out of nothing, but because it is a process in which settlements gradually transform into urban districts and squatters into citizens (Holston, 1991).

It is estimated that about 60% of Lima's urban area is auto-constructed (Metzger, Gluski, Robert, & Sierra, 2015). Today, many of the districts that have been constructed by residents in the 20th century are fully consolidated and integrated into the urban fabric (Fernández-Maldonado, 2008). Many more recently inhabited areas are still in the midst of this process. These auto-constructing communities, often living in partial informality, thus form a driving force in the urbanization of Lima, including the expansion of its water distribution system. Residents continue to play an essential role in the development, operation, and maintenance of the water infrastructure. However, it is a fine line between appreciating the resourcefulness and creativity in auto-construction without romanticizing the retreat of the state in service provision (Jiménez, 2014). In contrast to self-built neighborhoods, co-housing, and participatory planning practices in the global North, auto-construction in urban centers in the Global South is often a symptom of poverty and born out of necessity due to the lack of basic services provided by the state (Caldeira, 2017).

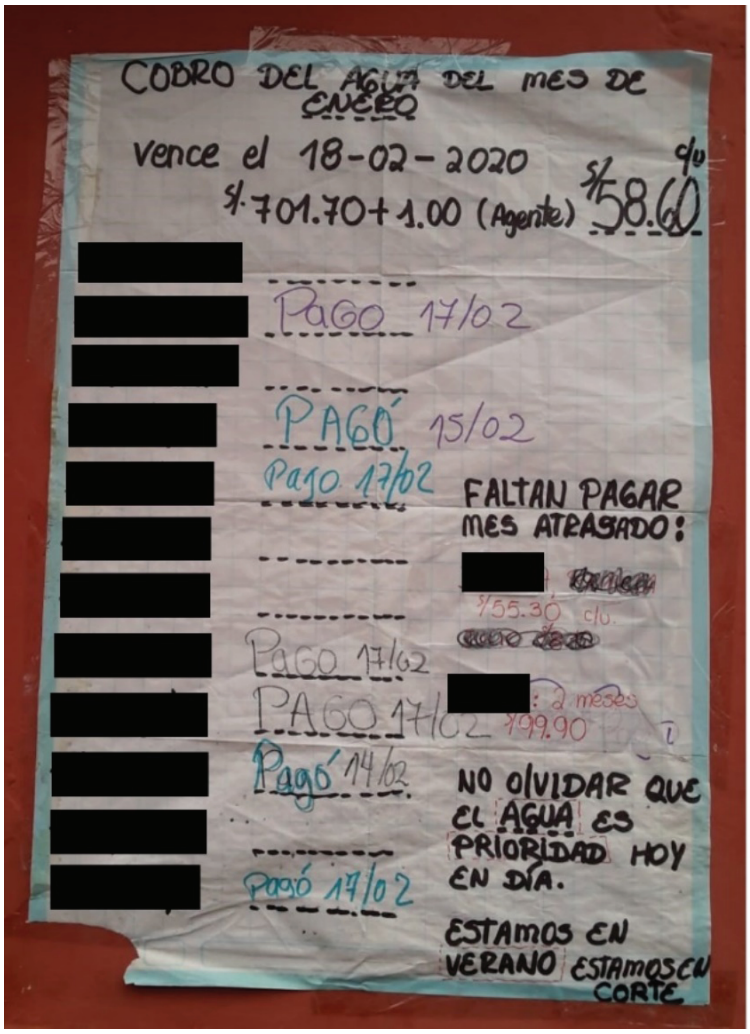
In peripheral neighborhoods, residents invest their labor and time in laying pipes, building reservoirs, and designing a system of pumps, tanks, and hoses to distribute water to the different homes in the neighborhood. In the central areas of Lima, such as Barrios Altos, where piped infrastructure is often physically close, but individual households or *quintas* (traditional courtyards with multi-household dwellings) are not yet connected, people construct clandestine connections to the primary grid or the networks of their neighbors. As a result, one Barrios Altos resident explained that the system is often overburdened:

> We do not respect the laws, we do not comply….While I pay, there are five neighbors who pay nothing, and now I have to bathe at 6 pm or at 5 pm, if I want to bathe at 10 or 11, I can't, I don't get it. In Barrios Altos, I am next to the river or near…and I cannot take a bath because it does not reach me, because from the pipe that comes five people are pulling [water]. (FG, Barrios Altos, 12 February 2020).

On the city's edge, in José Carlos Mariategui, geography plays a significant role in the types of systems that have been developed. The steepness of the hills and the quality of the roads that connect the area determine whether or not trucks carrying water (*cisternas*) can access the residents. In the most distant areas, where the *cisternas* cannot reach, residents generally construct a communal reservoir in a lower-laying part of the area. From this reservoir, the water is pumped through a network of hoses that service the different households. This system requires frequent maintenance and repair as the pump and the hoses are vulnerable to breakdown. Even for those who do live along the route of the *cisternas*, access to water remains a challenge. Residents are never entirely certain when the truck will pass their homes and if it will stop. To mitigate this, many residents have invested in constructing water reservoirs that, when filled, will last them for a couple of days.

Additionally, community boards coordinate the water management and administration within their areas (see Figure 2) and work towards formalizing the water distribution system in cooperation with SEDAPAL. The success of these practices varies and depends largely on the community's capacity to self-organize and work together. On a smaller scale, and in communities that are serviced by SEDAPAL, residents tweak the system: households install reservoirs on their roofs to guarantee a continuous supply of water despite cuts, they implement filters so they can drink water from the tap, or even build connections between the sink and the toilet to ensure that dishwater can be re-used.

Analyzing the script of the auto-constructed infrastructure, we find that residents play a crucial role in all phases of the infrastructural life cycle. The distinction between the service provider and the consumers is blurred. Residents, as 'expert-amateurs,' play a significant role in continuously expanding, improving, and maintaining the infrastructure (Caldeira, 2017;



Collection of payments for water for the month of January

Expires on 18–02–2020
S/. 701.70 + 1.00 (agent) S/58.60 pp

Paid 17/02

Paid 15/02
Paid 17/02

Missing Payment
Month overdue:

S/. 55.30 pp

Paid 17/02
Paid 17/02
Paid 14/02

2 months
S/ 99.90

Do not forget that water is a priority today

Paid 17/02

We are in summer.

We are in cuts

Figure 2. Poster on the communal wall in quinta, keeping track of the payments for the water bills. At the time, 58.60 soles corresponded to €16 or $17.3. Source: Liliana Miranda Sara. Translation by the authors.

Kuznetsov & Paulos, 2010). They take up the role of engineer, builder, and manager in one, thereby blurring the distinction between service provider and consumer, and adjusting the infrastructure to align with their needs and practices. Contrary to the formal infrastructural planning in Lima, which is a highly bureaucratic process, the auto-constructed infrastructure can respond quickly to the changing needs of residents. Within the auto-constructed infrastructure, the demarcations between the different stages of the infrastructural cycle are less clear, continually moving between planning, construction, operation, and maintenance. Nonetheless, aside from calls to residents to save water and consume responsibly, SEDAPAL's master plans often do not acknowledge their labor and knowledge in shaping the water distribution system. Although some of these constructions have been in place for decades, the work of residents is almost without exception characterized as tinkering around in the margins. The systems they construct are seen as provisional, a placeholder for when SEDAPAL integrates these areas in their centralized and digitalized infrastructure.

3.2. How Digitalization Redistributes Roles within the Operation of Lima's Water Infrastructure

As the infrastructure transitions from decentralized and auto-constructed to centralized and digital, we see that tasks that previously were the domain of the residents are now shifted towards SEDAPAL as the main service provider. In this section, we analyze how the introduction of the water meter and the customer contact center have (i) facilitated the centralization of the operation of the water infrastructure and (ii) re-inscribed the roles of residents within the operation of the water distribution system.

Operationally, the meter and customer contact center are efficient tools for monitoring the consumption behavior of users and the functioning of Lima's water infrastructure right from the central water treatment plant, La Atarjea. The implementation of the meter thus helps to centralize the control and supervision of the infrastructure, bringing Lima's water distribution network one step closer to the 'integrated infrastructure ideal.' The meter enables the enumeration of the water

consumed on a small scale and the inclusion of this data in the GIS-based systems used for the supervision and operation of the water distribution system. The type of meter implemented varies depending on the technology available at the time of installation, the width of the pipe, and the pressure of the flow. As a result, some household consumption meters in Lima need to be read manually, while others can potentially be read at a distance through electronic pulse emitters or radio frequencies (INACAL, 2020). In December 2019, 95% of the residential connections to the piped water infrastructure were metered. However, the meter coverage ranges from 41% in the least covered district to near full coverage in other districts (SEDAPAL, 2019). Households with an unmetered are charged a flat rate based on the average hours of water supply, or communities share a water bill and self-manage their payment. Upon the meter's arrival, households receive an individual bill reflecting the meter's measurement of the amount of water consumed that month. Additionally, through the meters, SEDAPAL can detect leakages and clandestine connections much easier, which leads to a reduction in the percentage of non-revenue water in their system.

Likewise, the textual and visual data generated through the customer contact center help SEDAPAL monitor the infrastructure through residents' reports, effectively providing feedback on the system's functioning. Initially, SEPAPAL hosted the call center itself, to which users could report issues with the infrastructure via phone. Today, the contact center has been outsourced and expanded, integrating various media such as e-mail, social media (Facebook, Twitter, and Instagram), a chatbot, video calls, and photo sharing into one service. The calls and the operator's movements on-screen are recorded and compiled in a file linked to the caller's customer number and, therefore, disclosing personal information such as their address and geo-location. This allows the operator to return to the conversation at any moment later in time. With the operators recording incidences and passing on this information to the relevant directories, SEDAPAL has a continuous flow of digital information coming in, reporting on the quality of its service.

In both cases, we see that the data provide information about the operation of the infrastructure on multiple levels. The data from the meter, translated into a water bill, offers residents information about their consumption patterns and can serve as a gauge to keep track of changes or failures in the system. In a number of cases, residents had received extremely high bills due to undetected ruptures or leakages in the pipes. Talking about this issue, one participant explained:

> We have had serious problems because a receipt for 6,000 has arrived! 6,000 as if we lived three, two more buildings or we would have a large pool….Of course, you pay first and then you reclaim [the money]. But we found the flaw. It was at the entrance. (FG, Miraflores, 23 January 2020).

Additionally, the spatially fine-grained (household scale) and monthly updated data from the household consumption meters provide information to SEDAPAL on the functioning of its water distribution system. Similarly, the reports continuously coming in through the customer contact center offer information on the function of the water infrastructure through the eyes of the residents. There is, of course, a bias in the self-reporting of residents as they will more likely report issues that affect them negatively rather than positively, either in their access to water or financially. Yet, through the customer contact center, SEDAPAL can capture issues that would otherwise go unreported.

At the operational level, the imperative of achieving a fully integrated infrastructure, and hence, the implementation of digital infrastructure to supervise and control the water distribution system from a central point, has been a powerful driver in the reconfiguration of information flows and relationships within the system. For residents, the digital infrastructure signifies a transition in the roles they have within the system. The implementation of the water meter shifts the administration of the water bills from the residents to SEDAPAL. From constructors, engineers, and bookkeepers, residents transition into the role of 'smart citizens' and form a critical link in the provision of data. Specifically, they play a crucial role in constructing new information flows, both to SEDAPAL and their communities and households. While the meters gather background information about household consumption, rendering residents into passive data providers, the customer contact center relies on the active involvement of consumers in reporting the malfunctioning of the system. As a result, in the script of the digitalized infrastructure, residents take up different roles than in the auto-constructed infrastructure. Rather than physically constructing or operating the infrastructure, they re-inscribe it through their passive or active production of data.

3.3. How Digitalization Reconfigures Residents According to Its Embedded Normative Framework

In this section, we analyze how the re-scription from auto-constructed to digital infrastructure is tied to concerns about the integrity of the technology and how the meter and customer contact center prescribe residents the roles of 'smart citizens' and 'responsible users' rather than auto-constructors based on the infrastructure's embedded norms.

In conversations with SEDAPAL, the digital information infrastructure represents the modernization of the distribution system and overall 'progress.' Modernization, in this case, signifies a clear relationship between the residents as customers and SEDAPAL as sole service-provider. Particularly in the *quintas* of Barrios Altos, the residents welcomed this transition. From our analysis, it emerged that the administration of the water consumption amongst these communities

was often paired with stress and conflict, either due to the fact that not all neighbors would pay their respective share in time or because people would construct clandestine connections to avoid payment. Whereas previously, it was necessary for several households to make collective agreements about payment of the water bill, the meter individualizes this process and decreases one's dependency on neighbors. One participant alluded to the way the meter offers residents a certain degree of protection from their neighbors. They explained that the meter provides transparency concerning who is paying for the water, and therefore makes it visible who has constructed a clandestine connection and is 'stealing' the water from their neighbors.

While this change is welcomed by many, the implementation of the meter is also regarded with suspicion by others. The residents expressed uncertainty about interpreting the data generated by the meter and its accuracy in reflecting the households' consumption. For example, it was not understood how it was possible that after the implementation of the meter, their water bill had gone up. Or, in Miraflores, why their consumption was registered as so much higher than in other areas. During FGs, participants hypothesized that these issues could be explained by the quality of the meters installed:

> You see the meters that SEDAPAL puts, the air passes and [the meter] rotates and should not rotate for the air, only when the liquid passes (FG, Barrios Altos, 12 December 2019)

Or by SEDAPAL taking advantage of the opacity in the data flows to their benefit:

> Participant 1: It may also be that they are inflating the consumption.
>
> Participant 2: I wouldn't be surprised at all. (FG, Miraflores, 23 January 2020).

As a result of this lack of trust in the integrity of the technology and SEDAPAL, in Miraflores, the overwhelmingly highly educated crowd in the focus group discussed the possibility of partnering with accredited laboratories to measure the accuracy of the meter and check the water quality. In discussing their options, the importance of working together with an official notary and working with certified material was emphasized to avoid all possibilities of not being taken seriously. Similar concerns were voiced, and possibilities for actions discussed in Barrios Altos and José Carlos Mariategui. However, contrary to the specialist approach discussed by the residents in Miraflores, the envisioned options of residents in Barrios Altos and José Carlos Mariategui were to file complaints with SEDAPAL directly via the customer contact center or on social media, a process which was described as tedious and often dead-ended:

> Participant 1: I think you can report what's happening on social media, right?
>
> Participant 2: Yes, but they never answer you, one calls for any accident, your pipe breaks, and they never answer. It is a bit difficult to talk to them.
>
> Participant 3: Practically, they have [the costumer contact center] as a screen. (FG, José Carlos Mariategui, 11 December 2019)

Thus, although designed as an instrument for enhancing the service provision to the users and improving the residents' relationship with SEDAPAL, in conversations, residents frequently shared their frustrations with us regarding the customer contact center. Residents explained they were put on hold for a long time and that when they managed to get through did not receive the help they expected. On the other hand, officials of SEDAPAL said that there are often inconsistencies in user reports, and people try to twist the truth for it to suit them better.

This highlights the contradictions in people's responses to the implementation of digital infrastructures and the roles they play in their becoming. The (digital) technologies, and by extension the digital data they produce, change the script of the system by creating new information flows between the infrastructure and SEDAPAL, as well as between the residents and their water consumption. This suggests an increase in efficiency and transparency: Two much-needed properties for the administration of basic services (Ioris, 2016; Martinez, Pfeffer, & van Dijk, 2011). Additionally, since users with a meter see the changes in their consumption pattern directly reflected in the monthly water bill, the presence of the meter incentivizes responsible water consumption (Brown & Pena, 2016). However, given residents' general skepticism towards the integrity and capacity of SEDAPAL, the meter represents the presence of an institution that is mistrusted, and it is widely linked to stories of malfunctioning.

We notice a difference in the ways that residents, coming from various socioeconomic backgrounds, navigate these contradictions. As part of the residents embrace the implementation of the meters, others have refused to them installed in their neighborhoods or have taken them out of the infrastructure upon installation. This is closely tied to normative discussions about what it means to be a responsible consumer of water. While skepticism towards SEDAPAL and the water meters is widespread, residents who refused to have meters installed are often questioned for their motives. It was stated by fellow residents and SEDAPAL alike that their unacceptance of the water meter and unwillingness to share information came from a wish to maintain clandestine connections rather than concerns about the integrity of the technology. The distrust towards these communities is reflected in the policies of SEDAPAL, which only provides water 24/7 to infras-

tructural sectors with meters installed. The other sectors are rationed and receive water for limited hours per day since it is assumed that non-metered residents will consume irresponsibly.

Thus, the meter and the customer contact center, as pivotal objects in the digitalization of Lima's water infrastructure, reconfigure the role of residents within the system, not only operationally, but also morally. The meter contributes to the independence of households in their administration of water consumption and can serve as a tool for people to become 'responsible water consumers.' The people who opt out of this transition are regarded as irresponsible consumers and punished for not following the script. Interestingly, the digitalization of the infrastructure does not lead to a similar transition in residents' perception of SEDAPAL and the state at large. The meter does not improve the public image of the SEDAPAL by increasing efficiency and transparency. In practice, quite the opposite has occurred. By its association with SEDAPAL, the meter is perceived and experienced as counterfactual and part of a fraudulent infrastructural assemblage.

4. Agency and Self-Determination within Digitalized Infrastructure

As Simone (2019) writes, urban residents inhabit the process of urbanization, rather than the place. This is specifically true for Lima's working-class residents who live through the different iterations of the script of the water infrastructure, which requires different tasks, relationships, and skills from them each time. Focusing on the work that is necessary to construct and operate infrastructure illustrates how this transition does not take place automatically, nor is it always considered to be an improvement. The ways that residents relate to these changes are multiple, as are their strategies to navigate them.

This research has analyzed how the digitalization of the infrastructure alters the script of the system and redistributes tasks, roles, and responsibilities within the infrastructure. The construction and administration of the water infrastructure have increasingly become a governmental rather than a communal effort, reflecting the centralization of the infrastructural system. In the script of the auto-constructed infrastructure, people's roles are best conceptualized as 'expert-amateurs' (Kuznetsov & Paulos, 2010). The qualification of 'expert' is important in this case since the residents have advanced tacit knowledge about the needs of the community and the design, operation, and administration of the water distribution systems they have developed. As auto-constructed systems are formalized and augmented with digitalized infrastructure, residents transition from these roles into various types of data providers, i.e., smart citizens.

The conceptualization of residents' roles as 'smart citizens' is a useful heuristic to think through the exclusionary ways in which the position of people within the infrastructure changes (Calzada, 2018; Vanolo, 2016). When only digitally enabled participation, be it active or passive, is considered valuable, the work and engagement of non-digital residents remain hidden (Tenney & Sieber, 2016). Our analysis shows that despite the normative push of the infrastructure to mold people into 'responsible consumers' or 'smart citizens,' residents find different ways to exercise their agency. This includes opting out of the system, providing information in the shape of data, questioning the workings of the (digital) infrastructure, and critically engaging with SEDAPAL's policies through protests, marches, and public debate. Residents' practices often go against the logic of the integrated infrastructure. They 'disobey' the normative script, sometimes leading to tensions while doing so (Akrich, 1992; Jelsma, 2006).

Nonetheless, the skills needed to exercise agency in the new script are drastically different from the previous forms of the infrastructure. Within the digitalized system, an understanding of (digital) technology and (data) policy becomes more important than constructing expertise or communal organization skills. The digitalization reconfigures the agency of the residents around the expertise of the 'smart citizen,' and, as such, prescribes who has the capacity to act (Pilo', 2017; Shelton & Lodato, 2019). We see this illustrated in the different strategies employed by the residents in Barrios Altos and Miraflores to verify the measurements of the water meter. For non-digital residents, the digital infrastructure can be exclusionary and opaque, whereas these residents were considered experts within the auto-constructed infrastructure. As such, the digitalization of the infrastructure has implications for the self-determination and agency of Lima's residents. Explicitly considering the underlying socioeconomic inequalities in Lima, attention should be paid to developing a system that fosters the participation of all residents and avoids the peripheralization based on knowledge asymmetry (Rabari & Storper, 2015).

It is essential to consider the differences between the digitalization trajectory in formalized infrastructures and cities, compared to auto-constructed spaces. Particularly, as stressed by Vanolo (2016), smart cities are not built on empty land, and a variation in starting points lead to differences in the degrees of residents' participation that emerge. This is not only relevant when comparing various neighborhoods within the city of Lima but also when we conceptualize the influence of digital infrastructures between cities in the North and the South. The differences between residents with metered connections in Miraflores and Barrios Altos show how digitalization does not create homogeneous 'smart citizens' in Lima. Depending on the connections and skills of residents, 'smart citizens' can be integrated or excluded by the digital infrastructure. Similarly, just as the 'smart citizen' should not be considered as either a passive data point or an engaged co-developer (Vanolo, 2016), the 'expert amateurs' are at once marginalized and active-

ly re-inscribing the infrastructure in their neighborhoods or households.

Therefore, the case of Lima shows how thinking about integration and unbundling (Graham & Marvin, 2001) in a successive manner is not useful in the context of Lima, as both processes are happening at the same time. The digital infrastructure has effectively led to an increase in the centralization and integration of the water infrastructure and led to better service provision for citizens who are formally connected. Digital infrastructures are a useful tool in the operation of the water distribution system, provide the opportunity for people to voice their critique via the customer contact center, and cater to the individual household rather than the community. Nevertheless, simultaneously, the digitalization of the infrastructure increases the differentiation in terms of influence and agency and further disenfranchise people and places with little material and socioeconomic connections. While auto-construction continues to be an important form of infrastructural development in Lima, the changes in the infrastructural script hamper people from finding innovative ways to construct and manage water systems according to their own logic, a characteristic of auto-constructed systems which has advanced service provision in areas that are not (yet) serviced by SEDAPAL. As residents are required to switch roles and adapt their capacities to what is considered desirable within the integrated infrastructure, digitalization can further marginalize people and neighborhoods in particular life situations (Caldeira, 2017; Malgieri & Niklas, 2020).

5. The Peripheralization of the Non-Digital

As the smart city and its technologies unfold over the world, it is important to consider the integrity of the digital infrastructures that are called into being. This makes us think about what infrastructures are required to foster connection and inclusion in the margins. Our analysis of how digital infrastructures change the script of the water distribution system has shown how digitalization is not only a matter of efficiency but also leads to the reconfiguration and moralization of the position of diverse actors within the infrastructural system. Digitalization, as a result of the further transformation of auto-constructed to digital infrastructure, contributes to the further peripheralization of the non-digital city, and the non-digital resident as an exceptional category, outside of modern society. The role of the expert-amateur in the auto-constructed infrastructure becomes the 'absent citizen' (Shelton & Lodato, 2019) in the smart city. The acknowledgment of heterogeneity and differentiation can not only attune policies towards the particularities of implementing digital infrastructures in a Southern context (Coutard, 2008) but also make aware of how these transitions shift the roles of residents within the system. To overcome the perpetual creation of the center and the periphery through digitalization, urban water management should be sensitive to residents' innovative ways of getting access to water and managing resources within their households and communities. Future research on smart cities can take inspiration from the expert-amateurs in working towards technological and urban development that cultivates the self-determination of residents and ownership over the (digital) infrastructures created.

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Conflict of Interests

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