Technology in Society 38 (2014) 139–147

Contents lists available at ScienceDirect

Technology in Society

journal homepage: www.elsevier.com/locate/techsoc

STS beyond the "modern infrastructure ideal": Extending theory by engaging with infrastructure challenges in the South

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ARTICLE INFO

Article history:
Received 23 October 2013
Received in revised form 24 March 2014
Accepted 10 April 2014

Keywords:
Water supply
Global South
Disrepair
STS
Coexistence

ABSTRACT

With few exceptions, STS theories of infrastructure stability and change have not been applied to circumstances in the South. Developed in post-War Europe, these theories are often applied in ways that lack transferability to situations where infrastructure conditions are precarious and hybrid. This article seeks to broaden these theories by relating them to infrastructure challenges common to the South, drawing in particular on prevalent issues in water supply. Such engagement helps to identify shortcomings in these theories, to push their paradigms further, and to raise new questions related to infrastructure configuration, stability, and transition. As such, the study of sociotechnical systems across a range of contexts can be enriched. In particular, this article extends theory by placing coexistence among sociotechnical systems, as opposed to the universality of a single dominant infrastructure network, at the center of enquiry. Recognizing coexistence is important because it enables one to decouple key concepts in STS from the presumption of universalized and uniform networks, enabling them to become relevant for the South. Examples discussed in this essay include stability or "momentum" and transitions.

1. Introduction

Improving access to potable water and sanitation is recognized as one of the key challenges of our time. Still, success continues to be limited [1]. Reasons are manifold and include issues such as precarious land tenure, rapid urbanization, poorly funded utilities, weak institutions, and inequality [2,3]. However, important challenges also stem from contradictions between uniform infrastructure networks, derived from experiences in the North, and diverse realities in the South [4]. Instead of privileging a single universal infrastructure network, greater attention is now given to hybrid and disaggregated systems characterized by coexistence. In the North, where the "modern infrastructure ideal" of universal and uniform coverage by a single network was largely met [5], mounting pressures on the environment and utility capacity have encouraged the adoption of alternative infrastructure configurations [6]. In the South, water supply has long involved multiple systems in varying degrees of coexistence (e.g. piped water aside rainwater collection, tanker truck delivery, and communal systems, etc.). What remains controversial is whether to ignore what is external to the piped network, to regulate it, or to subsume it under the management of a single water provider [7].

At the same time, many local water systems are undergoing change. For Bakker, efforts in the South have focused on a transition from "artisanal" to "industrial" water supply [8]. Yet, in many cases, such efforts have given way to accepting diversity and coexistence among water

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http://dx.doi.org/10.1016/j.techsoc.2014.04.001
0160-791X/

supply alternatives [9]. Many prominent approaches to cities and infrastructure networks, including those from science and technology studies (STS), do not reflect this diversity, given their tendency to be derived from circumstances in the North [10,11]. But, even these are shifting. As such, certain analytical frameworks could be strengthened though engagement with coexistence between – as opposed to the uniformity of – sociotechnical systems. This implies submitting theories to empirical circumstances in the South, where such coexistence is more obvious [10].

In this way, there is mutual benefit to be derived from engaging the STS literature with that concerned with water supply access in the South. Geographers, for example, have dealt extensively with a variety of impediments to service extension in the South, often taking a political ecology approach that underscores the historical and political origins of environmental and resource inequalities [12]. Increasingly, they have taken an interest in the material components of water supply and how power is mobilized and transformed through artifacts [e.g. Refs. [13,14]]. Here, authors have drawn on the philosophical aspects of STS' engagement with materiality, but not the theoretical frameworks developed to analyze sociotechnical systems, specifically Large Technical Systems (LTS) and Multi-Level Transitions (MLT). The former focuses on explaining the evolution, function and stability of large technical networks like water and energy, while the latter is concerned with the transition from one sociotechnical system to another, e.g. from a transport system based on increasing highway capacity to one focused on collective modes [e.g. Ref. [15]].

LTS and MLT have been important to our understanding of sociotechnical systems. Yet, focused on the North, they have tended to take post-War, western sociotechnical systems as the apex of infrastructural development. Moreover, they are often apolitical in their application,[1] presenting a near one size fits all model of sociotechnical configuration. As such, LTS and MLT would seem to have little to say about infrastructure conditions in the South, which are often hybrid. Yet, at the same time, in addressing issues of sociotechnical configuration, stability and change, LTS and MLT theories force new questions about sociotechnical systems in the South with the potential for a broader understanding of the challenges and possibilities for transitioning to more equitable configurations.

Specifically, in engaging STS approaches with sociotechnical conditions in the South, I seek to question the conflation of "system" with uniformity, "stability" with universality, and "transition" with displacement. To do so, I draw on the existing (although limited) literature on sociotechnical transitions in the South, recent research in geography and anthropology on the work of objects in configuring water supply access, as well as aspects of my own research in Colombia. As such, this paper does not offer a comprehensive case study. Instead, it draws on both theoretical and empirical work in geography and STS to further current theorizations of large technical systems (LTS) and multi-level transitions (MLT). Thus, while the paper does not deal with a range of issues that are key to understanding service provision in the South, it engages with aspects that can shed new light on standard premises in STS and our understanding of sociotechnical systems in turn. In this way, the paper follows Geel's call to "accept some loss of empirical complexity" in order to introduce new questions into STS theory and take it beyond the conventional case study sites [17].

2. Beyond uniformity and universality: sociotechnical coexistence in the South

The evolution of large technical systems (LTS) has been an important topic in STS. Studies have focused primarily on western contexts where universal infrastructure networks have become an unconscious backdrop to everyday life [e.g. Refs. [18,19]]. Infrastructure, in this context, is considered "stabilized", "obdurate" and "black-boxed", that is, as essentially immune to change or external influence [e.g. Ref. [20]]. In these formulations, transition from one LTS configuration to another is possible, but rare. Many studies, for example, have focused on a "battle of the systems" whereby transition involves the total displacement of one technology by another, which thereby obtains a virtual "natural monopoly" [21]. Stability is not absolute, but major external shocks to a system are considered necessary for reconfiguration to occur, resulting in new stable configurations as opposed to dynamism [20,22].

To understand such reconfiguration, analyses in STS are often framed in terms of "multi-level transitions" (MLT). MLT theory posits three "levels" of interdependent activity through which transitions occur. Briefly, these include the level of technological development (niche), the institutions, norms and practices that surround a technology (the regime), as well as broader societal trends (the landscape) [e.g. Refs. [23,24]]. A key limitation of MLT in analyzing sociotechnical transitions in the South is that it assumes a universal system as the end point, i.e. one system is replaced by another [25]. Thus, while the MLT approach recognizes a range of pathways to change [26], ultimately a single, universal outcome is settled on. Consequently, the approach has rarely been applied to cases where the outcome it assumes is not already in place.[2]

Authors in disciplines like geography and planning have also been concerned with trends in infrastructure. Here, the influence of political-economic change, notably neoliberalism, has been a prominent focus [e.g. Ref. [28]]. From an MLT perspective, such research privileges the landscape to the virtual neglect of the niche or regime. Most prominent is the work of Graham and Marvin, which argues that policies of economic liberalization led to widespread network "unbundling" and the "splintering" of the urban experience [5]. Unlike MLT, this work does not assume a universal outcome to splintering, but it does assume universal networks as the starting point. For this reason, the "splintering urbanism" thesis is argued to be of limited applicability to experiences in the South [29]. There,

[1] This is a critique of STS more broadly [16].

[2] A recent exception is the application of Strategic Niche Management (SNM) – a variant of MLT – to biogas implementation in India [27]. This work is discussed in the final section.

infrastructure, existing in "archipelagoes" and not "networks" [8], could not splinter, as it was not universalized [29].

When thinking through sociotechnical transitions in the South, not only is it problematic to assume universal networks as either the origin or outcome of change, universality can be problematic as a goal. In some cases, the drive to universalization has compounded exclusion by creating service islands and encouraging sprawl [30], or by limiting alternatives in contexts of diversity [9]. For water, important public health issues can arise from efforts to displace existing options with a single piped supply. Such networks are often under-resourced and experience problems with maintenance, disrepair and service interruption [31]. Although interruption may be a "normal" aspect of networked infrastructure even in the North [10], with water supply in the South, it can have important consequences in creating what Gandy calls "landscapes of disaster" [32]. Public health research, for example, finds that even a few days of service interruption can "destroy the health benefit from the provision of clean drinking water" and increase the annual risk of illness by 100% [33]. As such, some advocate the improvement of existing water supply systems as opposed to their replacement [33].

There are good reasons for fostering coexistence among water supply systems as opposed to the universalization of a uniform and "black-boxed" network. First, in areas with a high degree of poverty, it is important to retain free sources of water for non-potable use [34]. To this end, rainwater collection in combination with piped water is promoted in many parts of the world [34]. By way of example, in Quibdó, Colombia, residents have traditionally relied on rainwater, where piped water has long been spatially limited, unreliable, and non-potable [35] and where rainfall levels are among the highest in the world [36]. To improve potable water access, a project to develop a functioning piped water system in coexistence with extensive rainwater collection was begun in 2010. Given a legal requirement for metered billing in Colombia, attempting to displace rainwater and restrict users to piped water could significantly raise household costs, presenting new barriers to access.

Second, utilities may often need the support of alternative water sources in order to extend piped water to unconnected households. This is considered to be among the key benefits of integrating rainwater collection with piped supply [37]: it reduces demand on limited treatment capacity. High consumption by those already connected to piped water systems has been a key impediment to projects to extend water infrastructure in Medellín [38] and throughout many parts of the world [39,40]. Continuing the example of Quibdó, there, the utility lacks sufficient treatment capacity to meet demand for all water uses for the city's entire population (approximately 100,000). As such, utility staff view rainwater as an alternative source that can help to reduce pressure on limited water treatment capacity, enabling network extension. This situation reflects the finding that, in response to scarcity, cities in the South must innovate in idiosyncratic ways that mix technical solutions and social understanding [41].

Yet, Quibdó is not alone. In many cities in both the North and the South, efforts are being made to develop rainwater collection systems in order to reduce pressure on treatment plants under conditions of population growth and/or water scarcity. Although integration is not simple, energy and environmental efficiencies have been found to increase over time [42]. Studies conducted across 62 cities in Brazil demonstrate that savings on piped water can range from 34% to 92% with the introduction of rainwater harvesting. Savings are especially significant in areas with high rainfall and low demand for piped water [37]. The decreased system demand can lower system peeks [43], mitigate pressure on water sources, as well as reduce pollution, flooding, and pressure on sewer systems [34]. All of these can help to facilitate service extension by reducing treatment and provision costs and well as pressure on water resources.

Users also seek coexistence. Recent studies show that users often continue to draw on a range of water sources in addition to piped water, even after getting a household connection. In low-income parts of Tijuana, Meehan finds that users remake the state planned piped water network by adding additional "objects" like rain barrels to their newly acquired centralized supply. They do this in order to maintain independence, control costs, and limit piped water consumption [13]. Meehan's findings are reflected in research in Medellín. There, a survey of neighborhoods recently connected to the piped water network shows a tendency to continue to draw on a variety of sources to meet water needs [38].

After connection, water supply systems can remain hybrid integrating the piped supply into existing systems or merging it with new techniques and artifacts. This does not necessarily reflect the inadequacies of a sociotechnical system that has failed to achieve uniformity and universality. It can also be a sign of the empowerment of users vis-à-vis the state system. For Meehan, it "make[s] new water worlds possible" by "enable[ing] institutional flexibility, local expertise, and technological malleability" [13]. Further, while such technologies like rain barrels may begin as "stop-gap" solutions to punctual issues in service delivery, their "longevity … signals a proliferation of infrastructure, and with that a variegated geography of power" [13]. These artifacts and the collective social practices they imply can "coexist with or even limit the spheres of state power" [44].

Following from the above, fostering coexistence – as opposed to uniformity – in a sociotechnical system can facilitate service extension and enable people to gain greater control over how they meet their water needs. Opening LTS theories to coexistence is also of increasing importance for understanding infrastructural change in the North. Current approaches tend to be fixated on an ideal of networked infrastructure as uniform and universal. Such configurations have been challenged by neoliberal policy reform as well as by environmental concerns. In fact, while studies have tended to focus on how cities in the North came to achieve an idealized infrastructure configuration, it must be acknowledged that both the experience and the stability of such configurations are relative. If I live in a poorly maintained building with inadequate plumbing in New York, I will not experience the water network as universal and invisible [see Ref. [45]]. Moreover, if I examine other aspects of urban water systems such as drainage, it is

not uniformity but coexistence – between technical infrastructure and what Carse calls "nature as infrastructure" [46] – that will dominate [47].[3]

3. Decoupling stability from the "ideal": momentum as a feature of disrepair

The presupposition of a "universal infrastructure ideal" in LTS and MLT theories can help to explain their lack of traction for studies focused on the South, where infrastructure is often characterized by "archipelagoes" and disrepair or even dilapidation. Still, concepts that have been reserved for the "ideal" have something to offer to other contexts. Recently, malfunction and disrepair have occupied new interest in the literature on urban infrastructure. Graham and Thrift's piece "out of order" stands as a critique of LTS theory as focused on "utterly fixed hard technologies … characterized by perfect order, completeness, immanence and internal homogeneity rather than leaky, partial and heterogeneous" [10]. This focus, as they note, has led LTS studies to neglect systems in the South [10]. Still, the authors are concerned with infrastructure in the North and understand disruption as about "learning, adaptation, and improvisation" rather than "catastrophe" [10]. Drawing on Summerton's idea of technical transitions through incremental change [49], they argue that disrepair can engender important system shifts through manifold incremental experiments focused on adaptation [10].

This cumulative adaption and learning, I argue, is also about custom and coping. When disrepair is normal and everyday, as opposed to aberrant, it can generate its own "momentum". Momentum is a concept developed by Hughes to describe how the links between society (including users and a variety of institutions) and technology evolve to create a stabilized sociotechnical system that is resistant to change [50]. In his reading of Hughes, Geels argues that momentum is derived from the relationships between people and things, "people adapt their lives to artifacts" [15]. Once an LTS achieves momentum, however, it is considered to uniformly dominate a geographical space and to be black-boxed, whereby its behavior is independent of context or user interaction [51,52]. In these formulations, the sociotechnical system has become embedded because of its invisibility and its normalization [51].

Indeed, while the South is more or less ignored in the application of STS theories of stability and change, the long-term and widespread difficulties of "transitioning" to the "universal infrastructure ideal" suggests a degree of momentum. That is, momentum can be a feature of sociotechnical systems characterized by coexistence, malfunction, and co-production (as opposed to universal, idealized, and black-boxed). Barnes and Alatout go some way to acknowledging this possibility in their discussion of the uniqueness of all sociotechnical systems, stating that their evolution and "the ways in which they are variously cemented, contested, and discarded is closely tied to the production of social worlds" [53]. That is, the ways in which they become stabilized – or "cemented" – is produced with the social context; it is not dependent upon the existence of a particular social context a priori.

How can this be understood? For Trentmann, like Graham and Thrift, disrepair and malfunction are normal elements of user relationships to infrastructure; they "are not freak accidents or aberrations but natural, constitutive features of lived normality" [54]. In the North, the normalization of breakdown and service interruption is derived from the adaptability (as opposed to the obduracy) of people's habits in the expectation that interruption is temporary. Once service returns, so too do the regular customs of use; alternate habits are only sustained through long-term shifts in the sociotechnical system [54]. This speaks to Star's assertion that infrastructure constitutes and is constitutive of communities of practice [55]: habits and customs are resistant to change, as they are bound-up in the wider social order. Such communities of practice need not be restricted to the "ideal" case. They can reasonably be expected to develop in conditions of persistent disrepair and dilapidation, to which people also "adapt their lives" [see the above citation of Ref. [15]].

Disruption and its assimilation by users are revealing in terms of the mutual construction of customs and performance. First, users "are not just recipients [of services] but co-producers, whose behavior is vital for managing shortages"; they play active roles in absorbing, coordinating, and even orchestrating disruption [54]. Further, user reactions to system function and breakdown are defined by perceptions of what is normal or aberrant for the sociotechnical system in question [54]. For example, the sometimes-disproportionate expectations of high-income groups can place undue strain on a network, engendering disruption [54]. Similarly, in the South, middle class users may demand a level of service that is unaffordable to other groups, limiting network extension [7]. Below, I further make the point that extremely low expectations of system performance can also result in practices on the part those connected to the network that place strain on it, complicating efforts to increase coverage.

These issues reflect Shove's concerns with habits and custom. For Shove, the focus on *efficiency* in terms of resource use is misplaced and "overshadows prior questions about the framing and formulation of 'normal' practice". It misses "the point that much consumption is customary, governed by collective norms and undertaken in a world of things and sociotechnical systems that have stabilizing effects on routines and habits" [56]. To understand and alter service use, we have to understand the "collective dynamic of normalization" [56]. The neglect of custom, moreover, engenders a focus on "educating" users [56]. Assumptions that the right information will induce behavioral change neglect the complexity of consumption [57] as well as the role of artifacts in constructing social practice [58].

Notably, convenience is an important factor in constituting the ways in which sociotechnical systems develop so that users are able to meet their needs. Convenience is not only about accessible services, it is about interactions with the sociotechnical system that allow users to manage their

[3] On the point of infrastructure coexistence in the North, see also Refs. [48] and [26].

time [56]. Thus, when a service is highly unreliable, users may seek strategies to improve reliability, either by opting out of the system, through clandestine connections, or through storage [59]. Understanding users as seeking system knowledge and reliability, not only in terms of timing and quality but also in terms of costs, helps to comprehend the potential "momentum" of sociotechnical systems of malfunction. Indeed, according to Shove and her colleagues, convenience becomes especially important where "there are problems of coordination" between users and an LTS leading to the proliferation of individualized solutions[4] [61]. These tendencies can place pressure on collective modes of consumption as user practices diverge [61].

In the context of persistent malfunction, however, such tendencies can make it difficult to transition to universalized systems; momentum can become a feature of disrepair. Recently, some STS scholars have sought to address this issue using strategic niche management (SNM) [e.g. Refs. [27,62,63]]. SNM, like much MLT work, privileges the niche as the locus of sociotechnical change [see Ref. [64]]. It understands "transitions" to emanate from the careful development and introduction of alternative – often more environmentally sound – technologies [23]. For these authors, malfunction and disrepair provide a window for change, but only up to a point. Malfunction opens opportunities for transition, but can also create barriers to change. That is, what they call an "unstable" system can prove rather stable; it can exhibit "momentum". Barriers arise because malfunction, and the governance issues from which it emanates, create uncertainty for investment in new technologies, limiting their diffusion [27,62]. According to Raven, persistent malfunction favors change until it creates too much uncertainty, at which point the potential for change is reduced [65].[5] Thus, for these authors, the effect of disrepair on sociotechnical change is all about degrees.

Recent studies in geography can help to contextualize the momentum witnessed. In an analysis of electricity services in Nicaragua, Cupples argues that "people's embodied experiences of electricity failure" explain the difficulty of introducing meters [58]. Citing Latour, she notes that an artifact "will work when all the relevant people are convinced" [66]. In Nicaragua, neither utility workers nor users are "convinced" and they assist each other is subverting the prescribed change [58]. Further, for Shaw and Meehan, "new political realities must be produced with objects, not in spite of them" [44]. This means that, where a sociotechnical system is characterized by malfunction, transitioning to "a configuration that works" [67] may be contingent on fostering reconfiguration and coexistence as opposed to displacement.

Returning to the Quibdó example, the long-term unreliability of the piped water system impedes the proposed transition to coexistence, whereby a reliable piped water system is supported by rainwater collection. Given the legacy of intermittent supply, in Quibdó as elsewhere, the logical response is to fill household storage tanks whenever tap water is available. Not knowing when this might be, taps need to be left open, which can lead to overflow. Moreover, in cases where a household has a hose, but no tap, the possibility to turn off the water does not exist. According to utility staff interviewed in 2011, for these reasons, a connected household can draw four to five times its actual monthly consumption. Given the intermittency of service, moreover, everyone who wants or needs water must draw simultaneously – i.e. when it happens to be flowing. Such demand on the piped system complicates network extension given limited treatment capacity.

Yet, water storage is logical. It enables people to have water when it is needed, and not simply when it happens to be provided. In fact, it is the same choice that users in the North make when faced with intermittent malfunction [see Ref. [54]]. But when it is function that is intermittent, storage becomes a dominant as opposed to an occasional practice. This can make it difficult to provide either continuous or potable water. It can limit service quality because the utility is unable to treat enough water to maintain continuous flow. Continuous flow is needed to ensure sufficient pressure without which negative pressures, infiltration, and contamination ensue. In piped water systems, microbiological growth becomes dislodged from pipe surfaces in conditions of intermittent flow [68]. Intermittency can also lead to contaminant infiltration, further encouraging bacteriological growth, consuming chlorine residuals, and potentially introducing fecal contaminants from the soil or nearby sewerage systems [69,70]. In response to intermittent supply, a vicious circle develops whereby intermittency makes water storage essential to bridge service gaps, which in turn makes continuous flow difficult to achieve, leading to contamination.

4. Decoupling transition from displacement: from malfunction to coexistence?

A 24-hour system, necessary to ensure potability, is dependent upon both the utility and upon users. Yet, the transition to such a sociotechnical system demands that users shift their practices before the promised service quality can materialize. That is, users need to develop habits consistent with a functioning system before the system actually begins to function. This poses evident problems given one's dependence on water.

In attempting to understand these issues, the ways that theories of LTS and MLT are generally applied pose certain constraints. Beyond the presumed displacement of one universal system by another, the theories have been critiqued for their lack of attention to users and consumption, a disregard for incremental change, and a focus on the "niche" as the locus of transition. I address each of these below. I do not pretend to offer an alternative theory of sociotechnical transition for cases of persistent disrepair. Yet, by underlining how the above issues inhibit engagement with common infrastructural conditions in the South, I hope to offer some considerations for extending STS theories to the study of sociotechnical change in situations characterized by shifting forms of coexistence and long-term disrepair.

[4] Here, the authors refer to Ref. [60].
[5] Referred to in Ref. [27].

First, the lack of attention to human agency has been widely identified as a shortcoming in STS approaches to technical networks [61,71].[6] Recalling Latour's assertion that an artifact will function "when all the relevant people are convinced" [66], what is made obvious by an engagement with conditions of disrepair is the need to expand the notion of "relevant people" within both LTS and MLT. According to Geels, the literature posits two basic groups of human actors: the "system builders" or "heros" who can affect transitions (e.g. scientists and policy makers); and the "faceless automata following iron rules, institutions or given roles/functions" that cannot affect change [75]. In general, the influence of users is considered only in the stabilization of a system through "habits", or in achieving change through mass protest [15]. This ignores how systems are continuously remade through everyday interaction [61].

The above treatment of human agency raises questions about how to think about networks. It focuses on infrastructure as a physical network but ignores the Latourian view of "networks" as relations between people and things. The concern with "heros" obfuscates the fact that often there are "no obvious 'system builders' … no key institutions enlisted and enrolled and no well-defined states of sociotechnical development" [61]. Here, Shove is talking about the laundry, but this could also be said of systems characterized by persistent malfunction: they are marked by continual individual innovation [see Ref. [10]]. This follows Latour's point that networks are generally absent of central nodes of control; they are made of relations [76].[7] This position also informs Cupples' critique of looking to protest to explain sociotechnical change. For Cupples, the approach does not "come to terms with how it is that power is exerted across space", because it ignores the role of artifacts in explaining how relations of power and resistance are produced [58].

A second impediment to analyzing conditions of disrepair that arises from common applications of LTS and MLT is the lack of attention to incremental change. LTS transitions are typically defined as involving major "transformations in the way societal functions … are fulfilled" and as being "systemic in nature" [62]. For Shove, change is much more organic. It involves the shifting relationships between people and combinations of artifacts that yield changes in how services are conceptualized and thereby "reconstructed" [61]. According to Geels, this oversight results from the case studies chosen; a more diverse selection might show that "the new grows out of the old … through cumulative adjustments in new directions" [15].[8] Again, these interventions invoke a Latourian vision of networks, whereby the very premise of "durability" in relation to networks must be contested, as it is their current links to other "actants" (human and non-human) – and not their size – that construct their "dominance" [76].

A third area where LTS and MLT ought to be broadened is with respect to the focus on the niche as the locus of sociotechnical change. By privileging niche innovation, economism – a bias toward "the primacy of economic causes and factors"[9] in the explanation of social phenomena – is fostered. Specifically, innovation comes to be synonymous with commercial development and economic growth [41]. Consequently, the "technical niche" is often reduced to the "market niche". Verbong et al., for example, assess the potential for a transition to biogas in India through the targeting of "market niches currently not well served by the power regime" [27]. Similarly, Berkhout et al. see sustainability transitions in the South as occurring through the "co-evolution of new innovative capabilities within specific market and institutional setting" [62]. This prioritization of economic factors in explaining sociotechnical change may not be unique to LTS. For Hess, STS is generally marked by an inherent neoliberalism [79].

Beyond economism, the focus on niche innovations raises other issues. It has been criticized for ignoring the role of user interaction in "reconstructing" LTS [61]. For the particular case of water supply, the focus ignores the importance of simple, and well-known technologies in enabling sociotechnical change, such as rain barrels or low flow fixtures [74]. Whether for improved environmental performance in the North or for improved system reliability in the South, often it is the successful introduction of readily accessible household technologies as opposed to new technological innovations that are sought. Transition in such cases is less about *innovation* and more about *integration* into the physical as well as the Latourian network.

In light of the above discussions, I suggest a possible way forward for considering the circumstances through which "people are convinced". How can users whose "experiences embody" disrepair be "convinced" by proposed sociotechnical reconfigurations? Three strategies witnessed during my research offer potential pathways for investigation. First, in Medellín and Quibdó both utility personnel and representatives of communities newly connected (or awaiting connection) to the water network emphasized the importance of demonstrating project results, i.e. consistent improvements in service provision, over things like public education. Experiences elsewhere in Colombia echo this, finding that reducing the time-lag before concrete improvements in living conditions become apparent is crucial to garner project credibility [80].

Second, in Quibdó, the utility uses scheduled service provision in order to reduce the need for water storage. In 2011, the utility began to provide water all day by sectors, each sector getting one to two hours of service a day. The strategy of maintaining scheduled if intermittent service recalls Trentmann's assertion that planned disruption, through rolling blackouts or rota water disconnections, can serve "to reduce stress on crisis-prone systems" [54]. It can also help to addresses Shove's problem of convenience.

[6] Users, however, receive significant attention in other STS debates, most notably in relation to particular objects [72]. For examples where users have been important in analyses of networked infrastructure, see Refs. [56,73,74].

[7] The discussions of Latour's philosophy in the section draw on Harmon's (2009) see Ref. [76] analysis of Latour's *Irréductions* [77].

[8] See also Ref. [78].

[9] Source: Oxford English Dictionary.

Although water cannot be obtained at all times, users know that at particular times it is available. They can plan. Third, mediating technologies, that help users to regulate their consumption, can also be useful in improving convenience. In Quibdó, as in Tijuana [see Refs. [13]], this means providing floaters so that the water will automatically shut off when storage tanks are filled.

5. Conclusions

This analysis sought to open a discussion about sociotechnical coexistence, stability, and transition beyond the "modern infrastructure ideal". It sought to identify opportunities to extend theories of infrastructure in STS to include a wider variety of contexts and sociotechnical configurations. Despite the limitations of current theories for sociotechnical systems in the South, moving away from the presumption of universality/dominance in favor of coexistence reveals that LTS and MLT offer relevant insights for sociotechnical systems beyond the "ideal" case. This is important not only for applications in the South. If the theories are to continue to be relevant for studies of the North, they will likewise have to adjust to evolving conditions of coexistence [see Ref. [6]].

Starting from a premise of coexistence, not only enables an engagement with a wider variety of sociotechnical realities, it complicates and extends the analytical utility of certain key premises in STS. In particular, theories of stability and change, central to LTS and MLT, can have relevance beyond situations characterized by the "modern infrastructure ideal". In many cities in the South, large numbers of people have lived with persistent disrepair. They may have no service, sporadic service, and/or poor water quality [59]. Disrepair is the essential character of the network. But that network remains part of a sociotechnical system. As such, the continuous experience of unreliability can result in its own "momentum"; it can become stabilized and embedded. Recalling Hughes, momentum is not inherent in a technology but develops through the variety of social institutions and practices that have co-evolved with it [50]; infrastructure "shapes and is shaped by the conventions of a community of practice" [55]. Following this reasoning, the actual functionality or dominance of an LTS is not the sine qua none of momentum. Rather, it is the fact that society has adapted itself to that system, whatever its configuration, whatever its condition.

This is equally relevant for extending conceptualizations of "transition". By accepting that transition need not entail the displacement of one universal system by another, one can consider a broader range of configurations that may or may not "work". Moreover, and perhaps even more importantly, in tempering the need for significant change, one can consider pathways beyond niche innovation. Specifically, one can seek more modest changes that involve *integration* as opposed to *innovation*. For example, integrating simple and well-known technologies such as efficiency devices into existing sociotechnical configurations can act as "mediating technologies" that enable users to shift their relationships to existing infrastructures without making access to essential services more burdensome or uncertain. Such technologies can enable transitions in network performance without the wholesale displacement of one system by another [see Ref. [74]]. Accounting for this means an engagement with the social dimensions of transitions as well as those that are technical and economic.

Concepts of momentum and transition can be translated from their common usage in relation to studies of the North to enrich analyses of networked infrastructure in the South. Yet, for these studies, the role of the social in the sociotechnical must take both a geographical and a critical turn. That is, studies must recognize that the manifold and sometime conflicting relationships that people have to networks reflect the inequities in a given society [4,39]. In LTS studies, these relationships are generally neglected even where the role of users is given precedence. In sociotechnical systems of disrepair, divers actors develop not only "customs" but also interests in relation to the status quo; users are not alone in creating momentum around malfunction. In India, for example, when local councilors also act as private water vendors their conflicting economic and political interests inhibit the improvement of water supply [81]. As such, the power relations that perpetuate momentum and regulate transitions are not simply the purview of "system builders" but extend to historical and contemporary political and economic actors at a variety of scales.

Recent studies of access to infrastructure services in geography have been particularly apt in addressing these issues. Studies, for example, have underscored the importance of historical and contemporary practices of injustice in the perpetuation of sociotechnical inequality, including colonial and contemporary forms of discriminatory planning [39,82]. Engaging with such issues is necessary to enrich studies of sociotechnical relationships, and to mobilize insights from STS without losing sight of the power and exclusion that is inherent in water's production [39].

This paper emphasized the importance of coexistence and the transferability of certain concepts like momentum and transition, while underscoring the need to decouple them from assumptions of uniformity, dominance, and invisibility. This is of relevance in the North as well as the South. For the particular case of water supply, widespread concepts that are challenged by experiences common in the South include "natural monopolies" [see Refs. [2]], universal networks as opposed to sociotechnical coexistence, black-boxing versus user co-production, and the conflation of stability (or momentum) with dominance and uniformity. By engaging LTS and MLT with infrastructural conditions common in the South, steps can be taken toward a more critical approach to infrastructure that continues to account for the mutual construction of social and technical worlds.

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