Urban service co-production and technology: nine key issues

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ABSTRACT

This special issue investigates the role of technology in the co-production of urban services through six empirical articles based on case-studies from Asia, Africa and South America. This topic has not received yet extensive attention in the literature, despite the emergence of technology as the key mediator between the material and immaterial elements of co-production practice. Based on the analysis of the six contributions, this introductory paper presents nine key issues related to the role of technology in service co-production, which are considered from four analytical perspectives: materiality, knowledge, actors and outcome. Technology co-evolves with physical contexts and practices. It fosters synergic knowledge generation, while also being the product of its own application. It contributes to changing governance structures and the emergence of new intermediary actors. Finally, technology influences power dynamics and equality of access to service, resulting in service provision that may be inclusionary or exclusionary, emancipatory or restrictive.

1. Introduction

The debate on urban services is increasingly concerned with exploring the relationship between urbanisation, society and the environment, by focusing on the role of infrastructure – and the associated technical and governance structures – in shaping trajectories of urban sustainability (Monstadt 2009; Furlong 2014; Graham and McFarlane 2014; Jaglin 2014; Coutard and Rutherford 2015). This special issue contributes to that debate by investigating the role of technology in the co-production of urban services, a topic that has not yet received extensive attention in the literature.

Co-production was first defined by Elinor Ostrom as ‘the process through which inputs used to produce a good or service are contributed by individuals who are not “in” the same organisations’ (Ostrom 1996, p. 1073). However, when referring to urban services, there is not yet a broad consensus on a precise definition of the concept, although the existing research mostly agrees on the following interpretation: service co-production is a practice, institutionalised or not, often collaborative, that involves individuals or groups of citizens, intermediaries and the state (such as local administrators, state agencies), in one or more phases of the service delivery cycle (e.g. co-planning, co-design, co-management, co-assessment) (Joshi and Moore 2004; Nabatchi et al. 2017; Moretto et al. 2018; Faldi et al. 2019).

At the international level, Article 117 of United Nations Policy Paper 9 for Urban Services and Technology (Habitat III) has recently recognised co-production as a possible approach for service delivery in cities, to be pursued especially in informal settlements of cities in the Global South ([UN] United Nations 2016). At the scientific level, an increasing number of articles have been published in recent years on the topic of co-production of basic urban services, including 3 thematic issues in international journals (Ahlers et al. 2014; Moretto and Ranzato 2017; Mitlin and Bartlett 2018). Research on urban service
co-production includes not only the most “conventional” networked services, such as water, sanitation, energy and waste collection (see for example Gutberlet 2015; Button 2017; Pilo’ 2017; Ilito-Boozi and Moretto 2021), but it extends to consider less traditional non-networked services, such as urban mobility, disaster risk management and climate services (see for example Schaer and Hanonou 2017; Vincent et al. 2018; Jaspers and Steen 2021).

Research on service co-production has studied co-production from three different perspectives. First, research taking an institutional/governance perspective has mainly focused on the more managerial aspects of the practice (Bovaird 2007; Mitlin 2008; Bovaird and Loeffler 2012; Pestoff et al. 2012; Allen 2013; Jakobsen 2013; Ahlers et al. 2014; Nabatchi et al. 2017). Second, research more focused on the material aspects of co-production has introduced the consideration of the socio-technical, socio-ecological and spatial dimensions of the practice in relation to its managerial dimension (Yu et al. 2012; Cabrera 2015; Moretto and Ranzato 2017; Moretto et al. 2018; Ranzato and Moretto 2018; Faldi et al. 2019, 2020). Third, an emerging research perspective links the co-production of urban services to the issue of knowledge co-production, especially in the case of information-based services (Mitlin and Bartlett 2018; Ojeda et al. 2018; Vincent et al. 2018; Faldi et al. 2021).

Co-production is therefore a practice entailing a social and physical dimension, reflecting the interaction of different actors through material and immaterial connections that engage a dynamic relationship with the space and resources involved at multiple scales in the production of the urban service (Ahlers et al. 2014; Faldi et al. 2019). In this multi-dimensional view, the technology of co-production, defined as a socio-technical arrangement including both physical (e.g. technical devices) and social (e.g. actors-related skills) components (Van Vliet et al. 2005; Yu et al. 2012; Faldi et al. 2019), is the mediator connecting the material and immaterial elements of service co-production. It acts thus at the interplay between the co-production actors (user, providers, intermediaries) with their governance structure and knowledge, and the resource (e.g., water, wastewater, stormwater, solid waste, energy). It may also contribute to generating varied, sometimes novel, social structures, while assuming different spatial configurations. Research on service co-production has often mainly focused on the analysis of the social and physical dynamics underpinning the practice, considering technology as a mere tool of connection between them without assigning it adequate scientific relevance. Despite its key role, the research has rarely focused on the role technology plays in the conception, evolution, and outcomes of the practice.

The objective of this special issue is to provide a substantial contribution to the debate on sustainable urban service provision by questioning the role technology plays in service co-production, an aspect we consider fundamental to understanding the characteristics and sustainability of this unorthodox form of service delivery.

The issue approaches the study of service co-production technology on the basis of four different research questions:

1. **Technology and materiality**: technology is a means of physical change in both resource/space and human practices. Which are the relationships between the physical space in which actors co-produce, including the resource at the basis of an urban service, and the technology underpinning the practice? How does technology influence users’ material/spatial practices at different service co-production phases?

2. **Technology and knowledge**: technology is a means of knowledge exchanges between actors, relevant in generating new knowledge and applying it in human practices. How do knowledge synergies between co-producing actors take place through technology? How and to what extent is technology instrumental in expanding the collaboration and knowledge synergies between service recipients in the planning and implementation of the service?

3. **Technology and actors**: technology is a means of influencing social relationships between the actors of co-production. How does technology influence different governance structures (e.g. allows to constitute new/other governance arrangements), and vice versa? To what extent does technology change the roles of actors in service co-production? Which drivers are behind specific technology systems?
(4) Technology and the outcome of co-production: taking a normative perspective, technology is a means influencing equity and power in service co-production. To what extent (and how) does technology become the material means through which actor empowerment or disempowerment takes place in co-production? Is the use of a particular technology exclusionary with respect to certain groups of people, either with respect to access to the service or to the decision-making process?

In this introductory paper, we provide a crosscutting interpretation of the role of technology in the co-production of urban services, by presenting nine key issues related to the questions mentioned above. The paper is based on the analysis of the six articles included in the special issue, which explore one or more perspectives on technology and service co-production, focusing on different types of urban services and case studies from Asia, Africa, and South America. Federica Natalia Rosati, Luisa Moretto and Jacques Teller explore the relations between incremental transformations in the urban fabric and the relative changes in socio-technical arrangements in water and sanitation service co-production in Hanoi (Vietnam). Mélanie Rateau and Sylvy Jaglin examine the hybridisation of configurations to access electricity service in Cotonou (Benin) and Ibadan (Nigeria). Suchismita Chatterjee and Ratoola Kundu analyse the complex arrangements of technologies, practices and actors with their power relationships in producing water supply service in Baruipur (India). Sun Sheng Han investigates the actorial, policy, and technological factors influencing the inception and evolution of a bike sharing programme in China. Arya Lahasa Putra, Javier Martinez and Jeroen Verplanke explore the factors that enable the integration of co-production of climate services into spatial planning in Jakarta (Indonesia). Finally, Harry Smith, Soledad Garcia Ferrari, Gabriela M. Medero, Helena Rivera, Françoise Coupé, Mónica Elizabeth Mejia Escalante, Wilmar Castro Mera, Carlos Alberto Montoya Correa, Alex Abiko and Fernando A. M. Marinho evaluate different socio-technical arrangements developed in Medellín (Colombia) and Sao Paulo (Brazil) to co-produce a landslide risk management service.

2. Key issues on technology in urban service co-production

2.1 The relationship between technology and the physical context

The relationship between technology and the surrounding physical context has recently been the focus of several studies on the co-production of urban services (see for example Moretto et al. 2018; Ranzato and Moretto 2018; Faldi et al. 2019). These studies have highlighted that certain technological arrangements enable a closer relationship between actors and resources, and that the possibility for actors to operate directly on the socio-technical system creates ‘windows of opportunity’ for co-creation and technological innovation, potentially changing urban infrastructure landscapes. Special issue contributions help shed light on two inverse dynamics between technology and the physical space with its resources.

2.1.1 From space/resource to technology

Changing physical conditions, including reconfiguration of the built environment as well as spatial transformations, and locally available resources determine – and limit – the range of technology at the basis of co-production. Available technology for co-production depends in fact on the characteristics of a context, such as the type of settlement and resource, the urban morphology, housing density, as well as distance from the centralised system in the case of networked services (e.g. water, electricity) (Faldi et al. 2019).

This relation is clearly expressed by Rosati et al. (this issue) for the case of water and sanitation services in Hanoi. The authors show how the incremental transformation of the built environment has profoundly influenced the evolution and hybridisation of technological arrangements for the delivery of services. For instance, in the French District of the city, the progressive densification – and the consequent reconfiguration of urban blocks around narrow alleys – has led to the ‘multiplication of households’ technical devices (tanks) and branches (pipes and lines) connected to a newly built secondary drainage and water pipe’ (Rosati et al. this issue, p. 173). In order to adapt to the discontinuous frequency of the networked water supply system, storage and processing of the city’s drinking water intensively involve the local space via devices sized according to the physical conditions,
such as load capacity of facades and roofs, and the spaces available between buildings, which are roads and pathways.

Similarly, the spatially situated diagnosis of Rateau and Jaglin (this issue) of the energy co-production arrangements in Cotonou and Ibadan shows that there is a strong correlation between the socio-technical arrangements for energy-supply and the socio-spatial conditions of the city. The authors highlight that hybridisation of electricity configurations, with their specific technical arrangements (i.e. ‘spiderwebs’ through DIY grid connections, off-grid technologies such as generators and solar lamps, and storage technologies such as photovoltaic panels with batteries), is embedded in heterogeneous urban, ‘spatially situated’, environments. These heterogeneous and hybrid urban electricity systems of a multi-actor and multitechnology nature are developing in reaction to the multiple gaps of the conventional power grid system. In Cotonou in particular, a variegated technology makes it possible to co-produce energy supply arrangements via individual initiatives and everyday practices that attempt to overcome deficiencies in the supposed universal infrastructure coverage of the conventional system. By contrast, in Ibadan, with an ‘electricity landscape marked by a universal network with an erratic service, the purpose of the co-production of electricity access [...] is to secure the supply and maintain continuity’ (Rateau and Jaglin this issue, p. 191). In both cities, urban morphologies, remoteness, and urban densities together with economic availability influence the configurations and devices composing the variegated landscape of co-produced energy supply at the urban level.

2.1.2 From technology to space/resource
An inverse relationship of influence from technology to space and resources is equally evident in some special issue contributions. Through technological innovation and adaptation, inhabitants produce new or different urban spaces and modify their social relationships and spatial practices.

In the case of co-production of the landslide monitoring service in Pinares de Oriente (Medellin), citizens’ involvement in landslide monitoring via mobile phone encourages a change in their understanding and use of the neighbourhood spaces more at risk of landslide (Smith et al. this issue). Likewise, Rosati et al. (this issue, p. 176) show that, in Hanoi, new configurations of socio-technical infrastructure ‘play a central role in the incremental process of consolidation and reconfiguration of the built environment’. Technical hybridisations, taking the form of either an upgrade of the technological portfolio or the inclusion of new technologies in the system, ‘influence the ways different forms of co-production initiatives develop on different scales to guarantee and/or improve access to water and sanitation services’ (Rosati et al. this issue, p. 176). In the cases of soviet collective blocks (KKT) and the Linh Dam New Urban Area (NUA), the technological reconfigurations undertaken to adapt to water service deficiencies, specifically the installation of individual water tanks on building facades and the building of new supply lines (pipe, underground tanks, pump) respectively, modified private and shared spaces and the spatial practices of both individuals and resident management boards.

In general, the expansion of the technology portfolio makes it possible to differentiate the available resources and provide flexibility in the face of sudden system failures. For example, in Baruipur, the available technology (wells, pipes, mineral water plants) based on local exploitation of groundwater allows inhabitants to diversify their water supply rather than rely exclusively on the irregular municipal public water provisioning based on surface water. This multiplies the resources in use and secures local access to service (Chatterjee and Kundu this issue).

2.2 Practices of management and maintenance
According to Akrich (2010, p. 205), technical objects are ‘obligatory mediators in all our relations with the “real”’. They can be intended as complex compositions of different forces (Akrich 2010), including those forces related to the use of the object and the human practices associated with its use. It is therefore possible to find the practices associated with the use of the service inscribed in the technical apparatus employed in service co-production as much as maintenance and management practices. Special issue contributions show how the technologies employed make users act in different, sometimes multiple, roles in their everyday spatial practices related to different phases of service co-production.

2.2.1 Maintenance activities
To keep the co-produced service running, a number of maintenance activities are required. As Akrich (2010, p. 213) writes, ‘the technical object defines
actors, the space in which they move and [...] the relationships between these actors'. Technology can reveal who the actors involved in maintenance are, and therefore also whether maintenance activities are co-produced or not. In Medellin and Sao Paulo, the technology used for landslide risk monitoring enables local communities to have an active role in maintenance. Mobile phone photography shared in the instant messaging freeware WhatsApp allows the volunteers with a smartphone to engage in the process of monitoring critical landslide risk points in collaboration with local government agencies (Smith et al. this issue).

In China, the use of GPS navigation in the dockless bike-sharing service has allowed users to help better manage the service, by providing a sort of indirect maintenance, in the form of information necessary to keep the service running. The application of geofencing technology in smart locks, coupled with a subscription to the service and associated user identification, changed the previous erratic behaviour of users who then started to park their bikes correctly 'in line with government expectations for a good street order, and with providers’ expectation for a better parking management' (Han this issue, p. 221).

Homemade/unconventional electrical extensions of the grid in Cotonou and off-grid electricity supply systems both in Cotonou and Ibadan allow households to operate basic maintenance operations by themselves as much as possible, and to turn to technical services just for those aspects they cannot solve on their own. For instance, they do whatever they can to maintain their own generators, solar lamps, solar mini kits, domestic solar systems, domestic wind turbine, batteries and so on. However, the maintenance of the ‘spiderweb’ of unconventional networks can also cause ‘serious harm from fires or electrocution, for example, because of the failure to comply with electrical safety standards’, thus potentially requiring the support of specialised operators (Rateau and Jaglin this issue, p. 188).

Even in the KTT collective blocks in Hanoi, households can operate basic maintenance activities on their own technical apparatus for water service (mainly pumps, pipes, filters and tanks). Here, as regards the co-produced sanitation service, the septic tanks can be fairly easily monitored by the institutionalised resident group tổ dân phố (TDP), which outsources the emptying service to a private company (Rosati et al. this issue). Also in the neighbourhoods of Baruipur, the technological apparatus employed by the water vendors – deep tube wells, packaged drinking water units, and bottles – and by inhabitants with a shallow well – hand-pumped shallow tube wells, and sometimes a storage tank – is such that vendors can carry out a number of basic maintenance activities on their own (Chatterjee and Kundu this issue).

### 2.2.2 Management activities (other than maintenance)

In service co-production, the technical object, besides the mere use, also incorporates a number of practices of service management which sometimes appear mixed with the use itself. Here, ‘management’ is understood as the activities associated with service operations and continual service improvement of the service lifecycle. The scale and dimension of the technological apparatus (Rosati et al. this issue), but also its interface – ‘a situation, way, or place where two things come together and affect each other’ (Cambridge Dictionary 2022) – combine to define the possible management practices for the inhabitants and/or their representatives. According to Gramsci (1975), ‘there is no human activity from which any intellectual intervention can be excluded’, the practical activities associated with the service management could be – again in the words of the philosopher – more related either to cerebral intellectual processing or the muscular-nervous effort. The technical object embeds the possibility for one or the other of these two forms of intellectual activity.

In the new giant Linh Dam apartment towers built in Hanoi by private developers as part of the new urban areas (NUAs), the centralised water network offers households secure, constant water provision. Users are directly involved in the management of the service. Every 3–5 years, they elect representatives who become part of the technical board and are in charge of negotiating ‘the allocation of resources, lower costs of repair and maintenance’ with the property developer and the local authorities (Rosati et al. this issue, p. 172). However, beyond their own taps, households do not have access to interventions on the technological apparatus, which is in fact a large-scale infrastructure, and, for each housing block, made of two underground water tanks, pumps, two water tanks on the upper floor and all the related valves and pipes for the connection to each flat. In Cotonou, in the case of energy resellers via DIY
connections, users directly manage the service by reading an unconventional metre (i.e. a metre not recognised by the electricity distribution company) – if there is one, calculating the bill, and collecting the payments (Rateau and Jaglin this issue). A more ‘muscular-nervous’ effort is required, for instance, of the inhabitants of Cotonou and Ibadan who manage their off-grid electricity appliances. The small-scale technical devices for energy production and storage allow users to monitor continuously. In addition, those provided with a generator have to regularly refill it with fuel.

In Baruipur, instead, the maintenance of the technological apparatus for water provision involves users both intellectually and physically. For instance, the small off-network pumps normally installed at the household level are directly managed by the users, who also have to pump up their water by hand when the pump is not mechanised. Likewise, private water vendors with a licence to sell from the licencing department manage the entire service, both in the more ‘cerebral’ aspects such as pricing or bureaucratic issues, and in the more ‘muscular-nervous’ sense, such as bottling and bottle distribution (Chatterjee and Kundu this issue).

### 2.3 Technology and knowledge co-production

In service co-production literature, the focus on knowledge reflects the idea that creating synergies between different and complementary forms of knowledge can contribute to improving the capacities of the actors in producing the service in their local contexts, and consequently the final service outcomes (Ostrom 1996; Watson 2014; Mitlin and Bartlett 2018). The way in which this localised (Watson 2016), context-specific (Croese 2020), place-based (Faldi et al. 2021) knowledge is produced and used has a bidirectional relationship with the technology at the basis of service co-production. Special issue contributions show that technology emerges either as a procedural element, or as an outcome element.

#### 2.3.1 Technology as a procedural element

Technology is a procedural element when it acts as a means facilitating the creation of knowledge synergies between the actors of the co-production process. This is the case of services where co-production is ‘planned’, representing the explicit goal of a process most often initiated by researchers, experts (e.g. NGOs) or the state. Co-production rests on the primary idea that creating knowledge synergies is advantageous for more effective service planning and implementation. In the perspective of the initiators, technology therefore permits the gathering of users/citizen’s knowledge. Through technology, actors interact with the aim to better understand contextual problems, actors’ needs and capabilities, to provide the common ground for sharing values and meanings, and to open up a space for dialogue and potential improved solutions.

In Medellin and Sao Paulo (Smith et al. this issue), technical solutions (e.g. mobile and drone photography) at the basis of co-production experiences initiated by researchers are integrated into a platform including the knowledge of inhabitants and/or local communities, and favouring an improved service. Smith et al. (this issue, p. 259) show that community-based monitoring groups were able to systematically collect and analyse data, thus increasing ‘their understanding of the ground conditions and behaviour of rainwater in their neighbourhood’. They were also able to propose emergency landslide mitigation solutions to local government based on their increased knowledge of water flows in their neighbourhood. In Jakarta, the Participatory Urban Neighbourhood Assessment project was implemented by several NGOs in the most vulnerable coastal village, Marunda, in order to produce climate community knowledge as inputs for decision-making. The project shows the potential of web-GIS digital mapping as a technology platform to involve youth groups in sharing their knowledge of the territory (Putra et al. this issue).

#### 2.3.2 Technology as an outcome element

Technology is an outcome element when it is the result of knowledge synergies between the actors of the co-production process. This is rather the case of services where co-production is not planned, but it is a ‘spontaneous’, ‘insurgent’ practice initiated by individuals or groups of citizens to cope with the deficiencies of a networked system, through the installation of various, sometimes unexpected and innovative, technological arrangements. In many cities of the Global South, this type of co-production is a widespread practice, especially for services like water, sanitation and electricity that are rarely universally accessible.
In their effort to find a solution to adapt to service disruptions and thus secure a basic need, co-producers continuously mould and adapt technological arrangements according to their experiential knowledge, habits, social practices, and best approach to incorporating the system in their everyday context. Technology is thus the product of co-producers’ everyday experience, shaped by the continuous learning by doing processes associated with maintaining and repairing the urban infrastructure, and by the knowledge synergies established between other inhabitants involved in co-production. This process of mirroring knowledge into the technology of co-production is brilliantly represented in the special issue contributions by Rateau and Jaglin (this issue) and by Rosati et al. (this issue) through the concepts of ‘hybridisation’ and ‘incrementalism’ respectively.

Although the knowledge co-production process reveals the potential to create technological innovations capable of improving the service for many inhabitants within dynamic contexts such as Hanoi, Ibadan or Cotonou, these co-produced technological arrangements do not guarantee an effective and secured service. Exemplary in this sense is the case of Baruipur (Chatterjee and Kundu this issue), where the spread of co-produced practises (i.e. local water networks and informal water vendors) based on groundwater is fuelled by a false shared knowledge, namely the widespread perception that treated surface water distributed by the city networked system tastes worse than groundwater, which in reality has high levels of arsenic contamination hazardous to inhabitants’ health.

### 2.4 Technology between co-creation and implementation

Service co-production makes the user a ‘knowledgeable agent’ (Van Vliet 2012, p. 275) who, through technology, acts in collaboration with other actors (with their different knowledge) either in the planning or implementation of the service, or both. Technology can be instrumental in expanding the collaboration (and thus the knowledge synergies) of service recipients to include the planning of the service itself. Alternatively, technology can restrict participation to service implementation only. Brandsen and Honingh (2018) refer to co-creation of the service in the first case, and co-production in service implementation only, in the second. Co-production in service design, instead, occurs when recipients have a say in the design of the service but not at a strategic level – which essentially means that recipients are not among the initiators of the service itself (Brandsen and Honingh 2018).

#### 2.4.1 Co-creation

In Medellin and Sao Paulo, technology favoured co-creation of the service in many respects. In order for communities to participate in the strategic phase of the services implemented to counteract the local landslide risks – thus to be among the initiators – shared knowledge was the pre-requisite (Smith et al. this issue). In the wake of Freire (1972), the strategic phase was conceived to value ‘local’ and ‘indigenous’ knowledge – and technology – and to bring it into open dialogue with the technical knowledge of local institutions and researchers. The mitigation works undertaken at the neighbourhood, courtyard, and household levels – defined as secondary, tertiary and individual respectively – mix the technical knowledge of locals, experts, and researchers and lead to low-cost solutions made with materials that are local and appropriate for self-construction. Knowledge synergies were essential also in the implementation phase. The community works were often guided and coordinated by experts such as a consultant architect and/or local builders. But in Medellin and Sao Paulo, the technical dimension was also key to building shared knowledge as a base for the service planning phase. For instance, the use of drone photography by the research team both in El Pacífico and Carpinelo 2 (Medellin) and the drawn surveys conducted by students and local NGOs in all the four analysed settlements facilitated the participation of inhabitants as co-initiators of the landslide risk management service (Smith et al. this issue). In Benin, wealthy inhabitants of Cotonou who have no access to the standard power grid, equip themselves with off grid systems (Rateau and Jaglin this issue). They have the possibility – indeed they are often forced due to lack of other options – to plan and implement alternative energy supply configurations using generators, solar lamps, solar mini kits, domestic solar systems or a domestic wind turbine, etc.

#### 2.4.2 Indirect co-creation

Users of the dockless bike-sharing transport service in China contributed to shaping the service even at the strategic level, just by making use of it. With the Internet-of-Things, such as GPS technology in smart
locks, users participated in providing feedback loop data necessary to define the service, and also to avoid interruptions and improper bicycle parking (Han this issue). Yet, co-creation via digital technology does not imply the traditional active co-production elements and it is instead based on machine-to-machine interactions that, paradoxically, ‘increasingly take over the roles of citizens as active service co-producers’ (Lember 2018, p. 123).

2.4.3 Implementation

Both in Medellin and Sao Paulo, available technology, such as having a smart phone with a camera and the instant messaging freeware WhatsApp, allowed local volunteers to implement the monitoring of the service. Community volunteers were trained to take photographs of monitoring points using their own mobile phones and share them via WhatsApp groups (Smith et al. this issue). In Jakarta, digital technology enabled the community of Marunda to implement – and, to a certain extent, design – the climate service co-production. Youth groups collaborated with several local NGOs in developing digital mapping of identified risks using the Ushahidi2 and OpenStreetMap3 platforms (Putra et al. this issue). However, the fact that the inhabitants did not participate in the planning phase of the service led the initiators to underestimate the technological dimension of the digital divide. Because of the lack of internet connection and/or familiarity with digital cartography, some inhabitants cannot benefit from a service that is essentially telematic.

Technology also allows co-production in service implementation in Hanoi, where, in KTT collective buildings, inhabitants have set up storage systems at the dwelling level to cope with the discontinuous supply of drinking water. The drinking water service is self-upgraded thanks to a technical apparatus, which is small, versatile, light, and relatively low-tech (Rosati et al. this issue). However, water withdrawals and storage and distribution systems through pipes, does not allow the inhabitants to intervene in the strategic phase or the design, as it is often the case in centralised systems. Therefore, their co-production in design is limited to the hybridisation of the service provision system.

Co-production in service implementation can also be found in Benin. In Cotonou, the technological apparatus – poles, cables and sometimes unconventional metres –, though often not in compliance with the electrical safety standards, allows inhabitants to have access to electricity by extending the conventional grid (Rateau and Jaglin this issue). At the same time, in order to cope with interruptions to the centralised power service, households instal backup battery systems that can be recharged by means of an inverter connected to the standard power grid.

2.5 The technology-governance mutual relationship

The reciprocal influence between technology and governance in service co-production happens either uni- or bi-directionally (although sharp distinctions are difficult to draw). In almost all cases in which informal co-produced practices are present, the technology-governance relationship blurs the limits between formal and informal categories, and helps to sustain the legitimacy of informality within the state public authority (see Ahlers et al. 2014).

2.5.1 From technology to governance

Technology in service co-production has the potential to enable the design and management of new governance structures. In Smith et al. (this issue), the innovative community-based technology grounded on mobile phone photography – to monitor landslide risk points in informal settlements – allowed citizens to collect, analyse, and share new data. In turn, their new role in landslide risk management helped shift the engagement of communities ‘from confrontation to dialogue’ with local government agencies, and enhanced their credibility when dealing with public powers (Smith et al. this issue, p. 260). In the case of dockless bike-sharing in China, the Mobike prototype and the intelligent lock are ‘enabler[s] of the programme’ (Han this issue, p. 214). Although governments are initially on the side-lines, they become involved in the second phase of the programme (by producing the necessary regulation to cope with issues of vandalism and users’ minimum age), and the third phase (to regulate the number of available bikes, users’ deposits and public space standards in light of random bike parking). It is interesting to notice that the way technology modifies the geography of
2.5.2 Concurrent technology and governance changes

Technology and governance may also reveal a concurrent relationship. The heterogeneity of socio-technical electrical devices co-produced in Cotonou and Ibadan goes hand in hand with the plurality of actors involved in these delivery practices (Rateau and Jaglin this issue). The resulting hybrid arrangements question the traditional categories and roles in governance for service provision, by challenging the boundaries between ‘state/society, formal/informal, and conventional/alternative’ (Rateau and Jaglin this issue, p. 192). In the case of water and sanitation in Hanoi (Rosati et al. this issue), governance and technical changes mutually affect each other. The institutionalised resident groups tổ dân phố (TDPs), for instance, are at the same time the smallest branch of the Vietnamese political system, and are responsible for the technological apparatus of drainage and sewage in the condominiums of Hanoi. The authors contend that this double task for residents’ organisations ‘confirms the fluid nature of Vietnamese urbanisation processes, where popular, bottom-up impulses are incrementally accommodated within state-led dynamics of space production’ (Rosati et al. this issue, p. 176). Governance and technical incrementalism is also deemed to allow the navigation ‘from more formal to more informal ways of service provision and vice versa’ (Rosati et al. this issue, p. 174). Finally, by taking decisions on water network extensions, ward councillors, party workers and neighbourhood youth clubs ‘function as intermediaries in the everyday governance of basic services and water access’ in Baruipur (India) (Chatterjee and Kundu, this issue, p. 202). However, according to Chatterjee and Kundu (this issue, p. 202), their involvement in service co-production entails a ‘system of patronage and “party politics”, producing inequalities in the access to water infrastructure.

2.6 New intermediaries emerging through technology

Not only does co-production help broaden the range of actors involved in the process, it also allows new actors to appear, in the form of intermediaries. As highlighted by Moss et al. 2011, p. 2), intermediaries are ‘those actors working in-between [the] triad of provider, regulator and user. […] they can influence the direction that the technological transitions take, the sustainability of urban technical networks and the governance of these systems’. Different kinds of intermediaries are shaped by innovative technologies. In co-produced services, intermediaries are at the core of the choices concerning the technological apparatus. Han (this issue) shows how the innovative technology of dockless bike-sharing produced two kinds of intermediaries between the initiator-operator of the programme and the users: either ‘saboteurs’, derailing the service delivery, or ‘vigilantes’, trying to help and support the bike-sharing. Also, in Hanoi, the authors highlight the existence of ‘a number of intermediaries, such as community groups, volunteering associations, NGOs and private companies that might endorse different roles as co-producers and co-managers, thus contributing to negotiating the boundaries between state and society’ (Rosati et al. this issue, p. 164) and shaping the co-produced technical service. In Baruipur, Ward Councillors and members of local social institutions (i.e. party workers and neighbourhood youth clubs) act as intermediaries, who ‘localise’ the piped infrastructure (Chatterjee and Kundu this issue). In Medellin, the low-tech and low-cost technical solutions elaborated are the result of multidisciplinary work, based on the role of academics and researchers as intermediaries binding institutions and local communities (Smith et al. this issue). The scientific knowledge of academics and researchers allows for a downscaling and designing of the technological means required in co-production (thus enabling co-production) that are suited to the limited means of the local community and the local institutions. In Putra et al. (this issue), there is a strong inter-relation between the researchers, acting as intermediaries, and the technology selected. Intermediaries define, and somehow impose, the GIS technology at the basis of the co-production process.

Further to the proliferation of intermediaries in service co-production, technology plays a role in enabling users to become intermediaries. In Rateau
and Jaglin (this issue), users may endorse a role of intermediaries when they resell energy from their ‘spiderwebs’ to neighbourhoods. The diversity of socio-technical devices – together with the plurality of governance actors – allows users to navigate between the two roles of users and intermediaries. Still in Smith et al. (this issue), being the WhatsApp groups accessible only to some community members and thus making them represent the other members, some users become de facto intermediaries between the service provider and the service recipients. Finally, in Baruipur, Chatterjee and Kundu (this issue, p. 202) highlight how citizens also act as private vendors, considered as intermediaries who ‘bypass the Municipal water network by developing a system of water provision parallel to the state-led one’, and whose activity reflects a political interest in giving legitimacy to alternative practice and complementary technology.

2.7 The drivers of technology in service co-production

The literature has shown that different drivers trigger socio-technical arrangements in service co-production. These include material service improvements, service universalisation, business for profit/market commodification interests and cost saving options, political change/action and environmental sustainability/concerns (Jaglin 2012; Van Vliet 2012; Van Eijk and Steen 2014; Moretto and Ranzato 2017; Van Eijk and Gascó 2018; Ilito-Boozii and Moretto 2021). If the drivers of using specific technology in co-production can be multiple, they can also belong to different actors.

In the papers presented in this special issue, technological multiplications and hybridisations generally respond to the needs of an increasing urban population facing structural shortcomings in conventional service infrastructure. Most co-produced socio-technical arrangements are driven by the necessity and/or wish for better access to the service in terms of quality, quantity, and/or affordability (Rateau and Jaglin this issue). In these cases, citizens play a key role in co-producing technologies and practices for accessing services (such as constant supply and adequate water pressure in Hanoi (Rosati et al. this issue), or by participating in them because of the ‘desire to secure value-for-money’, as in the case of promotional packages offered by dockless bike-sharing programmes in China (Han this issue, p. 219).

State and market actors who enter the socio-technical co-production process are usually driven by other purposes. In certain cases, governmental missions and goals are powerful drivers. This can take the form of state oversight on local co-production initiatives, through the institutionalisation of previously informal resident groups (TDPs) and their technological mixing, such as in Hanoi (Rosati et al. this issue), or of consolidation of political power, as with the Ward Councillors in Baruipur (Chatterjee and Kundu this issue), who provide licences to private vendors to operate their alternative water supply socio-technical arrangement. Governmental drivers, on the other hand, can take the form of public responsibility, as with the dockless bike-sharing programmes, in which local governments support the new co-produced mobility service because they are ‘driven by their mandate to govern [and] at the same time to meet upper government expectations’ (Han this issue, p. 219). Profit for business also drives socio-technical co-production. In the case of access to electricity in Cotonou and Ibadan, technology is intended to connect all the elements of the electricity delivery channels. The driver behind these technological choices depends on the possibility of distributing the electrical service through the market actors and mechanisms at the basis of the co-production process (Rateau and Jaglin this issue).

Dockless bike sharing in Shanghai is driven by the initiative of business makers and venture capitalists seeing the opportunity for new markets related to the city’s commuting problems (Han this issue).

2.8 The ‘technological dimensions’ of power and equity in service co-production

From a political-ecological perspective, infrastructure is depicted as ‘force-full objects’ that help ‘create, destroy, or limit the contours of what we call the state’ (Meehan 2014, p. 216). Technology, by mediating co-production, contributes significantly to user empowerment/disempowerment and service equity, as it plays a key role in modifying or reproducing asymmetrical power relations between actors as well as the market-based drivers that affect different access to the service. Special issue contributions
show how technology becomes the material means through which power and equity dynamics take place in co-production.

2.8.1 Technology as a purely political tool
Technology can be used as a purely political tool to stabilise, reinforce or contest certain political relations between the actors of co-production – the state, intermediaries and users – and can therefore express either political control or dissent. Technology is the material expression of conservative political control when the local government and intermediaries in privileged political positions use it to affirm and reproduce their power over citizens/users with the aim of preserving existing dependencies and strengthening their political consensus.

As mentioned above, Chatterjee and Kundu (this issue, p. 205) show how the delivery of the water service through different hybrid infrastructure arrangements in Baruipur became an ‘intensely political process shaped by neighbourhood patronage relationships’. Elected local leaders (i.e. Councillors), with the support of party workers and neighbourhood clubs, use their power to drive infrastructure management and water distribution in the neighbourhood in different directions, either by ‘installing new public standposts, lobbying for piped network expansion, [and] approving household connection requests’ in the case of local piped water system or by controlling ‘licensing and permissions that enable vendor operations’. For the authors (this issue, p. 207), ‘technologies of infrastructure, can at times, produce, enforce and strengthen the local actors, their differentiated socio-political positions, and power vis-à-vis others through an intermediary role’, thus producing uneven and exclusionary service delivery modes.

Similarly, in the French district of Hanoi, the management of tertiary drainage lines connecting individual septic tanks to the municipal combined drainage system is entrusted to institutionalised resident groups that are part of the TDP, the lowest level of Vietnam’s political system and the ‘extended arm of the government’ (Rosati et al. this issue, p. 171). Although a certain degree of autonomy is guaranteed to the households, Rosati et al. (this issue) point out that in this case, the management of the technology embedded in the co-production of the sanitation service contributes to the maintenance of the government’s control over the territory.

Technology is the symbolic expression of dissent when it is damaged by specific user groups in order to break existing patterns, thus becoming a means of disagreement that potentially possesses a transformative value, such as in the case of the dockless bike sharing ‘saboteurs’ in China (Han this issue).

2.8.2 Technology as a selective tool
Selective access to technology can produce different geographies of power. When co-production is purely needs-driven, such as in systems where it is based on complementary, hybrid or decentralised technical solutions used to overcome the shortcomings of the centralised system (e.g. water, sanitation, energy), technology can act as a selective tool creating new systems of power.

Spatial differences and the economic possibility of accessing complementary technologies favour enabling or disabling conditions for different inhabitants, thus becoming a potential source of inequality. For instance, in the decentralised technological apparatus for water provision in the KTTs of Hanoi, Rosati et al. (this issue, p. 175) notice that ‘when the tenants of the lower floors store too much water (by buying tanks of greater capacity or providing their units with more than one tank), the tenants of the upper floors suffer from water shortages’. Still, as shown above, new power relations based on economic dependency may be established in connection with the emergence of new intermediaries who, having the financial capacity to access complementary technology, act as resource ‘resellers’ to neighbours lacking other service options. This is the case, for instance, for the ‘spider-web’ practices of access to electricity that are widespread in Cotonou’s unplanned settlements (Rateau and Jaglin this issue).

When co-production is information-driven, as in the case of co-produced services based on knowledge and data sharing, technology mediates access to the underlying participatory process, thus becoming a selective instrument of empowerment/politicisation or disempowerment/depoliticisation. For instance, in the case of Medellin (Smith et al. this issue), residents involved in monitoring landslide risk through the proposed technology acquired the right to stay in their homes, thus counteracting both the effects of landslides and the government’s original strategies based
on ‘evacuation, stabilisation, relocation and redirection’ (Smith et al. this issue, p. 254) which they considered inequitable.

2.8.3 Technology and market-based options

Based on the special issue papers, inequality in service access is not necessarily related to market-driven co-production. The relationship between market drivers, regulation mechanisms, technology and inequalities is varied. According to Han (this issue, p. 219), the market driven technological innovation in the dockless bike-sharing in China, ‘from a low-tech combination lock to an intelligent lock using the Internet-of-Things (IoT) technology, helped to overcome the free rider problem. This technology upgrade fostered citizenship by making it compulsory for all users to have equal access through a standardised subscription fee’. Specific regulations for the new bike programme were then produced by local governments. By contrast, energy co-production arrangements in Cotonou and Ibadan, for instance, involve socio-technical hybridisation processes that have created inequalities in service access that ‘have been left to market mechanisms and individual-scale arrangements’ (Rateau and Jaglin this issue, p. 193). Together with ‘lack (of) proper institutions and tools for their governance and regulation’, co-production arrangements have thus aggravated the differences between the wealthiest and most vulnerable households (Rateau and Jaglin this issue, p. 193).

2.9 Social geographies of high tech and low tech

The low, medium and high level of research and development intensity (R&D intensity) embedded in a technical object determines whether it is low, medium or high-tech. The employment of high/medium technology and low technology in service co-production can follow – and even exacerbate – the uneven urban distribution of wealth. In other words, there seems to be correspondence between social geographies and the geographies of services based on high/medium tech on the one side and low tech on the other. In turn, in many circumstances, high/medium tech and low tech correspond respectively to higher and lower service reliability.

In Cotonou and Ibadan, the energy co-production arrangements surveyed reveal a correlation between the level of R&D intensity in the socio-technical arrangements for obtaining energy at the household level and both the socio-spatial conditions of the neighbourhood and the financial means of the residents. When the conventional network is not available (Cotonou), or it is available but punctuated by outages (mainly in Ibadan), in wealthier neighbourhoods, expensive, certified and high-performing devices are employed for energy production (e.g. generators, solar panels) and storage (battery systems) (Rateau and Jaglin this issue). For instance, ‘the most well-to-do households have high capacity generators with automatic self-start, whereas poorer households make do with small, sometimes second-hand generators, which they repair and refuel according to their financial capacities’ (Rateau and Jaglin this issue, p. 189).

In Hanoi, small and low technology is used in the co-production of the water service in the KTT low-income housing, while, in the new Linh Dam middle-class tower apartments, the technological apparatus for ensuring drinking water is not only larger, but also has a higher technological level and is more reliable (Rosati et al. this issue).

In Baruipur, both low-income citizens and middle-class citizens living in the formal settlement in the peripheral areas of the town ‘depend on several low-technology, hand-pump operated tube wells that lift untreated groundwater’ (Chatterjee and Kundu this issue, p. 200). Access to the centralised municipal piped network, which is equipped with a somewhat higher level of technology – such as a treatment plant for filtering and processing river water, underground reservoirs, mechanised pumping stations and elevated reservoirs – is conditional on proof of a valid property tax receipt. This condition excludes poorer households – and those in informal settlements – from benefiting from a safer alternative water source to the existing service that depends on groundwater, which in Baruipur has high levels of arsenic (Chatterjee and Kundu this issue).

Different geographies of income do not necessarily seem to be accentuated by the use of smartphones with a camera and the instant messaging freeware WhatsApp for the monitoring phase of the landslide risk mitigation service in Medellin and Sao Paulo (Smith et al. this issue), or by the employment of digital devices for reporting problems and collecting/using other information of climate risk service in
Jakarta (Putra et al. this issue). They do, however, highlight the varying cultural power of inhabitants with respect to the ability to access digital technology, the so-called digital divide.

3. Conclusions

This introduction to the special issue offers a framework for the investigation of the role of technology in the co-production of urban services, based on an overall interpretation of the six contributions. The focus of the special issue is on the co-evolution of technological configurations and spatial practices, on the one hand, and question of socio-technical hybridisation and adaptability to the context, on the other. In turn, the synergic knowledge that is generated by and applied through co-produced socio-technical arrangements during service co-production phases is explored. The issue also addresses the influence of technology on institutional forms of service users, providers and/or possible intermediaries and the drivers moving them in their selection and operation of the technical systems. Finally, the influence of technology on power dynamics and equal access to service is considered, all important elements when examining the ‘technological dimension’ of co-production outcomes.

In his famous essay Tools for Conviviality, Ivan Illich identified the technical tool as a decisive element. The philosopher’s interest lay in the possibility of enabling ‘the layman to shape his immediate environment to his taste’ and, accordingly, he asserted that it is up to science to simplify the technical equipment to make this possible (Illich 2009, p. 43). However, this conviviality does not necessarily depend on the technological level of the tool, rather on the possibility to freely access it, as long as the use one makes of it does not infringe the freedom of others to do likewise (Illich 2009).

Obviously, the technical equipment employed in the cases of co-production presented in the six contributions of this special issue all have the capacity to engage the user in one way or another. However, it also emerges that the differentiation – as opposed to the universality (Furlong 2014) – of socio-technical arrangements used to address a problem with, or outright lack of, service becomes in many cases a multiplier of inequalities. As Illich would perhaps say, the active role of the user is no guarantee of conviviality.

To a certain extent, some of the insights on technology in service co-production offered by this special issue reinforce the powerful idea that co-production, standing for the collective and solidary initiative of citizens (Mitlin and Bartlett 2018), is challenged by the contested and competitive connotations that this arrangement takes on in certain cases (Guillou 2022; Chatterjee and Kundu this issue). In the landslide risk mitigation service in Medellin and Sao Paulo, in the flood risk monitoring service in Jakarta, in the sanitation service of the KTTs, and in the water and sanitation service of the Linh Dâm towers in Hanoi, technology mediates various forms of collaboration between citizens. By contrast, technology fosters competition among citizens in the co-production of energy provision in Cotonou and Ibadan, and especially the dockless bike sharing in China and the water supply in Baruipur. In this latter case, Chatterjee and Kundu (this issue, p. 205) point out how hybrid service provisions are not always characterised by cooperative and collaborative dynamics, but are ‘driven by political and economic motives, hybrid arrangements […] and] produce differentiated outcomes that are uneven, exclusionary and unpredictable; reflecting unequal power dynamics’.

To date, most research on co-production has encompassed a normative view of co-production outcomes by focusing on questions of efficacy, equity, empowerment and citizenship. Some studies have highlighted that the participatory nature of service co-production can contribute to more efficient service and urban governance through increased social capital and the improvement in citizens’ skills, thereby favouring citizenship and empowerment outcomes (see for example Mitlin 2008; Pestoff et al. 2012; Allen 2013; Pestoff 2014; Moretto et al. 2018). Yet, other studies have pointed out that co-production does not always provide positive outcomes. The risk remains of elite capture, disempowerment, discrimination, and exclusion of the most vulnerable groups from accessing services (see for example Ahlers et al. 2014; McMillan et al. 2014; Mitlin and Bartlett 2018; Faldi et al. 2019, 2020). Ultimately, service inequalities can partially be addressed through a larger and more diversified offer of co-produced services and their relative technologies. Appropriate regulatory mechanisms appear essential in reducing inequalities and lead to an ‘enhanced citizenship’, which involves the capacity of
citizens to negotiate and collaborate with other actors, and also to challenge power structures, as described by Mitlin and Bartlett (2018, p. 356).

This special issue goes one step further, revealing the relevance of the technology behind the co-production of services, and how it determines whether a service provision is inclusionary or exclusionary, emancipatory (and convivial) or restrictive.

**Disclosure statement**

No potential conflict of interest was reported by the author(s).

**Funding**

This work was supported by the FNRS - Fonds de la Recherche Scientifique under Grant T.0174.16, in the framework of the PDR project ‘Typologies of Institutionalised Coproduction of Water and Sanitation Services in the Urban South’ (TYCO-WSS).

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