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## TOPICAL REVIEW

# ‘What is infrastructure? What does it do?’: anthropological perspectives on the workings of infrastructure(s)

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## Abstract

Infrastructure is often thought of in big material terms: dams, buildings, roads, and so on. This study, instead, draws on literatures in anthropology and the social sciences to analyse infrastructures in relation to society and environment, and so cast current conceptions of infrastructure in a new light. Situating the analysis in context of President Biden’s recent infrastructure bill, the paper expands what is meant by and included in discussions of infrastructure. The study examines what it means for different kinds of material infrastructures to function (and for whom) or not, and considers how the immaterial infrastructure of human relations are manifested in, for example, labour, as well as how infrastructures may create intended or unintended consequences in enabling or disabling social processes. Further, in this study, we examine concepts embedded in thinking about infrastructure such as often presumed distinctions between the technical and the social, nature and culture, the human and the non-human, and the urban and the rural, and how all of these are actually implicated in thinking about infrastructure. Our analysis, thus, draws from a growing body of work on infrastructure in anthropology and the social sciences, enriches it with ethnographic insights from our own field research, and so extends what it means to study ‘infrastructures’ in the 21st century.

## Introduction: expanding infrastructure

In this study we seek to enlarge what is meant by infrastructure, and therefore extend what is included in discussions of building and/or maintaining infrastructure. There is much at stake in investigating what constitutes infrastructure and what is meant by it. For example, consider the recent bill proposed by US President Joe Biden, which seeks to revitalize infrastructure in the United States through a 2+ trillion dollars spending plan (cf The White House 2021, March 31). The bill seeks to repair and modernize highways and roads, improve airports and inland waterways, strengthen tele-communication networks, and promote ‘climate-friendly’ technologies such as electric vehicles. But the plan has faced criticism for including funding for programs that are traditionally not considered ‘infrastructure,’ such as healthcare, job training, education, and housing—which is being glossed as ‘human infrastructure’ (cf The White House 2021, March 31; Pramuk 2021, Hansen 2021, Subramaniam and Lybrand 2021). In push-back to this, Representative Kevin McCarthy reportedly said ‘we first have to start with the definition of what is infrastructure. That’s not home health, that’s roads, bridges, highways, airports, broadband’ (CNN Transcripts 2021).

Here, Representative McCarthy espouses a common understanding of ‘infrastructure,’ pointing to its physical-material basis and operational functions. His position would be corroborated by, for example, the Oxford English Dictionary, which states that infrastructures are the ‘basic physical and organizational structures and facilities (e.g. buildings, roads, power supplies) needed for the operation of a society or enterprise’ (Lexico 2020). Similarly, the Wikipedia page for ‘infrastructure’ would further indicate that infrastructures

involve ‘assets and facilities’ such as airports, bridges, canals, dams, ports, rail, roads, sewage, telecommunications, water supply, and wastewater (Wikipedia 2021). Such assets and facilities, it is understood, stand under, and make possible, modern human life. They are seen to be material enablers for (primarily) human flourishing.

Whereas we acknowledge such common understandings of material infrastructures that enable or enhance human living, we also see infrastructures relationally in broader socio-historical and environmental contexts by inquiring into what they presume, who they are built for, how they get used, and to what effect. Therefore, in this paper, we propose to expand what is meant by ‘infrastructures’ by drawing on literature in anthropology and the social sciences. Here, it is worth reflecting briefly on the word ‘infrastructure’ itself. Very often, commentators have drawn attention to the ‘infra’ part of ‘infrastructure’, emphasizing how infrastructures ‘stand below’ other things, and so become a ‘foundation’ for other kinds of development, buildings or structures. Similarly, words for ‘infrastructure’ in other languages have translated this early 20th century English word keeping this aspect in mind: for example, the Hindi translation of the English word ‘infrastructure’ is *आधारकि संरचना* (‘aadhaarik samrachanaa’) which literally means something akin to ‘foundational structure’. However, consider the ‘structure’ part of the word ‘infrastructure’. This word derives from the past-passive form of Latin *struere*-o, -is, which means ‘to place together, heap up, pile, arrange’ (cf Lewis and Short 1879). In other words, that which is placed together or arranged is that which is *con-struct*-ed. In this respect, there is an afterlife of the Latin root in the English word ‘construe’ which means ‘to put together, to make meaning of, to assemble’. Etymologically, then, infrastructures are not just foundations for material structures, they are also the foundational systems that mediate, enable, or disable the making of meaning and meaningful action (cf Kockelman 2013a). And, by extension, the question of what counts as infrastructure, politically, becomes a site of contestation: there is an explicit battle over the concept of ‘infrastructure’ and what is properly included versus excluded in it (cf Kleinman *et al* 2021, Avery *et al* 2021).

In this context, anthropologists see ‘infrastructures’ as revealing of social relations, rather than merely as objects of techno-scientific study in their own rights whose efficiency, precision, accuracy or functioning needs to be optimized through technical interventions. Studying infrastructures lets us examine the different kinds of forces and social relations at work in particular sites (cf Carse 2017). By studying the presumptions built into what is classified as infrastructure, we are able to more clearly identify and work towards goals of equity and social justice (cf Bowker and Star 1999). Therefore, in this study, we draw on select work in anthropology, and the social sciences more broadly, to cast current conceptions of infrastructure in a different light by reflecting on its immaterial as well as material dimensions (cf Larkin 2013, Kockelman 2013b). As anthropologists have noted, what distinguishes infrastructures from other kinds of technologies is that infrastructures ‘create the grounds on which other objects operate, and when they do so they operate as systems’ (Larkin 2013:329). We examine what it means for different kinds of material infrastructures to function—and for whom—or not; how they are implicated in the immaterial infrastructure of human relations; as well as how infrastructures may create both intended and unintended consequences in enabling or disabling social processes. Further, we examine concepts embedded in thinking about infrastructure that complicate easy distinctions between nature and culture, the technical and the social, the human and non-human, the rural and the urban, and instead emphasize their interconnections (through, for example, labor). Our analysis, thus, draws on a growing body of work on infrastructure in anthropology, enriches it with ethnographic insights, and so extends what it means to study ‘infrastructures’ in the 21st century.

In the first section of this study, we draw attention to social dimensions of seemingly technical urban infrastructure with a focus on water (e.g. Swyngedouw 2004, Gandy 2014, Anand 2017). In the second, we shift focus away from physical infrastructure’s oft-assumed relationship with urban spaces (e.g. Graham and Marvin 2001, Gandy 2014, Hirsh 2016) to ‘biotic infrastructure’ in agrarian contexts, extending what counts as—and elaborating some political dimensions of—infrastructure. In the third section, and extending the idea of ‘biotic infrastructure’, we draw attention to the workings of a different kind of ‘green infrastructure’: that of non-human beings and objects (e.g. Hastrup 2013, Krieg *et al* 2020, Barua 2021) as they are harnessed to combat uncertain futures in the era of climate change (Moore 2016). The fourth section brings together these widened conceptions of infrastructure to rethink what it means for infrastructures to ‘work’ and how they implicate humans through labor, subjectivity, and interpretive endeavors (e.g. Collier 2011, Harvey and Knox 2015, Schwenkel 2020).

In other words, three of the following sections take up one conventional dimension of infrastructure and expand it through an inclusion of its apparently opposite aspect: the technical (and the social); the urban (and the rural); the human (and the non-human), while the fourth also explores their interconnections. We conclude our study with a brief summary and a discussion of the moral implications of infrastructure’s varied workings and failures in the quest to build a more just and equitable world.

## 1. Technically social infrastructure

Infrastructures are almost always associated, in their building and maintenance, with technical-scientific knowledge that is oriented towards the performance of a set of functions. However, because infrastructures are embedded in social contexts, their effects are considerably more than just their stated functions. As such, it is necessary to carry out a more-than-functional reading of what infrastructures do or do not do. Here, we propose that infrastructure is *technically social* in two senses: (1) it is a technical system illuminating the social, which we discuss first, and (2) it is fundamentally social, where humans themselves become part of the infrastructure, which we discuss at the end of this study.

Anthropological analysis of infrastructure as a technical system can illuminate interconnected social dimensions and relations, while granting that infrastructure is a bundle of invisible (and sometimes visible) networks that transport things—goods, information, etc—or people. The amplified focus on infrastructures over the past 20 years in anthropology, in what scholars have termed ‘the infrastructural turn’, begins with attention to the mundane. A seminal piece in this pivot is Susan Leigh Star’s (1999) ‘Ethnography of Infrastructure,’ where she advocates for a methodology of studying boring things and their systems. She proposes to study the systems of substrates that underlie and propel the built environment, which can be ‘frequently mundane to the point of boredom’ (Star 1999:380). The anthropological study of infrastructure has also benefited from Geoffrey Bowker’s (1994) proposal for ‘infrastructural inversion,’ where the figure-ground relationship is reversed: instead of infrastructure serving as the ground that enable other functions or activity (cf Larkin 2013), the focus is on infrastructure’ as an object of study it itself, and on situating infrastructures within their social contexts.

Critical studies of infrastructure have proliferated, especially as linked to forms of unequal distribution or access (Anand *et al* 2018, Larkin 2013, Graham and Marvin 2001). Infrastructure studies have gone beyond questioning things-that-lie-beneath (as the Latin prefix *infra-* goes), with scholars now likening the infrastructure’s primacy in shaping the conditions of everyday life to that of states and corporations (Anand 2017, Appel 2019, Simone 2010, Simone 2012). A key element of this is water: around the world infrastructural flows of water are key to sustaining physical and social reproduction. Here, we offer two perspectives on the socialities of water infrastructure: the construction of urban pipe(dream)s (cf Jensen 2017), and destructive flooding.

Piped water infrastructure, at first glance, seems like a technical system. But it has important social dimensions and offer a glimpse into the workings of socio-material infrastructural configurations. As Lisa Björkman writes, such studies provide an ‘entryway to the sociopolitical and material forces underpinning otherwise taken-for-granted urban processes and geographies—a means by which to explore the technologies, materialities, and politics that infuse everyday life in the city’ (Björkman 2015:12). Since those who wield or can demonstrate command of hydraulic knowledge also become and are recognized as politically powerful (cf Anand 2017), water becomes a great medium to study processes of power. In Vietnam’s Vinh City, water infrastructure captured the initial promises of development, but slowly morphed into conditions of decay (Schwenkel 2015, Schwenkel 2020). The city’s initial modernist aspirations were captured in an enchanted view of socialist housing, where East German technicians and engineers brought their international expertise to bear through the introduction of iron pipes and ceramic squat toilets (Schwenkel 2015). This aesthetic and political project was positioned to legitimize the state’s rule, but it soon led to water insecurity and dry taps due to poor distribution systems and maintenance—caught at the interstice of inter-household dynamics, state neglect, and impending demolition (Schwenkel 2015). Many residents refused to attend to these systems and pipes because they had expected the state to maintain them (Schwenkel 2015). They lived in what Cairns and Jacobs (2014) call ‘obduracy-in-obsolescence’, residing in a building that has fallen out of time but remains in use (cited in Schwenkel 2020:250). Pipes are not merely neutral lines on a technical grid either and, they are situated in a specific space-time, intended to project the state’s dreams of modernity but beset with socially inflected frustrations.

Similarly, pipes in Mumbai’s waterscapes are simultaneously social and technical. Nikhil Anand writes that leaks are not natural: the very concept of leaks depends on a technological imaginary of total control of water flows (Anand 2017:168), a conceptual framing that is produced and reproduced by key stakeholders such as city councilors, engineers, and residents (Anand 2017). Many Mumbai residents take advantage of the unaccounted leakages in pipes to illegally tap the system, and the state further supports social leaks by feigning ignorance (Anand 2017). These material and social leakages in a ‘technical’ system of water supply demonstrate how different the lived realities of many residents are from the pipedream of 24/7 water supply, wherein water is transported from its source to the tap on-demand at any time. These urban fantasies of aesthetic toilets and hermetically sealed pipes—imbricated as they are in a constellation of social relations—are incongruent with the urban reality.



**Figure 1.** Composite photograph re-enacting an individual navigating the 2011 flood (photograph by Al Lim, 2019).

Hydraulic infrastructures also encompass the ways people might address natural disasters like flooding as a consequence of failed control. The causes as well as effects of natural disasters are hardly natural (cf Klinenberg 2002). In Nong Hoi in Chiang Mai, Thailand, the effects of the country's worst flooding in 2011 are still evident almost a decade later. Residents point to the mud stains on their walls, the tangible legacy of the devastating flood, and recount how they had to wade, neck-deep, through the floodwaters to supply food to those who needed it. They formed human chains during the flood to deliver food and supplies to vulnerable community members, grasping these walls of support where needed, as the walls were the only object visible above the brown waters (figure 1). Much of their property was destroyed, even the documents and ledgers sealed in drawers. Some have still not recuperated from this disaster, with leaking walls still being plugged by paper due to a lack of funds for repair.

Flood risk and precarity was directly related to infrastructure design and implementation. Nong Hoi residents asserted that it was not just their position next to the Ping river that threatened them. Whereas one edge of the community is bordered by the river's eastern bank, its other edge borders another kind of infrastructure—a highway, which exacerbated the 2011 flooding. Thus, the natural infrastructure of the Ping river intersected with the social infrastructure of the highway to create a perfect storm, or basin—inevitably social in its construction and impacts.

Studying maladaptive forms of climate change adaptation, Anguelovski *et al* (2016:334) suggest that 'omission' occurs when elite actors protect economically valuable areas over low-income areas, and devolve adaptation in the latter case to private responsibility. In Nong Hoi, such omission occurs at two scales. At the city scale, the construction of the highway was not accompanied by a commensurate flood plan, which resulted in heightened local vulnerability to flooding. At the street scale in Nong Hoi, Bangkok-based investors and speculators have been buying up land and then elevating it above the flood zone (*tohm din*), which actually exacerbates the risk of flooding in the remaining low-lying lands of the poor. As Thongchai Winichakul (1994) demonstrates, maps in Thailand have a complicated history beyond simple lines and borders. The highway and river are dynamically political, social, and spatial and extend beyond technical apparatuses of transporting goods from one place to another, playing vital roles in shaping the residents' lived conditions and experiences of vulnerability.

## 2. Agricultural infrastructures

The Biden administration's proposal to develop 'human infrastructure', which includes categorizing such things as care-giving as infrastructure, has prompted a charge by those opposed to it: is everything now infrastructure? A salutary outcome of the proposal, the response, and the ensuing debate has been to de-naturalize everyday definitions of infrastructure, to point out that it has been an unexamined concept. The debate raises

the question: is the common definition of infrastructure a product of a particular western, industrial history? And it prompts us to ask what other definitions are possible.

One possible site to look for other models of infrastructure is non-western agriculture, for example agriculture in the Indo-Malay realm, both in colonial and post-colonial times. Popular, external views of agriculture in this region tend to be of cultivation of estate crops—rubber, sugar, oil palm—on plantations. Mechanized, regimented, industrial, heavily capitalized, and large in scale, these look like a familiar type of infrastructure. But these are in no way native: they reflect carving out of discrete spaces into which alien species, systems of labor, and ecological relations were imposed, initially by colonial regimes, and then continued in the post-colonial era by multi-national corporations (Mintz 1986).

Systems of food crop agriculture relying on complex systems of irrigation—the great hydraulic civilizations of Asia—are less vulnerable to this charge of an alien origin. Thus, systems of irrigated rice cultivation, as in Bali (Lansing 1991) or Northern Luzon (Conklin 1980), have deep histories, epitomize traditional knowledge, and have long impressed western visitors, like Wallace (1869). With their complex terraces and systems of dams and canals, they are engineered in a way that is familiar to a western observer. Upon closer inspection, however, they present a somewhat more complicated picture, involving the ‘paradox of rice’. Irrigated rice cultivation in Southeast Asia is actually a precarious endeavor, the rise of which has to do with state development, modernization, and perhaps even colonialism (Dove 2021).

This brings us to the other principal system of subsistence cultivation in the region, dryland agriculture, in particular shifting cultivation or slash-and-burn agriculture, by preference called ‘swidden cultivation’ by anthropologists. This is one of the oldest systems of cultivation in the region, and around the world. It involves the use of fire, along with adze and brush-sword, to clear forests for temporary cultivation of annual crops, in systems of rotational forest-fallows.

Swidden systems were and are politically marginal. They are ill suited to the imperatives of a centralized state to sedentarize and surveil a population from whose labor a surplus product can be extracted. Often called a ‘fugitive’ system of cultivation (Scott 1998:282–3), their diversified cropping pattern, high ratio of fallowed to cultivated land, and lack of capital investment make them difficult to tax, and their more dispersed population is more difficult to control. As a result, not only in the Indo-Malay region but all around the globe, swidden agriculture was the *bête noire* of colonial rule, disparaged, penalized, prohibited—a stance that has often persisted into post-colonial rule as well.

Swidden cultivation was not unknown in the west: a form of swidden was practised in Western and Northern Europe well into the 19th century, and it was integral to frontier resource management in the European colonization of North America. This fact notwithstanding, European colonizers in the Indo-Malay region viewed native swidden agriculture as an alien, irrational, and destructive form of agriculture. The use of fire to clear the forest horrified colonial observers; the intensely intercropped fields violated European Apollonian ideals of geometric, monocropped fields; and the idea that secondary forest was actually a managed and productive fallow was not understood. This is reflected in the colonial Dutch term for swidden, *rooibouw* ‘exhaustive or robber agriculture’, because they saw the burning and then abandonment of the forest as destructive, profligate behavior, which robbed nature of its resources, and was thus unsustainable (Jansonius 1950:1245). Colonial administrators did not see swidden as any sort of ‘infrastructural’ endeavor.

Nevertheless, it is possible to see swidden agriculture as ‘infrastructure’, following Morita’s (2017) analysis of floating rice as part of a multispecies study in Thailand. The labor required for the initial clearance of old-growth forest is excessive, and for this reason swidden peoples generally prefer to clear secondary forest, which is thus treated as a valuable asset and husbanded for return cultivation (figure 2). The desired landscape in many traditional swidden systems was a mosaic of open fields and managed fallows under secondary forest. Such a mosaic husbanded human energy by minimizing the amount of labor needed for the annual clearing of the forest, and by maximizing reliance on the natural dynamics of vegetative succession to restore the forest cover after each instance of clearing and cropping. In circumstances of modest population/land ratios, this system of tropical land-use was sustainable over periods of centuries (Lawrence and Schlesinger 2001). This managed landscape was, in effect, a ‘built’ landscape, an anthropogenic landscape, a ‘biotic infrastructure’, whose purpose was to husband human labor in natural resource management. Failure to understand this biotic investment in the landscape underpinned the tenacious and widespread myth that all swidden cultivators were ‘nomadic’, ever searching for virgin forest to clear, ignorant of the labor preference for secondary forest and, hence, continuous residence in a fixed territory in which fields were rotated but not abandoned.

A different sort of infrastructural ethos is involved here, a principle of mimicry not transformation. Swidden agriculture relied on understanding and adapting to local ecological dynamics. It harnessed the energy of the tropic forest itself, through spontaneous reforestation of fallowed fields. The swidden itself has been said to resemble the natural tropical forest: ‘the swidden plot is not a ‘field’ at all in the proper sense, but a miniaturized

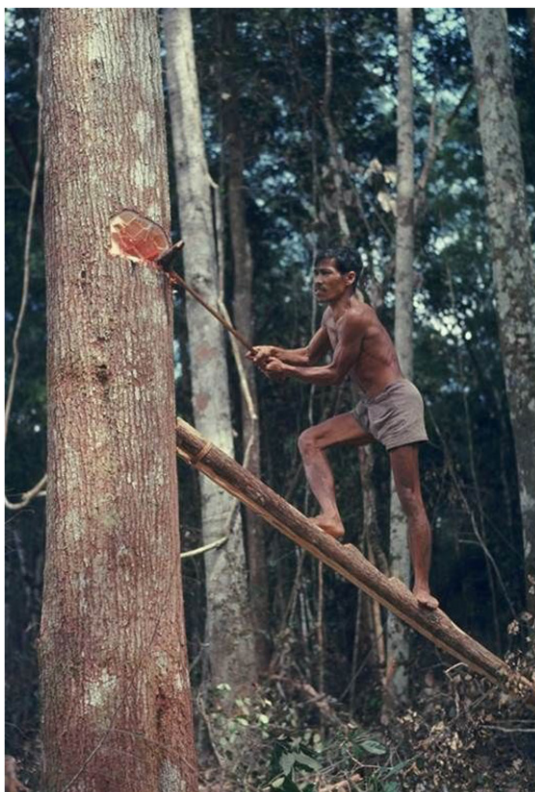


Figure 2. Primary forest is challenging to clear for swidden (photograph by Michael R Dove).

tropical forest, composed mainly of food-producing and other useful cultivates' (Geertz 1963:25). This mimicking of nature was ill-suited to colonial, Cartesian value systems, in which the more natural the livelihood system, the more 'natural' and uncivilized the people involved.

This principle of mimicry is similarly foreign to the western history of infrastructure, which celebrated the transformation of nature: damming, diverting, straightening, and confining rivers, clearing forests, draining swamps, and exterminating species. Within that tradition, it is difficult to see something like a seemingly un-engineered like swidden landscape as infrastructure. As the western infrastructural ethos changes, however, with un-damming and 'recurving' of rivers, reintroduction of animal species in former habitats, restoration of wetlands and mangroves—the rewilding of landscapes, perhaps even of the earth's atmosphere (Hulme 2015)—there is an opportunity for recognition of biotic infrastructures like swidden. The importance of the principle of natural mimicry in rewilding initiatives resonates with the centrality of mimicry to swidden cultivation.

The lesson from the case of swidden is a reminder that the current debate in the US is not unique in arguing over what is/is not infrastructure. Recognition of infrastructure involves recognition of labor, and knowledge, and rights. For these reasons, denial of vernacular infrastructure has long been a political tactic; and there are winners and losers with any definition.

### 3. Non-human infrastructure

Whilst infrastructure often brings to mind man-made structures such as water pipes, canals, and roads (Anand 2017, Carse 2012, Harvey and Knox 2015) that make urban lives possible, the multispecies turn in anthropology (Chao 2018, Kirksey and Helmreich 2010, Morita 2017, Tsing 2015) has precipitated what Lisa Krieg *et al* (2020) describe as 'an infrastructuring of non-human worlds.' An example of this in relation to swidden landscapes was presented in the preceding section, which explored some socio-political and historical causes behind the lack of recognition of biotic infrastructures as infrastructure. As anthropologists have begun to recognize and study the political lives of nonhumans, the interface between infrastructure and environment is an increasingly fuzzy one such that both terms 'straddle the terrain once held by concepts such as 'context'' (Hetherington 2019:6). In this section, we present a wider definition of biotic infrastructure in order to draw out the multiple ways in which infrastructure governance is enacted and contested across urban-rural spaces.

Non-humans are increasingly seen as vital elements in natural infrastructures confronting the ecological threats posed in the Anthropocene (Besky and Blanchette 2018, Helmreich 2007). The recognition of increasingly unpredictable futures introduces questions pertaining to ‘infrastructural being, temporality and politics’ (Barua 2021:17). Wrestling with the uncertainty posed by an era of persistent environmental catastrophe (Hurricanes Katrina, Sandy, Harvey, to name a few in the United States alone), climate adaptation involves a reckoning with the limits of expert knowledge and a rethinking of what it means to be vulnerable (Moore 2016). Scholars have demonstrated that nature can be harnessed as a biopolitical tool for contemporary environmental challenges, as environmental consultants (affiliated with the government) plant mangroves along the coast to buttress sea defences (Vaughn 2017), hunters and biologists keep count of the number of narwhals to track climate-related changes in the environment (Hastrup 2013), and scientists observe ice sheets to forecast how close or far we are from tipping points (Petryna 2015). If experts are then tasked to think *with* nature, as Wakefield (2020; see also Wakefield and Braun 2019) describes in her study of city planners’ usage of oysters to prepare for rising seas and storm surges in post-Hurricane Sandy New York City Wakefield (2020), we might then surmise that akin to metres, valves, and cables, nature has become a technology of government (Agrawal 2005), harnessed to secure human life in the face of looming disaster.

Scholars also argue for the need to ask ‘which bodies matter in infrastructural engagements’, and what are ‘the possibilities and limits of an infrastructural analytic for addressing this intersection of contemporary environmental challenges and questions of social justice’ (Stoetzer 2016, citing Butler 2011). The turn toward harnessing nature as capital, as seen through wetland banking programmes and blue carbon projects that financialise mangroves through carbon credit sales, is an example of an attempt by the ‘state-capital nexus to economize life, where biopower functions as an element of capitalism’ (Barua 2020; also cf Robertson 2004, 2006, Zeng *et al* 2021). The system of buying and selling wetland credits transforms the wetland into an infrastructure that provides ‘ecosystems services’ and is rendered legible and useful for further capitalist development (Robertson 2004).

Another mode of incorporating nonhumans into infrastructure is through a recruitment of their biophysical form and metabolic labor. Tying together the entangled relationship between capital, the military-industrial complex, and the bodies of bees, Kosek (2010:663, 651) studies the involvement of honeybees in experimental bioengineering projects that render bees as ‘sensory prostheses,’ as these bees become part of a ‘growing militarized ecology’ in which alarming new relations and forms of both insects and humans are constructed Kosek (2010). Enquiries into political entomology can also be connected to the modern city’s desire to develop ‘smarter’ and ‘greener’ infrastructure, as Chinese scientists raise black soldier flies to consume municipal waste. The appropriation of biophysical nature into a waste infrastructure naturalizes ‘a techno-utopian imaginary and render[s] the extraction of human and nonhuman labor invisible’ (Zhang 2020:78; also cf Zhang 2019). Not all organisms are welcomed by state actors to enact clean and green imaginaries. Jacob Doherty (2019:S321) contends that marabou storks that occupy Kampala’s green spaces are ‘both waste infrastructure and waste themselves,’ not unlike that of informal waste collectors who lead precarious lives. Despite the fact that these storks consume up to 2 kg per bird per day of Kampala’s organic matter in garbage dumps, the state considers these ‘weedy birds’ (Doherty 2019; cf Tsing 2015) as filthy pests that pollute the city. For the *Balmiki Dalit* community in India, pigs are not only infrastructure that transform ‘toxic, abandoned environments into urban farmyards,’ but they also illuminate the uneven caste dynamics that render the *Balmiki* as ‘untouchables’ who must deal with precarity as a result of state abandonment (Gutgutia 2020).

These scholars argue that the metabolic labor of non-human beings constitute value that ‘capital presupposes but does not itself produce’ (Barua 2019:652; see also Beldo 2017, Blanchette 2015, Shukin 2009). As Maan Barua (2019:654) writes, capital transforms the nonhuman body into ‘an accumulation strategy, where conditions for its growth are intensified to realize relative surplus value.’ Thus, the multiple ways in which non-human lives have been reimagined, reconstructed, and redeployed to make them amenable to humans bring to the fore the political stakes of infrastructural arrangements, from the consequences of the war on terror to the inequalities of caste politics. These ‘ecologies of infrastructure’ (Krieg *et al* 2020) draw our attention to, and open up the possibility of reconfiguring the specific ‘terms of connection’ (Karak 2016, Stoetzer 2016) that govern human/nonhuman relations.

#### 4. Linkages, subjects, and failures—rethinking how infrastructure ‘works’

The previous three sections have offered expanded takes on infrastructures by showing how they reveal and shape social relations, or take on biotic and non-human forms. This section recasts these broader views of infrastructure to rethink how we assess the success or failure of conventional technical systems with regard to their supposed functions and promises. Early calls for the anthropological study of infrastructure noted that infrastructure becomes visible only when it ‘breaks down’ (Star 1999); but a more recent body of work has challenged this by demonstrating how the very notions of ‘breakdown’ and ‘normalcy’ are contingent to the



infrastructure's place in broader social, political, and material circumstances. Here, we highlight three interrelated frameworks that productively expand the notion of infrastructural workings: (1) infrastructural linkages, (2) subjects of infrastructure, and (3) unintended consequences. These make clear how humans themselves get implicated in the workings of various forms of infrastructure—through their labor, subjectivity, and interpretive endeavors—which makes infrastructures 'technically social' in the second of the two senses (cf section 1 above) of infrastructure being a fundamentally social matter.

*Linked infrastructures.* Whether railways, water systems, or information networks, modern infrastructure technologies have historically developed alongside attendant, highly specialized fields of technical expertise (cf Mitchell 2002). However, actual infrastructures seldom work as discrete systems. Instead, they are enmeshed in a larger constellation of things and people. Larkin (2013:329) writes:

'Take, for example, the computer I have used to write this article. What is its infrastructure? Electricity may be the most obvious substratum that allows the computer to operate. But, as Edwards (1998) notes, although electricity is the infrastructure of the computer, the computer is the infrastructure of electricity supply, as the entire transmission industry is regulated by computers. Electricity, in turn, has other infrastructures, which can include oil production [...], financial mechanisms innovated in the wake of decentralization that allow electricity to be sold on an open market, or the labor networks necessary to produce and transmit power.'

Infrastructure is thus embedded in a complex web of material and social relationships that together make up a heterogeneous yet linked assemblage.

One key infrastructure within these linkages is humans themselves. As AbdouMaliq Simone (2010) puts it, 'people are infrastructure.' Based on ethnographic work across numerous parts of the global south, he writes that 'people are the infrastructure that bear the responsibility for articulating different locations, resources, and stories into viable opportunities' (Simone 2010:124). Their practices and social interactions fill systemic gaps, which infuse life and new forms of dynamism into cities that are otherwise seen as dysfunctional and consigned off the map (Robinson 2006, Roy 2009). A messy marketplace in Kinshasa, viewed by someone who is used to large air-conditioned or 'smart' malls, might seem dysfunctional; but that view misses the 'thick' and dynamic modes of interaction occurring in such a marketplace, functioning as an infrastructure for goods exchange. A ubiquitous example of human infrastructure are the systems of human labor that repair, maintain, and hold infrastructure together as a functional technical and communicative unit (for repair labor, see Fisch 2018, Jackson 2016, Mattern 2018; for communicative labor see Elyachar 2010, Sopranzetti 2018). As Graham and Thrift (2007:3) point out, repair work is often a site of tremendous creativity, which seeks to achieve a 'practical equilibrium' through improvisation rather than a return to an original state of perfection (Graham and Thrift 2007). Human labor, interactions, and improvisations are thus often integral to the working of seemingly technical infrastructural systems, turning them into 'ontological experiments,' in which encounters between seemingly disparate elements and agents constantly generate new social and material worlds (Jensen and Morita 2015).

The imbrication of modern infrastructure in the broader world is far from politically neutral, insofar as its construction and maintenance entails a large amount of resources, whether material, financial, or political (e.g., the proposed 2 trillion dollar US infrastructure plan). In his seminal book *Nature's Metropolis*, Cronon (1991) traces how the development of transportation infrastructure in the 19th century, which fostered the rise of Chicago as a metropolitan marketplace, also implicated distant hinterlands to the city's east and west. Investments first in canals and later in railways dramatically transformed the landscape surrounding Chicago into a vast agricultural hinterland. By fueling the production of commodities like grain and meat to be traded in Chicago's booming markets, the new mode of spatial connectivity gave rise to a novel geography of capital. Indeed, development of infrastructures like roads and railways have been central to making and exploiting resource frontiers in many parts of the world, transforming regional social and ecological landscapes into an infrastructure for institutions such as the market and the state (e.g. Ferguson 1990, Gordillo 2018, White 1995). On the other hand, infrastructural disconnection and disrepair within such linked systems can produce violent, racialized, gendered, and classed exclusions through which states or corporations assert disengagement and deny social responsibility (Appel 2012, Chu 2014, Gandy 2002). In adopting a broader notion of infrastructure and debating its boundaries, we should consider the implications of including or excluding these various components that remain linked to, or rely on, what we traditionally consider to be infrastructure.

*Subjects of infrastructure.* Infrastructure cannot fulfill its intended purposes simply by creating linkages among multiple technical and human labor systems; it must also build relations with its intended beneficiaries through the formation of particular kinds of subjects. In his study of the US national security state during the War on Terror, Joseph Masco (2014) argues that the state's constant evocation of unknown threats promoted its ever-expanding military investment in defense infrastructures. This infrastructural expansion was

justified by conjuring American citizens as excitable subjects to serve as the ‘affective and imaginative infrastructures that are required to build a permanently militarized society’ (Masco 2014:41). The combination of the linked technical systems and the concomitant public affect of national security was highly effective. Such infrastructural subject formation is often facilitated by the materiality of the system itself. In his analysis of the rise of the modern commuter train network in early 20th-century Japan, James Fujii (1999) shows how the system subjected commuters to a homogenous spatiotemporal rhythm, which helped commodify them into an abstract labor force (cf Lamarre 2015, Schivelbusch 2014). By remaking the temporal and spatial configuration of everyday life, infrastructure works by implicating the subjectivity of those who access and labor in it (cf Anand 2017).

But the subjects of infrastructure do not always fully succumb to domination by such powerful forces. Modern infrastructures often become sites of political contestation over the public good and claims to inalienable rights (Bear and Mathur 2015, Chalfin 2014, Muehlebach 2018). Such contestations can manifest quite subtly. Writing about the implementation of electricity prepayment meters in post-Apartheid South Africa, Antina von Schnitzler (2013) demonstrates how this new infrastructure became the very terrain of techno-politics in which to contest and subvert the state’s administrative agenda. The state intended the prepaid meters to be a technology for suppressing rent boycotts and producing governable, self-responsible subjects by cultivating a disposition to rational calculation, precision, and alertness among their users. But this disciplinary attempt resulted in an ongoing struggle between engineers tasked with developing ever more sophisticated meters and residents who continually found ways to subvert this administrative imposition. Prepaid meters, in other words, came to materially mediate the negotiation over access to basic services and limits of citizenship in South Africa’s post-apartheid democracy. This is not always the case, as evinced by Baptista’s study (2016) of electricity prepayment in Maputo, Mozambique Baptista 2016, where residents harness prepayment to secure future access to power amid the uncertainty of life in the city’s *bairros* (‘slums’). But even when an infrastructural arrangement faces opposition or evasion from its presumed users as in von Schnitzler’s case in South Africa, this does not necessarily reflect infrastructural failure per se. Rather, it is precisely through these instances of seeming resistance that citizens get implicated in an evolving relationship with the state and its infrastructures (cf Schwenkel 2015). Such dialectics of infrastructure and its subjects ultimately shape its forms and sustain its working (Anand 2017, Collier 2011).

*Infrastructural normalcies and excesses.* As infrastructure ‘works’ by involving a vast web of things and subjects, this interconnectedness can exceed its planners’ technical intentions. As David Perrow (1984) has noted, the utter complexity of contemporary infrastructures has normalized accidents, breakdowns, and other catastrophic consequences. Highways exacerbate floods (see section 1) and become a ground for road deaths (Harms 2011); nuclear plants go out of control, explode, and precipitate long-term social and environmental sufferings in their immediate vicinities and far beyond (Petryna 2002, Pritchard 2012, Sternsdorff-Cisterna 2018); even efforts of infrastructural repair and reconstruction not infrequently (re)produce a whole set of challenges and inequalities (Adams 2013, Murphy 2013, Ureta 2014). The inherent vulnerability of infrastructural systems is only entrenched today by rampant state austerity and disinvestment from public infrastructures in many parts of the world (Bear 2015, Fortun 2012). This imminent possibility of infrastructural derangement demands attention to the fragility of even seemingly state-of-the-art systems and cultivation of what Jasanoff (2007:33) calls the ‘technologies of humility’, which give us a method to ‘accommodate the partiality of scientific knowledge and to act under irredeemable uncertainty’ Jasanoff (2007).

These disastrous potentials notwithstanding, moments of breakdown and technical failure do not necessarily affect infrastructure’s social and political generativity. Large-scale infrastructures like roads, railways, and dams have often been infused with a potent aura of modernity (Harvey and Knox 2012, Scott 1998). This promise of technological progress and material comfort can be mobilized by its vanguards to stage their authority and political legitimacy. Conversely, spectacular infrastructures can also become an object of political commentary and satire through which broader political critiques get deployed to counter the zeal for modernist progress (Humphrey 2005; cf Ong 2011). Infrastructures become a particularly heated site of politics and reflexivity when they fail to work in the way initially intended or promoted. In her ethnography of Pakistan’s first Motorway, Khan (2006) explores how this novel infrastructure ended up unpopular and underused despite its promise to grant equal democratic access to mobility to all citizens. The deeply felt dissonance between the road’s modernist fantasy and concerns over its safety deterred many from driving on it, reflecting the ambivalence of Pakistan’s modernity, which interlaces hope with suspicion (cf Anand *et al* 2018, Harms 2011, Masquelier 2002). When failed infrastructure makes audible oft-silenced yet socially salient experiences and desires, this is another way in which infrastructures ‘work.’ Not just the material function but also the discursive representation of infrastructures can reveal the nuances of their workings in the social worlds of their subjects (Larkin 2013:335). Then, what might be the political implications of ‘fixing’ and ‘updating’ these generative infrastructural failures, as the Biden bill proposes? Once we recognize these social and political lives of

technical systems including ‘failing’ ones, even the seemingly well-intended act of infrastructural repair is no longer a neutral move, but one requiring careful assessment of its potential implications.

## 5. Conclusion: towards moral infrastructures

Infrastructures, we have argued, are more than just technical matters. They are equally social and political in their conceptions and workings; and they are implicated in the dynamics of moral ecologies (Scaramelli 2019). Lauren Baker *et al* (2017:47) propose that moral ecologies are premised upon ‘the necessity of reciprocity in relations between society and environment, which underpins the mutually constitutive nature of people and places, the importance of ecosystems for livelihoods and culture, and the rights of landscapes and non-human species to survive and thrive in the future.’<sup>1</sup> In this study, we have accordingly expanded some key dimensions of what is usually presumed to constitute infrastructure: the technical (and the social); the urban (and the rural); the human (and the non-human). Each of the foregoing sections have elaborated on one such conventional dimension (and its expansion), and a fourth has sought to highlight linkages and interconnectedness across these dimensions through the lens of labor and subjectivity. These expanded aspects of infrastructure help us attend to the moral relationships that undergird infrastructure.

Further, as Scott (1998) asserts, infrastructure is a major vector for the state’s organization of society, often under the remit of development. The various matrices of the state and accompanying stakeholders have enabled forms of accumulation that transcend urban-rural, nature-culture boundaries, enacting various forms of violence and inequality. A paradigmatic lens on understanding the cross-cutting effects and moral implications of infrastructure is Graham and Marvin’s (2001) study of ‘splintering urbanism’, which analyzes the fracture, fragmentation, and uneven distribution of urban infrastructure. They emphasize how privatization and liberalization have created sociotechnical power symmetries, which splintered the urban fabric based on differing modes of access (Graham and Marvin 2001). Violence is interwoven with infrastructural construction and destruction, in what Rodgers and O’Neill (2012) cast as forms of active or passive ‘infrastructural violence.’

Thus, in regard to moral infrastructures, several questions emerge: for example, for Nong Hoi residents, what kind of infrastructures can mitigate against flooding, and why have they not been built? How have these forms of morality been negotiated or regimented? What does this mean for what is considered ethical forms of socioeconomic developments? These questions illustrate the multiple and contested rationalities that drive built or unbuilt infrastructural landscapes. By bringing these questions to the foreground, we can theorize multiple paths of sustainability for infrastructure through a locally-rooted morality. As Appel *et al* propose, there is a need to make ‘more visible, and indeed more political, the formative role of infrastructure in the ways we think, build and inhabit our shared futures’ (2018:30) Appel *et al* 2018.

In sum, an anthropological approach to infrastructure asks us to rethink what it means for pipes, canals, and grids to ‘work’ beyond the promise of modern technological efficiency. The material form of infrastructure alone can be socially and politically generative in ways separate from their technical success and unforeseen by engineers. Further, the social worlds that infrastructure brings into being are often highly ambivalent with uneven outcomes. These considerations of the ‘working’ of infrastructure push us to widen the framing of our inquiry, and attend to the embeddedness of infrastructure(s) in social, political, and material life. This necessitates an expansion of what counts as infrastructure and inclusion of socio-political, environmental, material and immaterial factors in their workings. For example, returning to the infrastructure bill with which we began our analysis, our review enables us to look at the infrastructure bill in new and useful ways: rather than think of infrastructure in terms of building and repair, modernization and efficiency, these perspectives help us to attend to questions of equity and social justice. Only by recognizing a distributed nature of infrastructural workings, can we begin to address the question of responsibility for the success or failure of infrastructure in delivering basic services to those most in need (Ferguson 2012).

## Note

The authors have confirmed that any identifiable participants in this study have given their consent for publication.

<sup>1</sup> This set of balanced and reciprocal relations is based on Scott’s (1976) concept of ‘moral economy’ which explains peasant resistance in terms of violation of social relations, as well as Dove’s and Kammen’s (2015) comparative study of the boundaries of natural resource use systems.

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## Data availability statement

All data that support the findings of this study are included within the article (and any supplementary information files).

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